AUTOMATIC TRANSLATION

by

D. Yu. PANOV

Translated from the Russian by

R. KISCH

Edited by

A.J. MITCHELL
Computing Laboratory, University of Leeds

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Foreword

FOREWORD

This book gives an account of the problem of automatic translation from one language to another, and of some results of the work being done in this direction in the Institute of Precise Mechanics and Computing Technique and in the Institute of Scientific Information of the U.S.S.R. Academy of Sciences.

This work was begun in January 1955; at the end of 1955 the first experiments were made in translation of scientific and technical material from English into Russian, using the BESM electronic computer of the U.S.S.R. Academy of Sciences.

The philological part of the problem was worked out by I.K.Bel'skaya, and questions of programme planning and coding by I.S.Mukhin, L.N.Korolev, S.N. Razumovsky, N.P.Trifonov and G.P.Zelenkevich.

The first edition of this book appeared at the beginning of 1956. During the time which has since elapsed a great amount of work has been done in the field of automatic translation in the Institute of Precise Mechanics and Computing Technique of the U.S.S.R. Academy of Sciences, and in other institutions also. The present edition has been enlarged to give information on some new results. In the period just past different points of view have appeared on the principles which should be made the basis of machine translation, and on the scientific problems connected therewith. Mention is made in this book of these controversial matters as well.

D.Y.Panov.

1.INTRODUCTION

The idea of automatic translation is not new. For a long time there have been in existence devices for whose use no knowledge of the foreign language is required. Such are the various 'phrase books' and special dictionaries intended for travellers arriving in a foreign country and unable to make themselves understood in any other way. In dictionaries of this kind translations are given into another language of a certain number of words and common expressions, and it is an essential point here that the translation is always unambiguous. This spares the person using the dictionary any mental effort whatsoever, and enables him to find the word or expression needed automatically, so long as he is able to read it.

With the help of such phrase books it is easy to learn that the Russian phrase 'до свиданья' will be translated into French as 'au revoir', into German as 'auf Wiedersehen', into Finnish as 'Näkemää asti' , and so on.

It is however obvious that translation of this kind cannot satisfy us in many instances, even in some very simple ones. If, for example, we wish to indicate the English equivalent of the Russian expression 'до свиданья', then we shall have to give two expressions - 'good-bye' and 'bye-bye' - which are used by English people according to circumstances difficult to explain in the dictionary. Moreover it is highly characteristic of a living language that it uses different words to describe one and the same concept, and equally characteristic that several varying meanings are given to one and the same word. This explains the uselessness in practice of such very simple 'automatic translators' as 'phrase books' and similar publications.

One may however ask - Cannot some more perfect

system of translation be devised to cover the even-
tualities arising in the translation of a foreign
text, at least of a not too difficult one to start
with? Cannot dictionaries and rules for translation
be worked out which would take into account all the
structural peculiarities of a given sentence and
make it possible to establish without ambiguity the
sense of the words composing it and their inter-
relation in the text? In short, cannot rules for
automatic translation be elaborated which would make
it possible for a translation to be executed, on
condition that the rules be punctiliously observed,
by a person who does not know the language concern-
ed and can only read its letters? As it happens,
this can be done. And if this can be done, then
one can obviously hope to make the translation quite
automatically, without any human participation, using
programme-directed machines such as those, for
instance, which automatically carry out highly com-
plex computations.

   At first glance the assertion that it is poss-
ible to elaborate rules for automatic translation
appears incredible. But if a little thought be giv-
en to this problem, it is easy to understand that
there is nothing impossible about it. After all, a
language is a definite system in which ideas and
concepts must of necessity find a material express-
ion. The different meanings of words, and likewise
any changes in the meaning of words, are reflected
in the language materially by the media of vocabul-
ary and grammar. In a language there are no words
which mean nothing (unless they have been specially
invented), and there can be no content which
does not find its reflection in an order of words
and their mutual connection.

   If it were otherwise, the language would not be
able to fulfil its basic function - to be a means
of communication between people; it would be imposs-
ible to convey one's meaning to another person by
its means. And since each one of us knows from his
own experience that this happens continuously and
that in conversation and when reading we distinguish
exceedingly fine shades of meaning expressed in
words - then clearly some material means must exist
which would enable us to distinguish those words in
some definite, objective way.

It seems that the first attempt, chronologically speaking, to mechanise translation to some extent was made in 1933 by P.P. Troyansky. He proposed the construction of a 'machine for the selection and printing of words while translating from one language into another or into several others simultaneously.' For this invention P.P.Troyansky received an author's certificate (Fig.1), but at the time he did not succeed in carrying his project through. This is understandable, since at that time automatic installations suitable for the purpose had not yet been created.

Fig. 1.

In recent years, in connection with the enormous successes achieved in devising programme-directed automatic electronic computers, the idea of automatic translation has acquired particular interest for scientists. In 1948-49 British and American scientists discussed the question of whether it was possible to translate automatically from one language to another by means of electronic computers (Ref. 1, pp. 2-3). In various scientific institutions in Britain and the U.S.A. work in this direction was begun in the years 1950-51. On January 7, 1954, in the New York office of the International Business Machines Corporation, the first public demonstration was made of machine translation from Russian to English by means of that firm's computer IBM-701 (Ref. 2). A special dictionary consisting of 250 Russian words written in Latin characters was prepared for the test. The words were selected in such a way that each of them had one, or at the most, two meanings in English. The dictionary included,

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besides words, some case endings as well. For some words only the root was included, while some words were given in full, even the personal endings in the case of verbs, or in the plural. Table 1 shows an extract from this dictionary.

Besides the meaning in English, the dictionary also gives for each word three code numbers, used for directing the work of the machine. Very simple Russian phrases consisting of words included in the dictionary were taken for translation. Six syntactical rules were also worked out, which ensured a correct translation through code numbers. Using these rules and the dictionary one could translate phrases such as 'величина угла определяется отношением длины дуги к радиус'. Table 2 shows words and parts of words corresponding to those in the phrase, as given in the glossary, with indication of their equivalents in English, the guiding codes and the rules applied.

A formal application of the rules makes it possible to obtain automatically the translation: "magnitude of angle is determined by the relation of length of arc to radius."

For automatic translation the dictionary was first copied on to punch-cards of the type used in machine accounting installations, then inserted into the machine and recorded on a magnetic drum in the same way as a recording is made on magnetic tape in a tape recorder. A special programme was worked out containing about 2,400 instructions for the direction of the machine. The programme was then likewise inserted into the machine, after which the sentences to be translated were punched on cards and inserted. After an interval the machine automatically printed the translation in its output unit.

The report on the tests quotes examples of translations, which are shown in Table 3.

The International Business Machines experiment evoked immense interest all over the world. The numerous comments published in general and specialised journals, however, indicated that the experiment had been undertaken in pursuit of publicity rather than of scientific aims, and that it would be

TABLE   1

TAKEN   FROM DICTIONARY

Russian words	English equiv.		Codes		
	I	II	I	II	III
к	to	for	121	XXX	23
кислород-	oxygen	XXX	XXX	XXX	XX
лишени-	deprival	XXX	XXX	222	XX
материал-	material	XXX	XXX	XXX	XX
мы	we	XXX	XXX	XXX	23
мысли	thoughts	XXX	XXX	XXX	XX
мног-	many	XXX	XXX	XXX	XX
медь	copper	XXX	XXX	XXX	21
мест	place	site	151	XXX	23
механическ-	mechanical	XXX	XXX	242	XX
международн-	international	XXX	XXX	XXX	XX
на	on	for	121	XXX	23
нападени-	attack	attacks	121	XXX	XX
наука	a science	XXX	121	242	XX
обработка	processing	XXX	XXX	XXX	XX
объект	objective	objectives	121	XXX	XX
офицеран	officer	the officer	XXX	XXX	XX
-ого	of	XXX	131	XXX	23
-ом	by	XXX	131	XXX	XX
определяет	determines	XXX	XXX	XXX	XX
определяется	is determined	XXX	XXX	XXX	XX
оптическ-	optical	XXX	XXX	XXX	XX
орудне	gun	XXX	XXX	241	XX
отдел-	section	XXX	XXX	XXX	XX
отделение	division	squad	121	242	XX
отношение-	relation	the relation	151	XXX	XX

hard to rely upon practical results in the immediate
future. The majority of scientists were agreed that
what was first required was work on questions con-
nected with the translation of scientific and tech-
nical texts, in particular the compilation of
specialised dictionaries for each branch of technic-
al science.

Articles published noted the great difficulties
connected with automatic translation. It was pointed
out that the programme directing the work of the

machine was extremely complicated; even for the
translation of the simplest phrases a programme was
required embodying considerably more instructions
than were required for the solution of complex mathe-
matical problems. Many scientific workers drew
attention to the size of the dictionary needed for
automatic translation, indicating that in modern
German, for example, there are about 400,000 words,
and that this makes impossible demands on the extent
of the dictionary. On the other hand, however, it
was noted that in 90 per cent of cases only 5,000 of
these words are used (Ref. 3). The extent of the
dictionaries needed for specialised subject-matter
was estimated in the case of English at 1,000 words
of a general nature and 1,000 specialised terms (Ref.
4). But in the opinion of most scientific workers
a dictionary of this size is still impossible to use
as yet, and for this reason it is not so far possible
to undertake the translation even of specialised
scientific books, still less that of works of liter-
ature .

TABLE 2

Russian words	English equiv.		Codes			Rule used
	I	II	I	II	III	
величина	magnitude		XXX	XXX	XX	6
угл-	coal	angle	121	XXX	25	2
-а	of		131	222	25	3
Определяется	is determined		XXX	XXX	XX	6
отношени-	relation	the relation	151	XXX	XX	5
-ем	by		131	XXX	XX	3
длин-	length		XXX	XXX	XX	6
-и*	of		131	XXX	25	3
дуг-	arc		XXX	XXX	XX	6
и-	of		131	XXX	25	3
к	to		121	XXX	23	2
радиус-	radius		XXX	221	XX	6
-у	to		131	XXX	XX	3

*No distinction between Ъ and Ы.

It is quite clear that the translation of
colloquial speech or of a literary work presents
considerably greater difficulty than that of scien-
tific material. It is not merely a matter of vocab-
ulary nor even of special expressions (idioms) which
cannot be translated according to the usual grammat-
ical rules, but must be replaced by an expression in

the other language which is equivalent to it in meaning (e.g. the English greeting "How do you do", etc.). From the material that follows it will become clear that such idioms can without difficulty be included in the vocabulary in the same way as separate words. The difficulties arise over the fact that in works of literature the sentences are sometimes very intimately bound up with the very nature of the language, and have their roots deep in the life and habits of the people. When a translation is made which takes into account all these considerations, it evokes in the reader thoughts and associations more or less corresponding to what the author of the text translated had in mind.

Gogol ends his story "The Nose" like this: "..А однако же, при всем том, хотя, конечно, можно допустить и то, и другое, и третье, может даже... ну да и где ж не бывает несообразностей? — А все однако же, как поразмыслишь, во всем этом, право, есть что-то. Кто что ни говори, а подобные происшествия бывают на свете; редко, но бывают".

In these phrases there is no single word that would not have its equivalent in English. It is possible without especial difficulty to put together combinations of English words, each of which will correspond to the appropriate Russian word and which will bear the appropriate grammatical relationships one to the other. One can be sure, though, that in such a formal translation these phrases will be completely incomprehensible to an English reader, and in order to convey in English the import of the passage quoted, one would have to do something quite different - in effect, one would have to re-write it as an English text which would convey with a greater or lesser degree of fidelity the content of Gogol's words. To make a translation of this kind by machine is, of course, a problem of exceptional complexity.

It would seem that it will not soon be possible to use machines for the automatic translation of literary works. But besides the translation of literature there are other questions requiring a solution. The scientists of all countries are faced with the immense task of making themselves familiar with scientific literature in other languages, and this is a task that we can undoubtedly hope to

master with the help of automatic translation. The
first steps in this direction have already been taken
and real progress in this field can be looked for
in the next few years.

TABLE 3

Russian phrase	Machine Translation
Качество угля определ-яется калорийностью.	The quality of coal is determined by calory con-tent.
Крахмал вырабатывает-ся механическим путем из картофеля.	Starch is produced by mechanical methods from potatoes.
Обработка повышает качество нефти.	Processing improves the quality of crude oil.
Динамит приготовляет-ся химическим процес-сом из нитроглицерина с применением инертных соединений.	Dynamite is prepared by chemical process from nitro-glycerine with admixture of inert compounds.
Международное понима-ние является важным фактором в решении политических вопросов.	International understand-ing constitutes an import-and factor in decision of political questions.

2. THE TECHNIQUE OF ORDINARY TRANSLATION

In order to gain a clearer idea of how automatic translation must proceed, let us consider in some detail what a translator does when translating an ordinary scientific or technical text of medium difficulty, without pretensions to literary merit. In so doing we shall try to note very small details of the translation process which usually pass unnoticed.

Let us suppose that the translator is to some extent familiar with the language from which he is translating - English, say. Let us assume that he knows the rules of grammar and has in his memory a number of "key" words, i.e., of the kind which appear as signposts in the sentence, as it were, enabling one to make a quick assessment of its structure and to determine what syntactical functions are performed in it by different words. Some "key" words of this kind are the pronouns, prepositions and verbs, and some other words; the translator must remember a sufficient number of them if the process of translation is not to advance too slowly.

Before starting to translate, the translator reads a phrase and, using the words he remembers and some grammatical rules, determines the structure of the phrase just read.

By way of example, let us take any piece of scientific or technical text (Fig. 2).

Let us consider the process of translating one phrase. "All these operations can be done almost automatically by punch-card machines". (2,1.)

