[From: *Information retrieval and machine translation*, ed. Allen Kent. International conference… September 6-12, 1959, Cleveland, Ohio; part 2 (New York: Interscience Publishers, 1961)]

CHAPTER 35

Mechanical Translation at the Academy of Sciences of the USSR

O. S. KULAGINA. A. I. MARTYNOVA, T. M. NIKOLAYEVA

Institute of Exact Mechanics and Computing Technique of the Academy of Sciences of the USSR
V. A. Steklov Institute of Mathematics of the Academy of Sciences of the USSR, Moscow, U.S.S.R.

SUMMARY

Work in the field of mechanical translation was started in the Soviet Union in 1954 by the Academy of Sciences of the USSR. At present these works are afoot in full swing in many scientific centers of the Soviet Union—in Moscow, Leningrad, Kiev, Tbilisi, Jerevan, Gorky and many others.

Many languages are being studied: Russian, Chinese, Armenian, Georgian, Ukrainian, Hungarian, Arabian, Viet-Namese, English, Burmese, Norwegian, Turkish, Hindu, etc.

The elaboration of the problems of interlanguage correspondences is of importance not only for the purpose of practical realization of MT. These problems are a matter of principle because of the fact that the electronic computers are powerful instruments for raising the productivity of mental activities. The important component of intellectual activities in the human society is the exchange of information among its members. Electronic computers are able to exercise various kinds of information processing.

That is why, to extend the sphere of application of computers, it is very important to impart to computers the ability of dealing with human speech as a form of information. Mechanical translation (MT) is the first step in solving this problem. These are the chief problems arising in the work on MT:

1. Construction of a strictly formal system for describing natural languages;
2. Development of the algorithms for translating texts from one language into others;
3. Development of the principles of programming these algorithms and coding information in computer memory.

Different methods for solving these general problems were developed by the research workers of the Academy of Sciences of the USSR..

The variety of methods is conditioned by the difficulty of the problems.

It is quite natural that in speaking of MT at the Academy of Sciences we shall dwell on common points and on differences as well. The subject of the present report will be to represent possible ways and to give an idea of main aspects of the investigations that are being carried on.

CONSTRUCTION OF A STRICTLY FORMAL SYSTEM OF DESCRIBING NATURAL LANGUAGES

Among other problems that arise here, the question of major importance is that of the methods of formal description of