Reading this phrase, the translator easily establishes that the words can and be are the verbs and form part of the predicate. Translating these words as "can be", the translator then easily finds

Fig. 2.

the subject, which is clearly <u>All these operations</u>.

    Let us suppose that the translator, who is an engineer and has by this time forgotten some of his English, knows such words as <u>all</u>, <u>operations</u>, <u>automatically</u>, <u>machines</u> (he knows the word <u>all</u> from the expression 'all right', and the others are comprehensible from analogous words in Russian). He can then produce the following outline for a translated sentence - 'Все these операции могут быть done almost автоматически by punch-card машины'. (2,2)

    Using the word <u>by</u> also, the translator forms the instrumental case from the nominative машины thus getting машинами and omitting the word <u>by</u>. Then he begins looking in the dictionary, since the mental 'dictionary' of words he remembers is no longer sufficient. The word <u>almost</u> is easy; it has only one meaning - почти . The word <u>these</u> likewise does not cause especial difficulty, since the dictionary's reference back to <u>this</u> provides the meaning needed. <u>Done</u> has a very large number of meanings (Fig. 3); in the given case the most suitable is provided by the verb <u>do</u>. If the translator is not very good at English he will have a bad time here, because the different variations on the word do take up two whole columns in the dictionary (Fig. 4). By using the structure of the phrase which he has already deter-

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mined, the translator will in all probability pick
out the first meaning given, here the correct one;
but the chances are that he will use the verb
делать instead of выполнять.

The word <u>punch-card</u> is as a rule not found in
dictionaries, and if the translator is not a special-
ist on computing machines he will have a painful
mental search for connections between the words
цырявить, карта and машина. After some fruitless
cogitation he will write down his translation like
this - 'Все эти операции могут быть сделаны почти
автоматически punch-card машинами'   (2,3)

After a little more thought, taking into
account the preceding text, the translator will
probably make one more correction and re-write the
phrase like this - 'Все эти операции могут быть

Fig. 3.

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division [di'viʒn] n 1) деление; разделение; 2) мат. деление без остатка; 3) перегородка, барьер; 4) часть, раздел, отдел; административный или избирательный округ; 5) парл. разделение голосов во время голосования; голосование; 6) расхождение во взглядах, разногласия; 7) воен. дивизия; 8) мор. дивизион; 9) редк. шкала.

divisional [di'viʒanəl] a 1) относящийся к делению; дробный; 2) воен. дивизионный; d. area (тыловой) район дивизии.

divisor [di'vaizə] n мат. делитель.

divorce [di'vɔːs] 1. n 1) развод; 2) отделение, разъединение, разрыв; 2. v 1) расторгать брак; 2) отделять, разъединять; to d. from the soil обезземеливать.

divorcé [di'vɔːseɪ] фр. n разведённый (о супруге).

divorcée [di'vɔːseɪ] фр. n разведённая (о супруге).

divorcement [di'vɔːsmənt] n 1) развод, расторжение брака; 2) разрыв, разъединение.

divot ['divət] n шотл. дёрн.

divulgation [,daivʌl'geiʃn] n уст. разглашение (тайны).

divulge [dai'vʌldʒ] v разглашать (тайну).

Dixie ['diksi] n общее название южных штатов США (тж. D.('s) Land)

dixie, dixy ['diksi] n воен. разг. 1) походный кухонный котёл; 2) походный котелок.

dizen [daizn] v редк. наряжать.

dizzily ['dizili] adv головокружительно.

dizziness ['dizinis] n головокружение.

dizzy ['dizi] 1. a 1) чувствующий головокружение; I am d. у меня голова кружится; 2) головокружительный; 2. v вызывать головокружение; ошеломлять.

do I [duː (полная форма); du, də, d (редуцированные формы)] v (did, done) 1) делать, выполнять; to do one's work делать свою работу; to do lecturing читать лекции; to do a sum решать арифметическую задачу; what is done cannot be undone посл. сделанного не воротишь; to do one's best (sf. one's damnedest) не щадить усилий, сделать всё от себя зависящее; 2) устранять, приготовлять; to do one's hair причёсывать(ся); to do one's correspondence писать письма и отвечать на письма; room убирать комнату; to do bom приводить в порядок; to do one good быть идти на пользу; 4) to do homage оказывать; to do justice воздавать; 5) осматривать (достоп-

ности); to do the British Museum осматривать Британский музей; 6) исполнять (роль); to do Hamlet исполнять роль Гамлета; 7) разг. обманывать, надувать; I think you have been done я думаю, что вас надули; 8) занимать, угощать; обращаться с кем-л.; to do a man well хорошо обращаться с кем-л.; to do oneself well доставлять себе удовольствие; 9) подходить, годиться; this sort of work won't do for him эта работа ему не подойдёт; that will do достаточно; хорошо; it won't do to play all day нельзя целый день играть; 10) процветать, преуспевать; 11) поправляться, чувствовать себя хорошо; how do you do? здравствуйте; the invalid is ~ing well больной выздоравливает; flowers will not do in this soil цветы не будут расти на этой почве; 12) кончать, заканчивать (в формах perfect); I have done with my work я кончил свою работу; let us have done with it покончим с этим, оставим это; 13) в качестве вспомогат. глагола в отрицат. и вопросит. формах в present и past indefinite: I do not speak French я не говорю по-французски; he did not see me он меня не видел; did not you see me? разве вы меня не видели?; do you smoke? вы курите?; 14) для усиления: do come пожалуйста, приходите; I did say so and I do say now да, я это сказал и ещё раз повторю; 15) как замена другого глагола во избежание его повторения: he works as much as you do (=work) он работает столько же, сколько и вы; he likes bathing and so do I он любит купаться и я тоже; 16) при инверсии: well do I remember it я хорошо это помню; с предлог. и нареч.: do again переделывать; do away with уничтожать; раздеваться; this old custom is done away with этот старый обычай уничтожен; he did away with himself он покончил с собой; do by обращаться; do as you would be done by поступай с другими так, как ты хотел бы, чтобы поступали с тобой; do down разг. побороть, преодолеть; взять верх; под чинить себе; do for а) (ис)портить; б) губить, убивать; he is done for с ним покончено; в) заботиться, присматривать; to do for oneself обходиться без посторонней помощи sf. а) обмануть; б) погубить; в) разрушить; томить; д) одолеть; побеспокоить; do into переводить into English переведено на английский (язык); do off а) б) ам. разделять, отгородкой); do on наде-

Fig. 4.

выполнены почти автоматически' punch-card 'машинами'

(2,4)

having changed the meaning of the verb <u>do</u> and selected the one (carried out) which is most suitable in the Russian language to the nature of the text.

And lastly, it is very probable that he will re-write the phrase again like this - 'Все эти операции могут быть выполнены punch-card машинами почти автоматически'.   (2,5)

If our imaginary translator is a really ingenious individual, he may possibly now replace the English words <u>punch-card</u> by the 'Russian' панч-кард, after which it becomes immediately possible to make the phrase 'look Russian', like this - 'Все эти операции могут быть выполнены панч-кард машинами почти автоматически'.   (2,6)

Technical literature has also been enriched thereby through the introduction of a new term. It would seem that this is indeed the way in which our technical literature has acquired a plethora of such words as хонинг, рифайнинг, суперфиниш etc. (Trans. note: English words 'honing', 'refining', 'superfinish', transliterated into Russian).

It is of course also possible that the translator knows the subject and can find the correct Russian term without difficulty. In this case the phrase will assume this final form - 'Все эти операции могут быть выполнены счетно- аналитическими машинами почти автоматически'.   (2,7)

Now let us consider in order the operations performed by our translator in the process of translating. They may be described as follows (Table 4):

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TABLE 4

No. of operation	Content of operation	Example
1	Reading of English phrase to be trans- lated.	Reading of phrase (2,1)
2	Comparison of all words of phrase with words remembered by translator, and extraction of those which coincide. Deter- mination of meanings and elucidation of certain of their grammatical charact- eristics	Translation of words can, be, operations, auto- matically, machines in phrase (2,1), and deter- mination of their grammatical characteristics: can - verb; be - verb, infinitive; all - pronoun; operations - noun, feminine gender, plural; automatic- ally - adverb; machines - noun, feminine gender, plural.
3	Elucidation of additional grammat- ical characteristics of words extracted under 2 by comparison of these with one another and with remaining words of phrase	Elucidation of following addit- ional character- istics: can - 3rd person, plural, indic- ative (compar- ison with opera- tions); machines - instrumental case (comparison with by); oper- ations - nomin- ative case (as subject).

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TABLE 4 - concluded

No. of operation	Content of operation	Example
4	Search for remaining words in dictionary, determination of their meanings and grammatical characteristics.	
	a) direct determination of unambiguous words	Search for and translation of word almost - adverb.
	b) finding words with back references.	Search for words These, done; reference to this, do.
	c) selecting meaning for words which have several by comparison with other words in phrase.	These - pronoun, plural; done - participle; do - делать (comparison with operations and machines, done - сделаны
5	Rejection of words not to figure in translation	Rejection of word by, after use under 3
6	Composition of Russian phrase from Russian words found under 2 and 4, to correspond to grammatical characteristics determined under 2 and 3.	Composition of phrase (2,3)
7	Indication of words outside limits of dictionary used, in order to define them by other means	Note of word punch-card in phrase (2,3)
8	Editing to improve Russian phrase	Production of phrases (2,4), (2,5), (2,7).

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3. MECHANICAL TRANSLATION OF SCIENTIFIC AND TECHNICAL MATERIAL

Scientific and technical texts have a number of special characteristics. The most important of these are the following:

1. A comparatively small number of words is used. As has already been indicated, the number of words needed in a vocabulary for translating scientific and technical material has been estimated at 1,000 words of a general nature and 1,000 specialised terms for the field of work concerned
(Ref.4)

2. The number of possible meanings for words with multiple connotation is very sharply reduced when one is dealing with a scientific or technical text. The word <u>consider</u>, for instance, which in general can mean 'рассматривать, рассуждать, раз-мышлять, уважать, почитать, принимать за, полагать.' in a scientific text has only one meaning - 'рассматривать'.

3. The structure of the sentence is as a rule simpler in a scientific or technical text than in other forms of writing. In a Russian scientific text, for instance, many forms of the verb are in practice not used at all (the imperative mood, the first person singular and the second person singular and plural of the present and future tenses).

The order of words in the sentence is more standardised than in colloquial speech or literary prose. A count made by American workers, for example, showed that in only 1 case out of 1,469 did a noun stand before its adjective in Russian scientific texts (1, p.68), while in conversation the reverse order is often used ('человек хороший', 'друг милый', etc.).

Obviously, it is much easier under these circumstances to formulate the rules to be acted upon in automatic translation.

Let us see which of the operations performed by a translator and listed in Table 4 could be performed automatically.

Operation 1 (Table 4) can easily be mechanised, if the phrase is written down in an appropriate manner, punched out in holes, for instance, as is done on teletape. A machine can then 'read' it.

Operations 2 and 4 can be mechanised if the dictionary is 'recorded' in some way inside the machine and the words fed into the machine can be compared with those in this dictionary. The matter will be quite simple for such words as almost, for instance, which do not change their form and have only one meaning. With words having many meanings and forms the situation is considerably more complex, but it will be shown below how the difficulties which arise here can be overcome.

Operations 3 and 5 are rather more complicated to mechanise, and the main task of the philologist working on mechanisation of translation is the compilation of schemes for the execution of these particular operations.

Nevertheless this can also be done, at least for a particular type of text.

Operation 6 can be mechanised without any great difficulty, since by working to quite definite rules, it is possible to compose a correct Russian sentence from words whose grammatical characteristics and place in the sentence are known.

Operation 7 presents no difficulties, and operation 8 really belongs to the sphere of literary editing and will not be dealt with here for the time being.

Thus all the operations performed by a translator can be fitted into a system of rules that allows of automatic functioning. But both the degree of complexity of these rules and the extent of the dictionary will vary for different types of text. It is natural to start with the simplest form, scientific and technical text.

A general scheme for automatic translation is shown in Fig. 5.

```
┌─────────────────┐
│   Introduction  │
│     English     │
│      Text       │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│    Analysis     │
│     English     │
│      Text       │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│    Synthesis    │
│     Russian     │
│      Text       │
└─────────────────┘
         │
         ▼
┌─────────────────┐
│    Emission     │
│     Russian     │
│      Text       │
└─────────────────┘
```

Fig. 5.

18
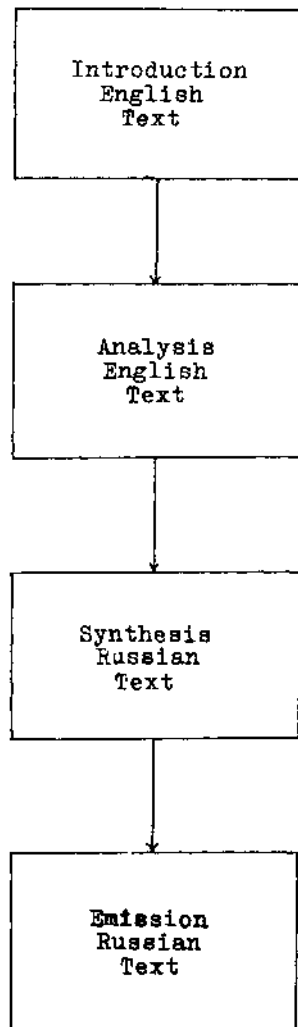
4. ELECTRONIC COMPUTERS
AND THEIR USE FOR AUTOMATIC TRANSLATION

We have seen that for the automatic execution
of the translating operations indicated in Table 4
there must be a dictionary recorded inside the
machine and it must be possible to compare the
words fed into the machine with the words included
in the dictionary. Determining the meaning of a
word and its grammatical characteristics calls for
the elucidation of the nature of many words in the
phrase, and a very large number of comparing oper-
ations is therefore required - hundreds and
thousands of them in order to determine the meaning
of one word alone. To do this in a short time, the
machine must work very rapidly. The speed of the
machine will in any case be such that there will be
no time to direct it by ordinary methods; the
machine must have automatic direction, programme
direction at that, since it will have to execute
further actions according to the results of the
preceding ones.

Fig. 6.

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There are already in existence machines with
such properties. These are what are known as
electronic computers, which perform at immense speed
(several thousand operations per second) arithmet-
ical calculations according to a complex previously-
prepared programme, and provide the answers to highly
complicated mathematical problems. Fig. 6 shows
one of these machines - the BESM high-speed
electronic computer of the U.S.S.R. Academy of
Sciences, planned and built under the direction of
Academician S.A.Lebedev.
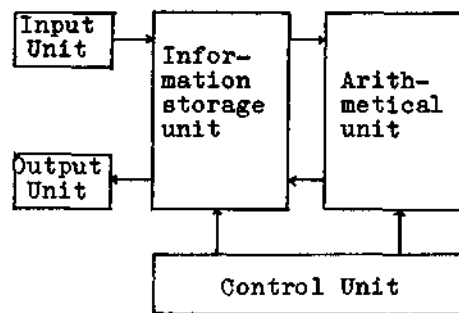
Fig.7.

An electronic digital computer consists of a
complex system of interconnected electronic elements
including several thousand valves, the principal
units within the machine being the following:
1) input unit, 2) information storage unit (the
store), 3) arithmetic unit, 4) control unit, and 5)
output unit (Fig. 7).

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The input unit is that into which are fed the
data - numbers and instructions - needed for the
work of the machine. Both numbers and instructions
are introduced in coded form, by means of perforated
tape (Fig.8). When a machine is used for trans-
lating, one can in the same manner feed in the
letters making up the words and the instructions
which tell the machine what it is to do with these
letters, if what is known as numerical code is used
for the recording of the letters.

Each letter of the Latin alphabet being
replaced by a particular two-digit number, each
word of the English text can be recorded in numer-
ical form.

Fig. 8.

If the letters of the Latin alphabet be repre-
sented by means of the well-known Baudot telegraphic
code, the numbers corresponding to them will be as
follows (Table 5):

TABLE 5

Letter	Number	Letter	Number	Letter	Number	Letter	Number
a	16	i	12	q	23	y	04
b	06	j	18	r	07	z	25
c	22	k	19	s	05		
d	30	l	27	t	21		00
e	08	m	11	u	20	.	31
f	14	n	15	v	29	,	03
g	10	o	28	w	13		
h	26	p	24	x	09		

Once such a system of recording the letters
has been decided on, any English word can be
replaced by a number.

The words the equations, therefore, method, for
instance, will be represented by the following
figures:

```
the          21-26-08 = 212608;

equations    08-23-20-16-21-12-28-15-05 =
             082320162112281505;

therefore    21-26-08-07-08-14-28-07-08 =
             212608070814280708

method       11-08-21-26-28-30 =
             110821262830
```

The words included in the dictionary are
recorded in the storage unit using the same system.
The main store is what is known as a magnetic drum
- a metal revolving drum whose surface is covered
with the same material as is used for coating the
tape of an ordinary tape-recorder (Fig. 9).

Fig. 9.

Figures, instructions and letters are recorded
on this surface, using the same code as on perfor-
ated tape; the only difference being that with
perforated tape holes are punched, while on a
magnetic drum magnetised spots are made, the record-
ing in the latter case being much more closely
spaced. The whole surface of the drum is divided
into separate sections or 'locations' (Fig.10),

each of which has its own number. This number is called the 'address' of that location. It is by this address that the location containing a certain word can be found.

The looking-up of words in the dictionary is easily done by a comparing operation which the electronic computer executes. This process may be visualised in a simplified way as follows. Suppose that from all the figures which represent the words in the dictionary, one after the other, be subtracted one and the same figure, corresponding to the word in the text whose meaning we wish to determine. When the remainder after such a subtraction is zero, our search is over: the number in the dictionary which corresponds exactly to the figure being subtracted has been found, therefore the word needed has been found in the dictionary.
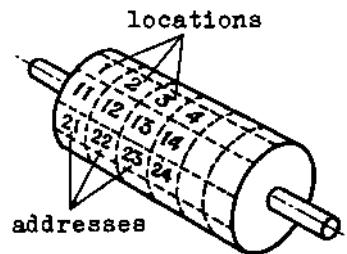
Fig. 10.

The words found in the dictionary are recorded in the storage unit of the machine in the form and order dictated by the programme, which takes into account the requirements of grammar.

When all the requirements of the programme concerning alteration and rearrangement of words have been met, those words are printed by the output unit in Russian letters corresponding to figures found in the Russian section of the dictionary, with the required case-endings etc.

5. THE AUTOMATIC DICTIONARY

Words which have only one meaning are easily translated from the dictionary, if the way in which they are written coincides exactly with that in which they appear in the dictionary.

Matters are considerably more complicated when words have many meanings. In this case one meaning out of the many possibilities must be chosen, which is the biggest difficulty in using a dictionary of the ordinary sort. The word do, for example, has numerous meanings (Fig. 4).

In order to pick out one of these, one must know the language very well, i.e., one must know in what combinations with what other words do will have this or that meaning. But the fact that the meaning of such a word depends upon the words surrounding it, while causing difficulty in translation, at the same time indicates the way to overcome the difficulty: in order to establish the needed meaning of a word which has many meanings, the words surrounding it must be analysed, attention must be paid to what words stand before it and what after, what their meanings and grammatical characteristics are, and so on. Such an analysis can be reduced to certain rules indicating a special set of criteria ensuring the correct choice of meaning for a word having many meanings.

The fact that we are translating scientific or technical material is of help in that it reduces considerably the number of words in our dictionary which have many meanings, but it does not exclude them altogether; even in such a dictionary about one-fifth of the words have many meanings. Given a set of criteria, however, choice of the correct meaning is no longer a difficulty and is executed automatically. The principle on which this is done is very similar to that used for finding plants or butterflies in a flora or entomological handbook.

These works, as everyone knows, arrange a number of characteristics in such a way that the species to which a given plant or butterfly belongs can be determined by their presence or absence.

Part of a page from a flora handbook is shown in Fig.11. Each of the numbers has under it two mutually exclusive characteristics - a thesis and an antithesis. No. 58, for instance, has as thesis 'several pistils' and as antithesis (marked <u>0</u>) 'l pistil'.

If the thesis is correct, one must go on to No. 59, if the antithesis is correct - to No. 62. Exactly the same thing can be done with words. The English word <u>example</u> is translated differently according to whether or not it is preceded by the word <u>for</u>.

This can be shown schematically (Fig.12). The same process is written out in Fig. 13 in the manner employed in the flora.

56. Стебель вьющийся.
    Convolvulus arvensis L. — Вьюнок **(428).**
0. **Стебель не вьющийся**   **56.**

  56. Столбик наверху трёхраздельный. Листья непарнопери-
стые.
    Polemonium coeruleum L. — Синюха **(429)**
0. **Столбик цельный.**
    Сем. Solanaceae — паслёновые. **Стр. 367**

  67. Венчик неправильный. Тычинок 8, сросшихся нитями
в трубку
    Polygala vulgaris L. — Истод **(353).**
О. **Венчик правильный**   **58.**
  58. Пестиков несколько   **59.**
0. **Пестик 1**   **62.**

  69. Лепестков и чашелистиков по 5. Тычинок 10.
    Сем. Crassulaceae — толстянковые. **Стр. 237**
0. **Околоцветник шестираздельый. Тычинок 6 или 9**   **60.**

  60. Цветки в зонтиках. Тычинок 9 (6 + 3). Пестиков 6.
    Butomus umbellatus L. — Сусак **(33).**
О. **Растения иные. Тычинок 6**   **61.**

Fig. 11.

As can easily be seen, the analogy is complete.
Furthermore it can be seen how with such a system
the correct meaning of a word can be found auto-
matically.

Fig. 14 shows an extract from an automatic
dictionary of this type; the section containing the
rules for translating the words many and much. In
Russian these words have five different meanings,
and the dictionary indicates how to determine which
of these meanings is to be taken. On each line
there is a note of what test is to be made, and at
the beginning there is an indication of which line
to pass on to next. Thus in line a, for example,
there is a sign a (b,c). This means that if the
result of the test is positive, one should proceed
to line b, and if negative - to line c. In order
to gain a better understanding of how such a dict-
ionary works, we shall take some cases of analysis
of actual sentences.

1. The subject would have been much better
   standardised.

On line a the requirement is to test whether
or not the word much or many is preceded by how.

```
              +-----------------+
              | Test the pre-   |
              | ceding word     |
              | for for         |
              +-----------------+
               |               |
        Yes    |               |   No
               v               v
    +-----------------+  +-----------------+
    | Translation:    |  | Translation:    |
    | Characteristics |  |  Characteristics|
    | introductory    |  | nouns, 1st decl.,|
    | word            |  | masc., hard stem|
    +-----------------+  +-----------------+
```
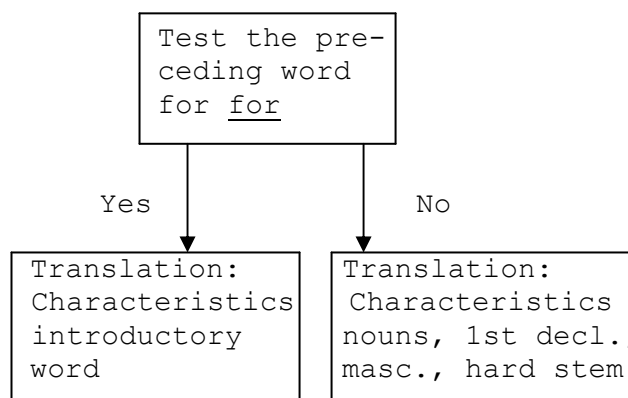
Fig.12.

This last word is not in the sentence, so the
answer is no, and we must proceed to line c. Now
we must test whether or not much or many is preceded
by as. Again the answer is no, and we pass on to line
line e. We test whether the word we have here is
much.

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119. **example** ~ Предыдущее слово - for

например - *вводное слово*

О. ~ Предыдущее слово-не for

пример-имя сущ.,1скл.,муж.р.,тв.осн.

Fig.13.

The answer is <u>yes</u>, and we pass on to line <u>g</u>. We test the preceding word and discover that it is not the word <u>very</u>. We proceed to line <u>k</u>. We test the succeeding word. In our case this is the word <u>better</u>, i.e. it is not a noun, and we therefore pass on to line <u>j</u>. Here the final answer is given - много. This answer is final because on this line we have the sign <u>j</u> (0,0), indicating that the search is at an end. Besides the exact translation of the word, we now also know some of its grammatical characteristics, and in particular that it is an adverb.

Fig. 14.

|62(a,63)	|many, much
a(b,c) a(b,c)	Check preceding word (directly) for <u>how</u>
b(0,0)	СКОЛЬКО (numeral, not declined)
c(d,e)	Check preceding word (directly) for <u>as</u>
d(0,0)	СТОЛЬКО ЖЕ (numeral declined)
e(g,i)	Check given word for <u>much</u>
f(0,0)	Not translated (adverb)
g(f,k)	Check preceding word (directly) for <u>very</u>
h(0,0)	МНОГИЙ (adjective, hard stem, with sibilant)

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Fig. 14 - cont.

i(h,j)	Check preceding word for preposition and succeeding word for noun.
j(0,0)	МНОГО (adverb)
k(l,j)	Check succeeding word for noun
1(0,0)	МНОГО (numeral, declined)

2. <u>The polynomial interpolating function is the most useful, and for many reasons.</u>

We go in order through the following steps:

<u>a</u> - answer <u>no</u>, pass to <u>c</u>;

<u>c</u> - answer <u>no</u>, pass to <u>e</u>;

<u>e</u> - answer <u>no</u>, pass to <u>i</u>;

<u>i</u> - answer <u>yes</u>, pass to <u>h</u>;

<u>h</u> - translation: 'многий.

3. How <u>many</u> places in the value found for x are reliable?

<u>a</u> - answer <u>yes</u>, pass to <u>b</u>;

<u>b</u> - translation: 'сколько.

4. There should be <u>as many</u> equations <u>as</u> there are dependent variables.

<u>a</u> - answer <u>no</u>; pass to <u>c</u>;

<u>c</u> - answer <u>yes</u>; pass to <u>d</u>;

<u>d</u> - translation 'столько же.

This, then, is the way in which determination of the meaning of words proceeds when an automatic dictionary is used. It will easily be understood that it is simpler for a person who does not know a language very well to use a dictionary of this sort rather than an ordinary one, even when a translation

is being made without the aid of a machine. The first such dictionaries are under preparation at the present time.

Up to now we have been assuming that the way in which the word concerned is written corresponds exactly to the way in which it is shown in the dictionary. Often, however, one must deal with words which do not appear directly in the given form in the dictionary. We shall not, for instance, find the word equations in the dictionary, because it has the ending - s for the plural number, whereas the dictionary gives the singular. In this case the search is somewhat complicated, since first one must get rid of the ending - s, or in other cases of analogous endings - - ing, - ed, - er, - est, - e, - y, etc.

If exact coincidence of a word in the text with a word in the dictionary is not found, a comparison is made of the ending of that word against all the above endings. When an ending is found it is then discarded, and the search through the dictionary repeated with the word minus its ending. The whole process of looking up words proceeds on a plan shown in Fig. 15, whose principle is the same one, of giving 'yes' or 'no' answers to questions, as we have seen used in the determination of the meaning of words which may have several, meanings.

We can now describe in more detail the dictionary which is used for automatic translation by machine. This consists of two parts. In one of these there are English words represented by digits. This part we shall refer to as the English section.

Each English word included in the dictionary has, besides its digital representation, a particular order number (dictionary number). For example, the words below (0608272813), device (300829122208), region (070810122815), whole (1326282708) have the following numbers in the dictionary: 110,211,570 and 748.

The dictionary for automatic translation differs from an ordinary dictionary again in showing besides the Russian word corresponding to the given English word, a number of further facts about, or characteristics of, that word. These characteristics relate to the grammar of the Russian word. For nouns there is an indication of their gender and declension, and of whether they denote animate or inanimate objects, and so on; for verbs conjugation, aspect etc. are shown. An extract from a dictionary of this type is given below.

22. admirably   - прекрасно (adverb)

23. affect   - влиять (verb 1st conj.)

24. after   - после (preposition and
                            genitive)

25. again   - опять (adverb)

26. aid   - помощь (noun fem. 3rd
                             declension)

27. all   - весь совсем (pronoun,
                                  adverb)

28. almost   - почти (adverb)

29. along   - далее (adverb)

30. also   - также (adverb)

31. alternate   - чередоваться (verb.1st
                                   conj.)

32. altogether   - вообще (adverb)

33. always   - всегда (adverb)

34. among   - среди (preposition and
                           genitive)

For English words having many meanings there are special figures indicated which represent the numbers of Russian words and show that these English words can have several translations into Russian, Choice of the word needed is made with the aid of a separate section of the automatic translation
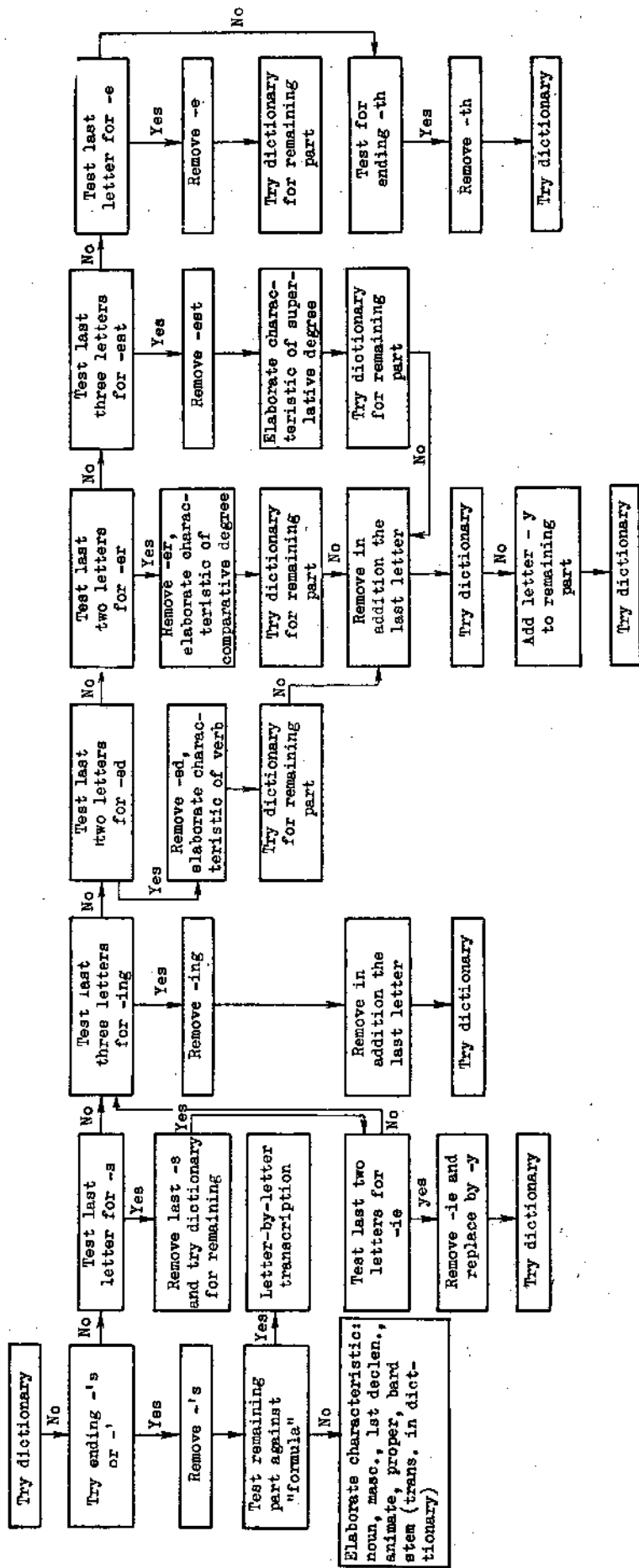
Fig. 15

Procedure for removal of English endings

programme - the dictionary of words with multiple
meanings; this part of the programme is a collect-
ion of systematised procedures like that described
earlier and shown in Fig.14.

If a word in the phrase being translated is
not to be found in either the dictionary or via
these procedures, it will be kept in the store of
the machine. When the translated phrase is printed
this untraced word will be printed in Latin letters
(Fig. 16). It is interesting to note here that
although the word remains untranslated, its place
and part in the translated phrases are as a rule
determined; looking at the example given in Fig. 16,
one can already see that the word establishes is a
verb of some sort.

**THIS RECURRENCE RELATION ESTABLISHES THE LAW OF PROPAGATION
OF ERROR THROUGHOUT THE COMPUTATION . PROVIDED THE VALUES OF T AND C ARE KNOWN
FOR EACH N.**

**ЭТО РЕКУРЕНТНОЕ СООТНОШЕНИЕ ESTABLISHES ЗАКОН РАСПРОСТРАНЕНИЯ
ОШИБКИ НА ВЧИСЛЕНИЯ. ЕСЛИ ЗНАЧЕНИЯ T И C ИЗВЕСТНИ ДЛЯ КАЖДОГО N.**

Fig. 16.

The second part of the dictionary consists of
Russian words written in the following code:

а—16	ж—29	н—15	у—20	щ—23
б—06	з—25	о—28	ф—14	э—*17*
в—13	и—12	п—24	х—26	ь—09
г-10	к—19	р—07	ц—22	ы—04
д—30	л—27	с—05	ч—23	ю—01
е-08	м—11	т—21	ш—09	я—03
	й-18	ъ—00		

and given in a special order (corresponding to the
numbers of the Russian words shown in the English
section of the dictionary). This part will be
referred to as the Russian section of the diction-
ary.

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6. DIGITAL EQUIVALENTS OF WORDS

We have seen that the numbers which represent words in the machine are very long. But besides the words themselves there is a great deal that we must know about them - the grammatical character- istics mentioned earlier. On the other hand, if the dictionary number of a word is known, it can always be found thereby. Hence the thought natur- ally arises of operating not with the words them- selves, not even as written in numerical form, but with numbers which will represent them - with their digital equivalents, which will contain information on all their grammatical characteristics and on the dictionary numbers of the words.

TABLE 6

Figure	Meaning
First	3 - adjective
Second	0 - word with hard stem 1 - " " soft "
Third	0 - second declension 1 - first "
Fourth	0 - stem of word does not end in sibilant or г,к,х 1 - stem of word ends in sibilant or г,к,х
Fifth	0 - word mutable 1 - " immutable
Sixth	0 - plural number 1 - singular "
Seventh	0 - not predicate 1 - predicate

TABLE 6 (continued)

Figure	Meaning
Eighth	0 - case not defined 1 - nominative case 2 - genitive case 3 - dative case 4 - accusative case 5 - instrumental case 6 - prepositional case
Ninth	0 - person of word not defined 1 - masculine gender 2 - feminine " 3 - neuter "

Tenth	0 - word indicates inanimate
	    object
	1 - word indicates animate
	    object

Eleventh	0 - adjective has full form 1 - adjective has short form

Twelfth	0 - word has no indication of
	    number
	1 - word has indication of
	    number

Thirteenth	0 - indication of degree and
	    participle not present
	1 - adjective of superlative
	    degree
	2 - adjective of comparative
	    degree
	3 - word is a participle

Fourteenth	0 - past tense 1 - present tense
Fifteenth	0 - word is not subject 1 - word is subject
Sixteenth	0 - word does not require definite case

TABLE 6 - concluded)

Figure	Meaning
Sixteenth (cont.)	1 - word requires nominative 2 - " " genitive 3 - " " dative 4 - " " accusative 5 - " " instrumental 6 - " " prepositional
Seventeenth	0 - English word has no ending 1 - " " " ending
Eighteenth	No. of word in English part of dictionary.

The digital equivalents are obtained in the following way. After a word has been found in the dictionary, all the information about the word is taken from the latter, the number of that word in the English section of the dictionary, the number of the corresponding Russian word, and the grammatical information given on that Russian word. Then, after working with the dictionary, the machine replaces the English words by their digital equivalents. Two locations per English word are set aside in the store for the storage of this information. The allowance of two locations rather than one, three or any other number is dependent upon the construction of the BESM machine used for automatic translation. The digital equivalent of the word is now put into the two locations of the store, where the information from the dictionary is kept.

In order that the machine shall be able automatically to distinguish the parts of speech, the figures denoting these are transferred from the dictionary to the locations where the digital equivalents of the words now stand always being placed in the same position in the location. The figure 1 corresponds to a noun, *2* - to a verb, 3 - to an adjective, 4 - to a numeral, 5 - to an adverb, 6 - to a preposition, 7 - to a conjunction, etc.

It has already been stated that two locations are set aside for each English word. In Tables 6-8

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examples are shown of the meaning of the figures
denoting a word's characteristics (and their
positioning in the first location); for an adject-
ive in Table 6, for a conjunction in Table 7, and
for an adverb in Table 8.

TABLE 7

Figure	Meaning
First	7 - conjunction
Second	1 - weak conjunction 2 - strong "
Third	0 - indication of beginning and end of clause not present 1 - indication of beginning of clause 2 - indication of end of clause 3 - indication of end of one clause and beginning of another
Fourth	0 - not subject 1 - not subject
Fifth	No. or word in English part of dictionary.

TABLE 8

Figure	Meaning
First	5 - adverb
Second	No. of word in English part of dictionary

Examples are given in the appendix (pp. 67 - 77)
which show what a first location in the store looks
like with the digital equivalent of a word in it.
In a second location there will be only a figure
indicating the number of the word in the Russian
section of the dictionary. If, after the whole
programme has been completed, this number has not
been discovered, the corresponding English word will
be printed in with the translation.

```
                    ┌──────────────────────┐
                    │ Eng. text insert     │
                    └──────────┬───────────┘
                    ┌──────────┴───────────┐
                    │ Eng.part of dic.     │
                    └──────────┬───────────┘
          ┌────────►┌──────────┴───────────┐
          │         │                      │
          │         └──────────┬───────────┘
          │         ┌──────────┴───────────┐
          │         │ Prepositions         │
          │         └──────────┬───────────┘
          │         ┌──────────┴───────────┐       Analysis of
          │         │ Formulae             │       English
          │         └──────────┬───────────┘       sentence
          │   ┌────►┌──────────┴───────────┐─ ─ ┐
          │   │     │ Verbs                │    ¦
          │   │     └──────────┬───────────┘    ¦
          │   │     ┌──────────┴───────────┐    ¦
          │   │     │ Syntax               │    ¦
          │   │     └──────────┬───────────┘    ¦
          │   │     ┌──────────┴───────────┐    ¦
          │   │     │ Numerals             │    ¦
          │   │     └──────────┬───────────┘    ¦
          │   │     ┌──────────┴───────────┐    ¦
          │   │     │ Nouns                │    ¦
          │   │     └──────────┬───────────┘    ¦
          │   │     ┌──────────┴───────────┐    ¦
          │   │     │ Adjectives           │    ¦
          │   │     └──────────┬───────────┘    ¦
          │   └ ─ ─ ─ ─ ─ ─ ─ ─┘                ¦
          │         ┌──────────┴───────────┐────┘
          │         │ Word-order alter.    │
          │         └──────────┬───────────┘
          │         ┌──────────┴───────────┐
          │         │ Russ.part of dic.    │
          │         └──────────┬───────────┘
          │         ┌──────────┴───────────┐       Synthesis
          │         │ Verbs                │       of Russian
          │         └──────────┬───────────┘       sentence
          │         ┌──────────┴───────────┐
          │         │ Adjectives           │
          │         └──────────┬───────────┘
          │         ┌──────────┴───────────┐
          │         │ Nouns                │
          │         └──────────┬───────────┘
          │         ┌──────────┴───────────┐
          │         │ Numerals             │
          │         └──────────┬───────────┘
          │         ┌──────────┴───────────┐
                    │ Russ.text print.     │
                    └──────────────────────┘
```

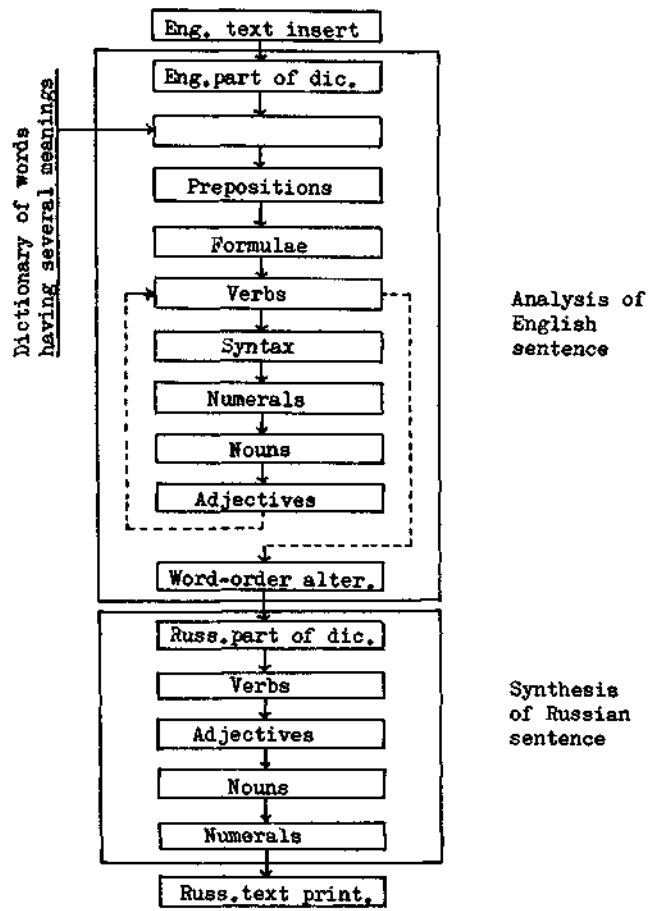Dictionary of words having several meanings

Fig. 17

7. THE PROGRAMME FOR AUTOMATIC TRANSLATION

The programme for automatic translation falls into two main parts - analysis and synthesis. Part one is the analysis of the English sentence. The task of this first part of the programme is to determine the grammatical form of the corresponding Russian words and their place in the translated sentence, from the way in which the English words are written, their places in the sentence and the presence of other words there, and their grammatical characteristics as taken from the dictionary. The information obtained is expressed by symbols and makes it possible to proceed to the second part of the programme - the synthesis of the Russian sentence. By means of this part of the programme Russian words from the dictionary which are there given in their basic form, acquire the form which corresponds to the rules of Russian grammar as applied to fit in with the symbolically-represented characteristics recorded, and are sorted into their proper places.

Grammar is represented in both the English and the Russian sections of the dictionary by a system of special 'procedures' for the main parts of speech: noun, verb, adjective, numeral, etc. The working of each procedure is based on one and the same system of 'testing' for the presence or absence of this or that grammatical (or morphological, or syntactical) characteristic in the word under analysis. Two answers, affirmative or negative, are possible, to each test. Either of them makes possible either a final conclusion and the elaboration of the corresponding characteristics for the given word, or the continuation of testing for successive characteristics until the final answer is obtained, indicating what grammatical characteristics must be elaborated for the word.

The order in which separate sections of the automatic translation programme come into operation is shown schematically in Fig. 17, while on pp. 40-42

are given parts of the grammatical procedures followed in treating English nouns and Russian verbs.

In these procedures, as in the dictionary, the following symbols are used: a marking $\underline{A}(\underline{B},(\underline{C})$ means that if test $\underline{A}$ is answered in the affirmative, one should proceed to test $\underline{B}$, while if it is answered in the negative one should proceed to test $\underline{C}$. A marking $\underline{A}(\underline{B},\underline{B})$ obviously indicates obligatory procedure to test $\underline{B}$. A marking $\underline{A}(\underline{0},\underline{0})$ indicates the final answer and the cessation of further search.

The different parts of the programme are arranged in an order which ensures that the characteristics first obtained are those which are required for further operations. The part played by different sections of the programme can be seen from their descriptions; a word should however be said about those sections which are called 'syntax' and 'changes in word order'.

Punctuation marks are put in, and the complex sentence broken down into simple ones by insertion of markings showing 'beginning' and 'end', by means of the programme section called 'syntax'. The programme section called 'changes in word order' carries out rearrangement of the words to accord with the rules of Russian grammar.

A repeat of the programme section for 'verbs' is called for because the final elaboration of the characteristics of the verbs involves preliminary execution of the sections for 'syntax', 'numerals', 'nouns', and 'adjectives'. Application of the 'verbs' section before that of the above-mentioned sections is essential because elucidation of some of the unknown quantities of the verbs, obtained through the first application of the 'verbs' section, is required for the working of the 'syntax', 'numerals', 'nouns' and 'adjectives' sections.

THE ENGLISH NOUN

1(2,7)	Test given word for 'us'
2(3,5)	Test next word for noun
3(0,0)	Elaborate characteristic of dative case
5(6,13)	Test (immediately) preceding word for 'let'
6(0,0)	Elaborate nominative case
7(8,13)	Test given word for 'it'
8(13,10)	Test 'it' for presence of characteristic of any gender
10(0,0)	Take gender from nearest preceding noun
13(14,15)	Test for presence of characteristic of singular or plural number
14(0,21)	Test for presence of characteristic of any case
15(16,19)	Test for ending '- s'
16(17,17)	Elaborate characteristic of plural number
17(18,14)	Test preceding word for formula without sign =
18(0,0)	Elaborate characteristic of genitive case
19(16,20)	Test preceding word for 'much' (*)
20(14,14)	Elaborate characteristic of singular number

21(22,23)	Test preceding word for 'let'
22(0,0)	Elaborate characteristic of nominative case and subject
23(24,28)	Test preceding word for characteristic of 'weak conjunction'
24(28,25)	Test words immediately preceding and following (in relation to weak conjunction) for adjective.
25(26,27)	Test all words for identity with given word
26(0,0)	Take case from noun thus found
27(0,0)	Take case from nearest preceding noun
28(18,29)	Test for ending '- s'

THE RUSSIAN VERB

115(116,120)	Test for presence of characteristic of 'plural number'
116(117,118)	Test for presence of characteristic of '1st person'
117(0,0)	Add ending - ЕМ
118(0,0)	Add ending - УТ
119(115,115)	Take given word without change from dictionary but before it place another word: БУД- plus ending found according to scheme

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120(0,0)	Add (to БУД-) ending - ЕТ
122(123,124)	Test for word ИСПРАВИТЬ
123(0,0)	Discard last three letters and in their place add -ЬТЕ to remaining part
124(125,126)	Test for word ПОКАЗЫВАТЬ
125(0,0)	Discard last six letters, then add ending -ЖИТЕ to remaining part
126(0,0)	Add to remaining part of word ending -ИТЕ
128(129,130)	Test for word ВЫЧИСЛЯТЬ
129(157,157)	Translation: ВЫЧИСЛИТЕЛЬНЫЙ Elaborate characteristic of "hard stem"
130(131,132)	Test for word ИДТИ
131(157,157)	Translation: ПРОИСХОДЯЩИЙ Elaborate characteristic of 'soft stem with sibilant'
132(133,134)	Test for word ПРЕДШЕСТВОВАТЬ
133(157,157)	Translation: ПРЕДЫДУЩИЙ Elaborate characteristic of 'soft stem with sibilant'
134(135,136)	Test for word УДИВИТЬ
135(157,157)	Translation: УДИВИТЕЛЬНЫЙ Elaborate characteristic of 'hard stem'
136(137,138)	Test for word ОТЛИЧАТЬСЯ
137(157,157)	Translation: РАЗЛИЧНЫЙ Elaborate characteristic of 'hard stem'

8. EXPERIMENTS IN AUTOMATIC TRANSLATION FROM ENGLISH INTO RUSSIAN ON THE BESM ELECTRONIC COMPUTER OP THE U.S.S.R. ACADEMY. OP SCIENCES

For the first experiments in automatic translation, made on the BESM electronic computer at the end of 1955, a dictionary of 952 English and 1073 Russian words was compiled, intended for the translation of specialised mathematical text, and a programme drawn up which could be used for the translation of such material.

This programme <u>does not depend upon the dictionary</u> for practical purposes. Extracts were taken for translation from Milne's <u>Numerical Solution of Differential Equations</u>.

'When a practical problem in science or technology permits mathematical formulation, the chances are rather good that it leads to one or more differential equations. This is true certainly of the vast category of problems associated with force and motion, so that whether we want to know the future path of Jupiter in the heavens or the path of an electron in an electron microscope we resort to differential equations. The same is true for the study of phenomena in continuous media, propagation of waves, flow of heat, diffusion, static or dynamic electricity, etc., except that we here deal with partial differential equations.'

Fig. 19.

Fig. 19 shows the Russian translation of this as printed by the machine.

если практическая задача в науке или технике допускает математическую формулировку, шанси довольно велики что это приводит к одному или более дифференциальным уравнениям. это верно безусловно для обширной категории задач связанных с силой и движением, так что хотим ли мы знать будущий путь юпитера в небесах или путь электрона в электронной микроскопе мы прибегаем к дифференциальным уравнениям. то же верно для изучения явлений в непрерывной среде, распространения волн, потока тепла, диффузий, статического или динамического электричества, и т д, за исключением того что мы здесь будем рассматривать дифференциальные уравнения в частных производных.

Fig. 19.

Since then the dictionary has been enlarged to cover approximately 5000 Russian and English words, and many translations of separate sentences and pieces of text have been made. Examples of these are given below.

Equations involving more than one independent variable and the partial derivatives of the dependent variables with respect to the independent variables are called partial differential equations.

Suppose that both equations actually contain all the possible partial derivatives of second order.

Уравнения, содержащие более чем одну независимую переменную, и частные производные зависимых переменных относительно независимых переменных называются дифференциальными уравнениями в частных производных.

Допустим, что оба уравнения действительно содержат все возможные частные производные второго порядка.

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In problems of this type numerical methods become a necessity due to absence of other methods for getting the requisite information out of the differential equations.

Even in cases where explicit or implicit solutions are known, it is sometimes easier to obtain a numerical solution than at» tempt to calculate numerical values from the known solution,

It is often impossible, however, to perform the actual eliminations, and hence this transformation is of theoretical rather than practical interest.

In this method a new point (x, y) is located by means of the slope at known point (x, y).

The process is illustrated by The same example that was used for Method I.

A convenient value of h is $h = 0.1$, which, in the present example will produce roughly three-decimal place accuracy in y.

В задачах этого типа численные методы становятся необходимостью, обусловленной отсутствием других методов для получения необходчмого сведения из дифференциальных уравнений.

Даже в случаях, где явные или неявные решения известны, иногда более легко получить численное решение, чем пытаться вычислить численные значения из известного решения.

Часто невозможно, тем не менее, выполнить действительные исключения, и следовательно это преобразование имеет теоретический скорее чем практический интерес.

В этом методе новая точка (x,y) определится при помощи производно в известной точке (x,y)

Метод иллюстрируется тем же примером, коорый был использован для метода I.

Удобное значение h есть $h =$ =0,1, которое в данном примере дает приблизительно три десятичных знака точности в y.

The translation programme which has been elaborated is quite universal in character. This was tested out by the following two experiments. A fragment of text from <u>The Times</u> was taken, which differed quite markedly in character from the texts from Milne's book previously used. The machine made a translation of it <u>without any alterations to the programme</u>. All that was required was to add to the dictionary a few words not previously given there. This translation is given below.

This was based on an expensive experiment done by myself and Dr. R. H. Richens, of Cambridge University, in which we worked out a method of translating small sections of selected text in foreign languages. We gave an account of this at a conference in Massachusetts in 1952, after which the International Business Machines Company, in conjunction with Georgetown University, applied our methods to give a popular demonstration which was limited to translating a few sentences from Russian into English. There

Это было основано на дорогом эксперименте проведенном мной и доктором R. H. Richens, от Кэмбриджского Университета, в котором мы разработали метод перевода малых отрывков выбранного текста на иностранные языки. Мы дали отчет о этом на конференции в Massachusetts в 1952, после которого I. B. M. компания в сотрудничестве с Джорджтаунским Университетом применили наши методы, чтобы дать наглядную демонстрацию, которая была ограничена переводом нескольких

is no possibility at present of translating a book as a work of art.

предложений с русского на английский. Не имеется возможности в настоящее время перевода книги как произведения искусства.

The second experiment was made with an extract from Dickens' David Copperfield. In this case the only guidance provided for the making of the translation was that of the rules incorporated in the automatic translation programme, and of the automatic dictionary already available. In this case as well the translation was made without any alterations to the programme, though a number of words were missing from the dictionary. This translation is given below.

«My entrance, and my saying what I wanted, roused her. It disturbed the Doctor too, for when I went back to replace the candle I had taken from the table, he was patting her head, in his fatherly way and saying he was a merciless drone to let her tempt him into reading on; and he would have her go to bed.

«Мой приход и то, что я сказал, чо я хотел, взволновали ее. Это расстроило докора тоже т.к. когда я пришел обратно, чтобы заменить свечу, которую я взял со стола, он отечески поглаживал ее голову и говорил, что он был бессердечным негодяем, который позволил ей склонить его читать дальше. И он бы хотел, чтобы она пошла спать.

But she asked him, in a rapid, urgent manner, to let her stay... And as she turned again towards him, after glancing at me as I left the room... I saw her cross her hands upon his knee, and look up at him with the same face, something quieted, as he resumed his reading.

Но она быстро, настойчиво попросила его позволить ей остаться... И когда она опять повернулась к нему, посмотрев на меня в то время как я покидал комнату... я увидел, что она скрестила руки на его колене и смотрела на него с тем же самым выражением лица, несколько успокоенная, в то время как он возобновил свое чтение

It made a great impression on me, and I remembered it along time afterwards, as I shall have occasion to narrate, when the time comes»*. (Ch. Dickens. David Copperfield, p. 243, Ch. XVI [См., 1949])

Это произвело большое впечатление на меня и я помнил это потом долгое время как я буду иметь случай рассказать, когда придет время».

* The words underlined were missing from the dictionary.

Of course this translation is extremely imperfect and can in no way be considered a satisfactory translation of a work of art, but it does show that in the programmes elaborated for automatic translation much has been taken into account which is not directly connected with the requirements of specialised scientific material.

It is interesting to compare the automatic translation with one made by an experienced translator. This is how the same fragment appears in the translation of A. Beketova:

"Мой приход как бы пробудил ее, а также изменил направление мыслей доктора, ибо, когда я вернулся, чтобы поставить на место взятую на столе свечу, он отечески гладил жену по голове и упрекал себя в бессердечности за то, что позволил ей сооб-лазить себя предложением почитать отрывок из своего труда, в то время как женушке давным-давно надо было лечь в постель.

Но она начала скороговоркой настойчиво упраш-ивать мужа позволить остаться....

Бросив на меня беглый взгляд в тот момент, когда я выходил из комнаты, миссис Стронг снова повернулась к мужу, скрестила свои руки на его коленях и стала снова так же глядеть на него. Пожалуй, лицо ее показалось мне все же несколько спокойнее. А доктор опять принялся за чтение своей рукописи.... Сцена эта произвела на меня сильнейшее впечатление, и я долго не мог забыть о ней".

Comparison shows that the automatic translation is much closer to the original. On the other hand, there are inaccuracies in our translation which stem from the fact that the dictionary being used was for mathematical material and in it some words have a meaning different from that they bear in the Dickens extract. In our dictionary, for instance, the word <u>replace</u> has only one meaning - заменить, and this was employed in the translation. But in Dickens' text it has the meaning поставить назад.

THIS IS TRUE CERTAINLY OF THE VAST CATEGORY OF PROBLEMS

ASSOCIATED WITH FORCE AND MOTION.

ЭТО ВЕРНО КОНЕЧНО ДЛЯ ОБШИРНОЙ КАТЕГОРИИ ЗАДАЧ СВЯЗА<u>ТЫХ</u> С

СИЛОЙ И ДВИЖЕНИЕМ.
<div align="center">Fig.20.</div>

SO THAT WHETHER WE WANT TO KNOW THE FUTURE PATH OF

JUPITER IN THE HEAVENS OR THE PATH OF AN ELECTRON IN AN

ELECTRON MICROSCOPE WE RESORT TO DIFFERENTIAL EQUATIONS.

ТАК ЧТО ХО<u>ЧЕМ</u> ЛИ МЫ ЗНАТЬ БУДУЩИЙ ПУТЬ ЮПИТЕРА В

НЕБЕСАХ ИЛИ ПУТЬ ЭЛЕКТРОНА В ЭЛЕКТРОННОМ МИКРОСКОПЕ МЫ ПРИБЕГАЕМ К

ДИФФЕРЕНЦИАЛЬНЫМ УРАВНЕНИЯМ.

Fig. 21.

As in any new enterprise, we encountered a number of mistakes in these first experiments in automatic translation. These were made, of course, not by the machine, but by the people who had drawn up the working programme for it. Examples of such mistakes in translation are given in Figs. 20 and 21. In both cases errors had been made in the compilation of the programme for the synthesis of the Russian sentence, and as a result words were given endings which did not belong to them. When these mistakes were discovered the programme was corrected, and now such mistakes do not appear, either in these or in analogous cases.

9. NEW INVESTIGATIONS IN THE FIELD OF AUTOMATIC TRANSLATION

Detailed investigation of the process of mechanising translation from English into Russian made it possible to start work on mechanising translation into Russian from further languages, and in particular from the Oriental languages. Work has now begun on mechanising translation from Chinese and Japanese into Russian. This is a very interesting though a very difficult task. Even the first step of all, the feeding into the machine of the characters used in Chinese and Japanese, is a serious problem. A solution of it can be found however. The key to it is the fact that there does exist a system of coding Chinese characters for transmission by telegraph. A page from a Chinese telegraph code book is shown in Fig. 22. This shows the characters in a certain order, and above each of them a four-digit number - its code. This coding does not differ in principle from that in use here, only instead of the two-digit numbers used for the Russian and Latin alphabets four-digit numbers must be used for the Chinese, as there are about 10,000 characters to be coded. In Fig. 23 a telegram from Peking to Shanghai is shown coded in this way; in it are employed, among others, characters nos. 6643 and 6670, which occur in Fig. 22. Clearly a text for feeding into a machine can be coded in exactly the same way as the Chinese telegraphists code telegrams. The programme for automatic translation from Chinese into Russian is very complicated. It has nevertheless been compiled, and the first experiments in automatic translation of Chinese mathematical texts have already been made.

Examples of such translations are given on page 51. These translations, which were made to check the programme, were not carried out on the machine but were made by a man who did not know Chinese, following the rules laid down in the automatic translation programme. It is, of course, too early

at the moment to say that the problem of automatic-
ally translating from Chinese into Russian is
solved. Only the very first steps towards a solu-
tion of this most knotty problem have as yet been
taken; work on it will be continued at the U.S.S.R.
Academy of Sciences and in the Academy of Sciences
of the Chinese People's Republic, the two bodies
having concluded an agreement on mutual aid.

66
JTW—JXR

6600	6601	6602	6603	6604	6605	6606	6607	6608	6609	
迤	迎	近	迓	退	迁	迢	迤	迥	迎	辵
JTW	JTX	JTY	JTZ	JUA	JUB	JUC	JUD	JUE	JUF	
6610	6611	6612	6613	6614	6615	6616	6617	6618	6619	
迨	迪	迫	迭	迮	述	迴	迷	进	迹	
JUG	JUH	JUI	JUJ	JUK	JUL	JUM	JUN	JUO	JUP	
6620	6621	6622	6623	6624	6625	6626	6627	6628	6629	
追	迺	退	送	适	逃	逅	逆	逋	逌	
JUQ	JUR	JUS	JUT	JUU	JUV	JUW	JUX	JUY	JUZ	
6630	6631	6632	6633	6634	6635	6636	6637	6638	6639	
逍	透	逐	逑	途	逕	逖	逗	這	通	
JVA	JVB	JVC	JVD	JVE	JVF	JVG	JVH	JVI	JVJ	
6640	6641	6642	6643	6644	6645	6646	6647	6648	6649	
逛	逝	逞	速	造	逢	逢	連	逭	逮	
JVK	JVL	JVM	JVN	JVO	JVP	JVQ	JVR	JVS	JVT	
6650	6651	6652	6653	6654	6655	6656	6657	6658	6659	
週	進	逵	逶	逸	逷	逼	遇	遁	遂	
JVU	JVV	JVW	JVX	JVY	JVZ	JWA	JWB	JWC	JWD	
6660	6661	6662	6663	6664	6665	6666	6667	6668	6669	
遄	逾	遊	運	遍	過	遐	道	遉	
JWE	JWF	JWG	JWH	JWI	JWJ	JWK	JWL	JWM	JWN	
6670	6671	6672	6673	6674	6675	6676	6677	6678	6679	
道	達	違	遘	遞	運	遜	遝	遠	遡	
JWO	JWP	JWQ	JWR	JWS	JWT	JWU	JWV	JWW	JWX	
6680	6681	6682	6683	6684	6685	6686	6687	6688	6689	
遣	遢	遥	遨	適	遭	遮	遯	遲	遴	六七
JWY	JWZ	JXA	JXB	JXC	JXD	JXE	JXF	JXG	JXH	
6690	6691	6692	6693	6694	6695	6696	6697	6698	6699	
遵	遶	遷	選	遹	遺	遻	遼	遽	避	
JXI	JXJ	JXK	JXL	JXM	JXN	JXO	JXP	JXQ	JXR	

Fig.22.

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Fig. 23.

1. 若M及N是相通的以P爲標的哈方陣，則S⁻¹M及S⁻¹N是相通的以一爲標的哈方陣。

Если M и N являются сознными матрицами Гамильтона, скаляр которых есть P, то $S^{-1}M$ и $C^{-1}N$ являются сознными матрицами Гамильтона, скаляр которых есть 1.

2. 一哈方陣若無迷向綫，則稱爲定號哈陣。

Если матрица Гамильтона не имеет изотропных линий, то она называется определенной матрицей Гамильтона.

3. 由定理1只須證明A是可逆的場合。

Согласно теореме 1 достаточно доказать случай, когда A является невырожденным.

4. 最後，下述定理把哈方陣的化簡理論引爲可逆的哈陣的化簡理論。

Наконец, следующая теорема сводит теорию упрощения матриц Гамильтона к теории упрощения невырожденных матриц Гамильтона.

5. 在討論實數域的性質之前，先研究 n 是偶數，S 的指數是U=ⁿ⁄₂的情况。

Прежде чем рассматривать свойства поля вещественых чисел, исследуем случай, когда n является четным числом, а показатель S составляет $V = \frac{n}{2}$.

Sample translations using the Chinese programme

10. SOME SCIENTIFIC QUESTIONS CONNECTED
WITH THE PROBLEM OF AUTOMATIC TRANSLATION

The problem of automatic translation lies on the borders of such apparently heterogeneous sciences as linguistics and mathematics. It is precisely this circumstance which makes it especially interesting. The first steps which were made in this field obliged scientists to turn their attention to a number of new and interesting scientific questions. In this chapter we should like to say a little about some of these.

STRUCTURAL ANALYSIS OF LANGUAGE

The first investigations in the field of automatic translation were made by mathematicians and engineers. These investigations were naturally more mathematical than linguistic in character. Some of these research workers posed the problem of automatic translation as a problem of decoding coded text. Warren Weaver, for instance, wrote that 'a book written in Chinese is simply a book written in, English but coded in Chinese code' (1). If this assertion were correct, then it would be possible to apply the same methods to automatic translation which have been successfully used for reading codes - statistical analysis and other mathematical procedures, i.e., one could make the problem basically a mathematical one. Among linguists also there are schools of thought which apply similar methods of analysis (analysis of structures, etc.), and a number of works on automatic translation follow the line of applying this method. It is however easy to understand that the task of decoding and the task of translating are in no way identical. In coding or decoding we are only changing the outward form of the words without touching the language itself, and it is natural that a task of this kind should be quite capable of solution by formal methods. But in translation we are changing the language, i.e., the

whole highly complex and subtle system of expressing thoughts, a system that has been elaborated down the ages by each nation and that is bound up in the closest possible fashion with that nation's thinking, history, way of life, etc.

Here we have the reason why the attempt to fit a language into some abstract scheme has proved of little effective use. For the purposes of translation, indeed, application of such methods is hardly reasonable at all. For any attempt to represent *a* language as an abstract scheme inevitably involves some abstraction from details, some rejection of the concept contained in them. And this is extremely detrimental to a translation; in a living language every word, the form of that word, and its place in the sentence, all have their sense, all give this or that shade to what is being said; if it were not so, the language would not have preserved the words and forms concerned. Furthermore, attempts to establish unvarying correspondence between linguistic structures in different languages do not yield sufficiently good results since structures develop in their own way in every language, and often there is in fact no such correspondence; two sentences completely identical from the point of view of form, in one language, will be translated into another language by means of sentences of different structure. English sentences using the verbs <u>should</u> and <u>would</u> are well-known examples.

Identical English constructions	Different Russian constructions
He should knock at the door before coming in.	Следовало бы ему постучать в дверь, прежде чем войти.
He would knock at the door before coming in.	Он бывало постучит в дверь, прежде чем войти.

Another example is provided by the translation into French of the Russian phrases я об этом говорю - j'en parle, and я об этом думаю - j'y pense.

In Russian these two phrases have a formal

structure which is identical, whereas the French make a quite subtle distinction, using in the first case en, equivalent to de cela, and in the second y, equivalent to à cela, thus giving what may be called a direction to the actions described by the verbs. One more example is the sharp change in meaning produced by changing the positions of noun and adjective in French in some cases, though in others such a change is possible. For instance, un vrai conte will be "настоящая сказка'in Russian while un conte vrai will be 'истинное присшествие' or 'быль'. But un joli papillon or un papillon joli will both mean 'красивая бабочка'.

Such difficulties arise even in the simplest cases of translation. What then is one to say of the more complex cases in literary translation? Clearly abstract structural analysis is powerless here. The nuances to be distinguished are too fine. We have already quoted an extract from the text of Gogol's The Nose, a text which it is extremely difficult to translate into another language. One can quote examples of another kind - sentences which are quite primitively simple in structure and yet exceedingly hard to translate. The concluding lines of Tyutchev's poem On the Road can be quoted as an example:

> Лишь кой-где бледные березы,
> Кустарник мелкий, мох седой,
> Как лихорадочные грезы,
> Смущают мертвенный покой.

The difficulty in translating these sentences lies not in their structure, but in finding equivalents for precisely those individual words which the poet has used, and which have entered into mutual relationships with one another which are exceedingly subtle and at the same time exceedingly precise. All that we have just stated will, we feel, explain why from our point of view the analysis of linguistic structures cannot solve the problem of translating automatically, although some scientists are attempting to apply this method in the U.S.A. and even in the U.S.S.R.

UNAMBIGUOUS LANGUAGES

One of the great difficulties that have to be taken into account in translating, particularly in making an automatic translation, is the <u>multiplicity of meanings</u> in all living languages, i.e., the presence in them of different means of expressing one and the same conception, and the possibility of one and the same word being used to mean different things. This multiplicity is no accident. A language reflects life in all its multiplicity of facets, life in which there are never two completely identical situations, life in which, in Heraclitus' words, "one cannot twice enter the same stream". But such richness of language is by no means always necessary. In a number of cases language has to fulfil much more modest functions. Let us suppose, for instance, that we are consulting a library catalogue for literature on the resilient properties of solid bodies. This is usually done from what is called a "subject catalogue", in which the titles of books or journal articles dealing with these subjects are given under headings such as "resilience", "solid state", "resilient properties", etc. The selection of books and papers to go under such subject headings is a very complex task, since it is very common to find that the title of a paper does not directly mention any of the words of which the headings are composed. Suppose, for example, that a paper is called "Hardening of Steel under Deformation". In order to relate this paper to the headings given above, one must know that the resilience of solid bodies is connected with their deformation, and that hardening is one of the resilient properties. In order to avoid cases when a paper which was needed could not be found owing to the incorrect description of its content, investigations were started into the possibility of creating an "<u>information language</u>" i.e., a language which would make it possible to outline the content of the paper in a highly summarised form and to do it in such a way that the summary would reflect all the essential material in the paper without any ambiguity whatever, i.e., with only one possible meaning. The absolute necessity of unambiguity is here obvious, as if this is neglected we shall not know whether the paper concerned should be included in a bibliography provided in answer to a request

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for literature. The information language has not
as yet been created, but work is in progress on the
elucidation of the properties it must possess, and
the first attempts in this field are already being
made. First of all it is clear that one can omit
all the connecting words, e.g., prepositions and
conjunctions, in this language. Adverbs and
pronouns are likewise not essential. What is more,
one can attempt to do without verbs, as the Chinese
and Japanese poets have done. This is the way in
which the lines quoted below are constructed; they
are from a poem by the Japanese poet Baso.

        (Re-translated from Russian)
                Winter night in the garden
        Moon in the sky like fine thread
        and the scarce-heard ringing of cicadas.

     If one pursues this course, it is easy to
realise that the information language must be a
language of concepts, in which, however, the
connections between those concepts or character-
istics which make up the informational elements
replacing sentences in our language, must be indic-
ated. The need to show some logical connections is
clear from the following examples. Let us suppose
that the subject-matter of a paper whose content
is to be described in the information language is
the destruction of microbes by X-rays. In this
case an informational element consisting of the
characteristics 'destruction', 'microbes', 'X-rays',
will unambiguously describe the content of the
paper. But if the paper deals with the destruction
of microbes by organic substances, an analogous
compilation of characteristics - 'destruction',
'microbes', 'organic substances' - will no longer
describe the paper's content unambiguously, since
it is not clear what is destroying what. In this
case a characteristic for the connection is also
necessary, to indicate what is being destroyed.
We may note here in passing that in our ordinary
language this characteristic is introduced by means
of alterations to the form of the words - 'уничтож-
ение микробОВ органическиМИ веществаМИ'
(= destruction OF microbes BY organic substances -
trans.),

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which does away with any ambiguity. In our inform-
ational element this can be done in an analogous
way, by adding to one of the characteristics a
special sign, '!' for instance, to give: 'destruc-
tion' - "microbes' - "organic substances' - !
Recording of the informational element in this
form is more convenient than writing it in the
ordinary way because it is a simple assembly of
characteristics, which may be taken in any order
and which do not change.

It will easily be seen, however, that the
necessity of introducing connections between the
characteristics calls for the creation of rules by
which these connections are brought in and read
back, i.e., the creation of a kind of grammar of the
informational language. This grammar will naturally
be much simpler than ordinary grammar, since the
language itself is not intended to express all that
can be expressed by ordinary language. Nevertheless
a special problem of translation will arise in the
course of using the informational language, if such
a language is created. It is clear that the contents
of all the papers on which bibliographical informat-
ion is going to be given will have to be recorded
in the informational language, with due observance
of the 'grammar' of that language. Haying for
instance decided to denote the characteristic
'destruction' by the letter A, that for 'microbes'
by the letter R, and 'organic substances' by the
letter C, we can write down the phrase 'destruction
of microbes by organic substances' as an information-
al element AC!R, thereby bringing in the rule of
'grammar' by which the sign !, denoting the active
agent, relates only to the symbol standing immediat-
ly before it, in this case to the letter G. When
the reader sends in his request to the library, this
request will have to be translated into the inform-
ation language, and after that the search for liter-
ature made by comparing the translated request with
the assembled records of contents of papers held by
the library; we shall call these assembled records
'the dictionary of informational elements'. It will
not be a dictionary in the ordinary sense of the
word, since every informational element represents
a sum total of ordinary words and special symbols
indicating the connections between the words; but
if the characteristics are recorded in a summarised
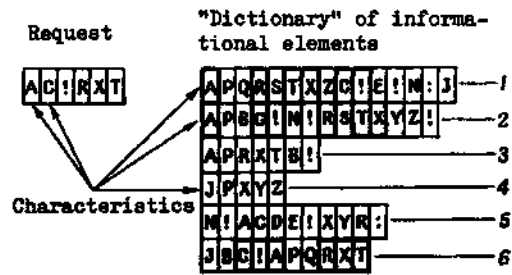
Fig. 24.
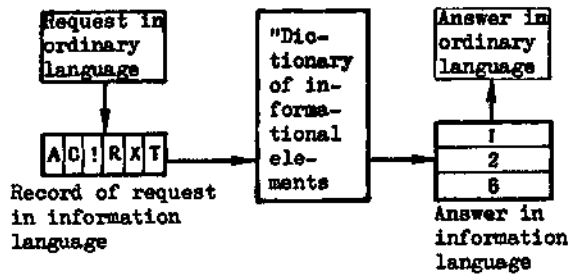
Fig. 25

way by letters, the informational elements will
externally resemble words, and the process of
comparing the content of the request with these
"words" will be like the process of looking some-
thing up in an automatic dictionary, the sole
difference being that here we are looking in the
"dictionary" not for "words" which coincide
exactly with the request, but those which contain
in full all the signs contained in the request, but
may also include other signs as well. Fig. 24
shows such a comparison: "words" 1,2 and 6 correspond
in this way to the request, consequently the papers
they represent will contain material such as is
called for by the request. It thus appears that the
task of mechanising bibliographical research has
much in common with that of mechanising translation,

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except that the former process has the peculiarity
of using an artificial informational language,
though its use is confined to the work done <u>within
the machine</u>, since after the research is completed
and the required papers selected the reader must be
given his answer in ordinary language once more
(Fig. 25).

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*54·42. $\vdash :: \alpha \epsilon 2 . \supset :. \beta C \alpha . \exists ! \beta . \beta + \alpha . = . \beta \epsilon \iota'' \alpha$

Dem.

$\vdash . *54·4 . \supset \vdash :: \alpha = \iota' x \cup \iota' y . \supset :.$

$\qquad \beta C \alpha . \exists ! \beta . \equiv : \beta = \Lambda . \vee . \beta = \iota' x . \vee . \beta = \iota' y . \vee . \beta = \alpha : \exists ! \beta :$

[*24·53·56.*51·161] $\qquad \equiv : \beta = \iota' x . \vee . \beta = \iota' y . \vee . \beta = \alpha$ (1)

$\vdash . *54·25 . \text{Transp} . *52·22 . \supset \vdash : x + y . \supset . \iota' x \cup \iota' y + \iota' x . \iota' x \cup \iota' y + \iota' y :$

[*13·12] $\supset \vdash : \alpha = \iota' x \cup \iota' y . x + y . \supset . \alpha + \iota' x . \alpha + \iota' y$ (2)

$\vdash . (1) . (2) . \supset \vdash :: \alpha = \iota' x \cup \iota' y . x + y . \supset :.$

$\qquad \beta C \alpha . \exists ! \beta . \beta + \alpha . \equiv : \beta = \iota' x . \vee . \beta = \iota' y :$

[*51·235] $\qquad \equiv : (\exists z) . z \epsilon \alpha . \beta = \iota' z :$

[*37·6] $\qquad \equiv : \beta \epsilon \iota'' \alpha$ (3)

$\vdash . (3) . *11·11·35 . *54·101 . \supset \vdash . \text{Prop}$

*54·43. $\vdash :. \alpha, \beta \epsilon 1 . \supset : \alpha \cap \beta = \Lambda . \equiv . \alpha \cup \beta \epsilon 2$

Dem.

$\vdash . *54·26 . \supset \vdash :. \alpha = \iota' x . \beta = \iota' y . \supset : \alpha \cup \beta \epsilon 2 . \equiv . x + y .$

[*51·231] $\qquad \equiv . \iota' x \cap \iota' y = \Lambda .$

[*13·12] $\qquad \equiv . \alpha \cap \beta = \Lambda$ (1)

$\vdash . (1) . *11·11·35 . \supset$

$\qquad \vdash :. (\exists x, y) . \alpha = \iota' x . \beta = \iota' y . \supset : \alpha \cup \beta \epsilon 2 . \equiv . \alpha \cap \beta = \Lambda$ (2)

$\vdash . (2) . *11·54 . *52·1 . \supset \vdash . \text{Prop}$

From this proposition it will follow, when arithmetical addition has been
defined, that 1 + 1 = 2.

Fig. 26.

From <u>Principia Mathematica</u> by A.N. Whitehead
and Bertrand Russell, F.R.S.Volume I p.362. By
permission of the Cambridge University Press.

Another interesting example of unambiguous
languages is provided by the <u>logical languages</u>
created by mathematicians for the purpose of
expounding with complete strictness, and without
any ambiguity whatever, the content of theorems
and their proofs. These languages also pursue
very limited aims and are intended, in essence,
for the exposition of the simplest possible state-
ments of the 'from A follows B', 'if from A follows
B, then from C follows D' type, etc.

One such language, elaborated by the English
mathematicians Russell and Whitehead was used by
these authors in writing the fundamental work,
Principia Mathematica. Part of a page from the
first volume of this work is shown in Fig. 26. It
gives some idea of the appearance of a text in a
'logical language'. It is interesting to note that
the strict exposition of even elementary mathematical
propositions requires a great deal of space. What
we see in Fig. 26 is part of p. 362 of the book, and
at the foot of it one may read, printed in ordinary
English, the sentence 'From this proposition it will
follow, when arithmetical addition has been defined,
that 1+1=2' . The example is interesting because it
shows what a heavy price must be paid for strictness
of exposition and complete unambiguity of language.
Our ordinary languages prove in this respect to be
very economical and effective instruments for the
expression of thoughts. This can be understood if
we picture to ourselves what a complex web of con-
ceptions, actions and characteristics is reflected
in even our simplest phrases; in a logical language
all these interwoven threads are as it were stretched
out into one long line.

ANALYSIS OF STYLE AND THE PROBLEM

OF LITERARY EDITING

We often speak of the 'style' of this or that
writer, of an author 're-creating the style of the
epoch' in his work, and so on. It would be inter-
esting to elucidate what objective facts underlie
these rather woolly phrases. What makes it possible
for us to distinguish the style of one writer from
that of another? It is in fact possible to give
an answer to these questions, and the answer is a
very simple one. It is natural that every writer
should pick out, from the practically inexhaustible
store of words, expressions and turns of phrase
available in every developed language, those partic-
ular ones which fit in with the theme of his work
and which are most near to him personally. In so
doing the author creates a kind of individual lang-
uage which forms a part of the national language in
which he is writing. This individual language has
its own peculiar characteristics. Its vocabulary
may differ from the generally-used vocabulary, by

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for instance including certain 'favourite words' of the author's, met with more frequently in his work than is usually the case, or by the occurrence of special words essential to the particular work. The syntax of this individual language may also be peculiar to it, and so on. Of course these distinctions will be much more subtle than the differences between, say, English and Russian or English and French, but they will still exist, and it is possible to attempt an analysis of them in the same way that we analyse the characteristics of a language for the purposes of automatic translation. In the work of the great writers, the master craftsmen of words, one can find many examples of the masterly use of such 'individual languages'. In Pushkin's short story <u>The Peasant Gentlewoman</u>, Liza Muromskaya's speech differs sharply from the speech she employs when she is playing the part of Akulina. 'What does she mean, papa?' she said in amazement, ' - Why are you limping? Where is your horse? Whose carriage is this?". "Ye were at our gentry's the night, master?' said she straightway to Aleksei, ' - What did ye think of the young mistress?'. It is interesting to note that in the second example Pushkin alters his vocabulary in his 'author's speech' also, introducing a word such as 'straightway', which accords well with Akulina's manner of speech.

Style understood in the above way enables an author to give very subtle characterisations of different features of background, time and place of action, etc. When Pushkin writes, in <u>The Shot</u>, 'We had a captain with us in the cavalry, a man fond of his joke and his pleasures,' and later gives a remark made by this captain - 'And I dare say your hand would not be raising itself to lift a bottle, my lad', that single remark contains almost in full the characterisation of the man already quoted. Analysis of stylistic peculiarities is of great importance for the problem of automatic translation. Today it is already quite clear that it is impossible to count on the creation in the near future of dictionaries and grammatical schemes <u>taking in the whole of a language</u>. We can think only in terms of <u>specialised dictionaries</u>; dictionaries to cover various fields of knowledge; dictionaries containing words characteristic of a given historical epoch;

regional dictionaries, of words used in different parts of the country, and so on. These 'partial' dictionaries will, however, be gradually filled in and extended, so that taken together they will at least offer the prospect of eventually covering the whole language. In exactly the same way specialised grammatical schemes dealing with various special turns of speech and so on will be made up, alongside the general grammatical ones. When some complex text is to be automatically translated one may foresee the process of its analysis providing for the automatic switching in of this or that dictionary or special grammatical scheme, if typical points calling for their use are encountered in the text. A problem of this kind is already arising in connexion with the need to translate American texts. As we all know, the English language as used in America has a number of features peculiar to it; in particular, the use of specifically 'American' words and colloquialisms is character-istic of this variant of English. By making some of these act as sign-posts, as it were, to indicate an American text, we can in translating such a text bring in an 'American' dictionary and 'American' schemes. Suppose, for instance, that in translating something we have come across the sentence ''Baloney', the detective remarked.'

Here we have a typically American expression 'baloney', meaning 'nonsense'. Noting this word, the machine accepts it as a sign indicating 'Americanism' and brings into play the appropriate dictionary, after which we shall easily perceive that the word 'buck' in a subsequent passage means 'dollar' although in English it means 'a deer', that the word 'grand' means 'a thousand dollars', and so on.

Another interesting problem, <u>literary editing by machine</u>, is closely connected with the analysis of style. At first glance this is a job that quite defies mechanisation, but this is not in fact so. In reality, the following are in the main functions performed in the course of literary editing:

a) bringing the author's text into line with the requirements of orthography, morphology and syntax;

b) removing repetitions of the same word at
close intervals by replacing it in some cases by
a synonym;

   c) reducing the text as far as possible to a
'readable' form, i.e., ensuring that it has a
rhythmic flow enabling it to be read aloud with
ease.

   It can easily be seen that work on text under
point a) can be made automatic by using practically
the same schemes as are employed for analysis and
synthesis in translation. The difference will
merely be that here the analysis and synthesis will
be made within the bounds of one and the same
language. Figuratively speaking, one may say that
a translation is being made in this operation, from
'not quite correct' Russian to 'quite correct'
Russian. Work under point b) can be done by the
compilation of a special dictionary of synonyms and
of a scheme for the replacement of words by synonyms,
taking into account preceding and subsequent words.
So far as point c) is concerned, it would appear
possible to construct an analytical procedure which
would take into account a statistical assessment of
the disposition of accented and unaccented syllables
in the text, etc.

TRANSLATION FROM AND INTO SEVERAL LANGUAGES AND

THE PROBLEM OF THE INTERMEDIARY LANGUAGE

   The problem of translating automatically is, as
yet, in its very earliest stages of development.
The results achieved, however, permit one to hope
for further successes in the immediate future, and
naturally call up dazzling prospects in the minds
of optimistically-inclined research workers. These
workers are thinking, for instance, of a universal
translating machine, which will make translations
from any one of the languages for which it caters
into any other of these. One will only need to press
the button marked 'Swedish' at the input end of the
machine, and the button marked 'Chinese' at the
output end, and the machine will produce a trans-
lation from Swedish into Chinese. Of course, we
have a long way to go before such a machine is
built, but some questions of 'multilingual' trans-

lation can be elucidated even now. First of all
it is easy to discover that it is not advantageous
to make direct language-to-language translations,
but better to make use of what is known as an inter-
mediary language. The point is that if one needs
to make translations from any one of n languages
into any other one of the same n languages, one will
require as many dictionaries and translation prog-
rammes as there are combinations of n by twos,
counting each combination twice. This number can
easily be calculated; it will be equal to $a_n=n(n-1)$.
But if one of these languages be singled out and
the translation always made first into that language
and then from it into the other language required,
the number of dictionaries and programmes needed
will be equal to $b_n=2(n-1)$. With different quant-
ities for n this will give us:

n	2	3	4	10	20
s_n	2	6	12	90	380
b_n	2	4	6	18	38

It is quite clear that it is more advantageous
to have an intermediary language. What language
should the latter be? Practically speaking, for a
country making such multilingual translations and
building an appropriate machine for the purpose,
the language of that country, since translations
from and into it will in any case have to be made.
For the U.S.S.R., consequently, the intermediary
language will be Russian. The question however
arises of whether it may not be worth while thinking
of elaborating an intermediary language specially
for the purpose, making its grammar particularly
simple and convenient for translation. More espec-
ially, is it not possible to use such 'international'
languages as Esperanto, Interlingua, Volapuk?.
It appears, however, that it will be difficult to
do this. No 'artificial' language is capable of
transmitting all the richness of naturally—develop-
ing languages, and translation into such a language
will therefore inevitably impoverish actual speech.
But these problems, incidentally, have had little
work devoted to them as yet.

We are proposing to concern ourselves very soon

with translation from one foreign language into
another, using Russian as an intermediary language.

$$E - V_{ER} - A_{ER} - S_R - R$$
$$\underbrace{\quad}_{VA_{ER}}$$

$$E - VA_{ER} - S_R - R$$
$$R - VA_{RF} - S_F - F$$
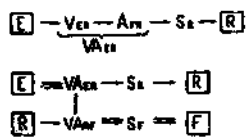
Fig. 27.

It should be noted that with our method of
machine translation this task will be susceptible
of quite simple solution. A scheme for the trans-
formation of an English sentence E into a Russian
one, R, is shown in Fig. 27.

The letter $\underline{V}$ denotes work with the dictionary,
and the letter $\underline{A}$ - the analytical part of the prog-
ramme. The indices $\underline{ER}$ denote "Eng.-Russ.". The
programme for synthesis is indicated by the letter
$\underline{S}$. Uniting under the symbol $\underline{VA}$ the result of the
work with the dictionary and the result of the
analysis, we note that after this stage of the
process has been completed we have the numbers of
all the words in the Russian part of the dictionary,
and all their grammatical characteristics. From
here one can proceed directly to work with, for
instance, the Russo-French dictionary, thereby
obtaining the numbers of the words in the French
part of the dictionary this time, and again all
their grammatical characteristics, which makes it
possible to bring into play immediately the pro-
gramme for synthesis of the French sentence, and so
complete the translation.

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11. CONCLUSION

It is, of course, a long way from the first attempts at automatic translation which have now been made in the U.S.S.R. and abroad to the practical realisation of the aim of translating by machine on any large scale. We feel, however, that the position is not as black as it is painted by some scientists abroad, and that there is every ground for expecting real successes in the immediate future, at least in the translation of scientific and technical material.

REFERENCES

1. Machine translation of languages. Edited by W. Locke and A. Booth, p.243 (1955).

2. N. Macdonald. Language translation by machine. Computers and Automation, 3, 2, 6-10.

3. Y. Bar-Hillel. Can translation be mechanised? American Scientist, 42, 2, 248-260 (1954).

4. A. Booth. Calculating machines and mechanical translation. Discovery, 15,7, 280-285 (1954).

APPENDIX

EXAMPLE OF THE
ANALYSIS OF AN ENGLISH SENTENCE
IN AUTOMATIC TRANSLATION

Let us consider the sentence 'This is true certainly of the vast category of problems associated with force and motion'.

In automatic translation the machine carries out the following procedure with each of the English words composing the sentence.

This

After work with the dictionary the machine determines that the English number of this word is 0451, and that further information on the word is to be taken from the supplement to the dictionary (empty spaces in the location of the Russian number).* In the notation used the dictionary information on the word this will be:

| | | | | | | | | | | | | | | | | 0451 |

Prom the supplement to the dictionary we obtain the following information on this word: translation – это;noun; neuter gender; hard stem; singular number; subject:

| 1 | | | 1 | | 3 | | | | 1 | 0 | | 0451 |

On the basis of the information from the dictionary and from the supplement to it the word this is dealt with according to the procedure for 'English nouns', and up to the point of the Russian section coming into play it has the following characteristics:

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* Editor's footnote: 'The author apparently means here 'that part of the programme which chooses the meaning appropriate to the context in the case of a word of multiple meaning''.

translation - это; noun; declined as adjective;
invariable; singular number; nominative case; neuter
gender; characteristic of numeral; subject; hard
stem; Russian no. 6327:

1	0	0	1	1	0	1	3	0	0	1	0	0	1	0	0	0	0451

<u>is</u>

After work with the dictionary we find that the
English number of the word is 0404; further inform-
ation on the word <u>is</u> is to be taken from the supple-
ment to the dictionary (empty spaces in the location
of the Russian number):

																	0404

From the supplement to the dictionary we get:
verb - predicate; present tense; 3rd person; sing-
ular number:

2				1	1			2		.			0	0404

The word <u>is</u> is dealt with under the procedure
for 'English verbs' and the following set of char-
acteristics is obtained: verb; characteristic of
numeral; <u>not translated</u> (empty space in square of
Russian number):

2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0404

<u>true</u>

After work with the dictionary the machine
determines that the word <u>true</u> is not in the dict-
ionary. Discarding the ending -e, the machine finds
in the dictionary the word <u>tru</u> and obtains informat-
ion on it: English number 0414. Further informat-
ion on the word to be taken from the supplement to
the dictionary:

																	0414

From the supplement to the dictionary we obtain:
translation - <u>верный</u>; adjective; hard stem; Russian
no. 6344:

| 3 | 0 | | | | | | | | | | | | 0414 |

The procedure for 'English adjectives' gives:
adjective; singular number; neuter gender; short
form; characteristic of numeral; Russian no. 6344:

| 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0414 |

<u>certainly</u>

From the dictionary we get the translation –
<u>безусловно</u>; introductory word; English number 0084.
The Russian number of the word is automatically
recorded in the appropriate location of Russian
numbers, i.e., there is no need to have recourse to
the supplement to the dictionary. The word does
not require to be treated under the procedure for
'Part of speech':

| 5 | 1 | 0084 |

<u>of</u>

From the dictionary we get: preposition;
English number 0138:

| 6 | | 0138 |

After the procedure for 'English prepositions'
has been operated we have the following information
on the word <u>of</u>; translation – <u>для</u>; preposition;
takes genitive case; Russian no. 5046:

| 6 | 2 | 0138 |

<u>the</u>

After work with the dictionary we find: English
number 0489; nothing in the appropriate location of
Russian numbers, i.e., further information to be

taken from the supplement to the dictionary:

| | | | | | | | | | | | | | | | | | | | 0489 |

From the supplement we obtain: the word is <u>not translated</u>, adjective. The characteristic 'adjective' indicates that the word is to be treated under the procedure for 'English adjectives':

| 3 | | | | | | | | | | | | | 0 | 0489 |

'English adjectives' gives us: adjective; singular number; genitive case; feminine gender; characteristic of numeral; <u>not translated.</u>

| 3 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0489 |

<u>vast</u>

From the dictionary we get: translation - <u>обширный</u>; adjective; hard stem; English number 0239; the appropriate number is in the location for Russian numbers, i.e., there is no need to use the supplement to the dictionary:

| 3 | 0 | | | | | | | | | | | | | | | | 0239 |

The procedure for "English adjectives" gives us: adjective; singular number; genitive case; feminine gender; characteristic of numeral; Russian no. 4410:

| 3 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0239 |

<u>category</u>

From the dictionary we have: translation - <u>категория</u>; noun; feminine gender; IInd declension; soft stem; English number 0082. The Russian number is recorded in the appropriate location of Russian numbers, i.e., there is no need to turn to the

supplement to the dictionary:

| 1 | 2 | | | | 2 | | | | | | | 1 | | 0082 |

From 'English nouns' we obtain (see Fig. 13):
noun; IInd declension; singular number; genitive
case; feminine gender; characteristic of numeral;
soft stem; Russian no. 2253:

| 1 | 2 | 0 | 0 | 1 | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0082 |

<u>of</u>

From the dictionary we obtain the same inform-
ation we have already had for <u>of</u> in our sentence,
that is:

| 6 | | 0138 |

After operation of the procedure 'English
prepositions' we find: preposition; takes genitive
case; <u>not translated</u>:

| 6 | 2 | 0138 |

<u>problems</u>

After work with the dictionary the machine
determines that the word <u>problems</u> is not in the
dictionary. Discarding the ending -s, the machine
finds the word <u>problem</u> and obtains information on it:
translation - <u>задача</u>; noun; feminine gender; IInd
declension; soft stem; sibilant; English number 0211:

| 1 | 2 | 1 | | | | | 2 | | | | | | | 1 | | 0211 |

After operation of the procedure for 'English
nouns' we obtain: noun; sibilant; IInd declension;
plural number; feminine gender; genitive case; char-
acteristic of numeral; ending -s present; soft stem;
Russian no. 3620:

70

1	2	1	0	0	0	2	2	0	0	1	0	0	0	1	0	0	0211

associated

In working with the dictionary the machine does not find the word associated. Discarding the ending -ed, the machine finds the word associat and obtains information on it: verb; Ist conjugation; imperfect aspect; takes accusative case. English number 0055. The presence of a Russian number sends us on to the procedure for "English verbs":

2		1				4		0						0055

After operation of 'English verbs' (the proced- ure works twice over) we obtain: adjective; Ist conjugation; plural number; genitive case; feminine gender; characteristic of numeral; characteristic of participle; past tense; takes accusative case; ending -ed present; Russian no. 2140:

3	1	1	0	0	0	0	4	2	0	1	0	0	0	0	0	1	0055

with

From the dictionary we get: preposition; English number 0243:

6		0243

After operation of 'English prepositions' we find: translation - C; preposition; takes instrum- ental case; Russian no. 5030:

6	5	0243

From the dictionary we get: translation – _сила_; noun; feminine gender; IInd declension; hard stem; English number 0138. Presence of a Russian number sends us on to "English nouns":

1	2					2					0		0138

The procedure "English nouns" gives us: noun; IInd declension; singular number; instrumental case; feminine gender; characteristic of numeral; Russian no. 3012:

1	2	0	0	1	0	5	2	0	0	1	0	0	0	0	0	0	0138

and

In the dictionary we find: English number 0404; nothing in the location of the Russian number, i.e., application needed to supplement to dictionary:

				0404

From the supplement to the dictionary we obtain: translation – _и_ conjunction; strong; Russian no. 6470:

After operation of the procedure 'Conjunctions' we obtain: strong conjunction; Russian no. 6470:

7	1	0	0	0404

motion

From the dictionary we discover: translation – _движение;_ noun neuter gender; Ist declension; soft stem; English number 0119. Presence of a Russian number sends us on to 'English nouns':

1	1					3						1		0119

After operation of 'English nouns' procedure
we obtain: noun; Ist declension; singular number;
instrumental case; neuter gender; soft stem; Russian
no. 3367:

1	1	0	0	1	0	5	3	0	0	0	0	0	0	1	0	0	0	19

* * *

After the digital equivalents of the trans-
lated words are determined, the corresponding Russian
words are altered to the required form by operating
the procedures for synthesis of the Russian sentence,
and then printed.

'Это верно безусловно для обширной категории
задач, связанных с силой и движением'.

(This is undoubtedly true for a wide range of
problems linked with force and movement).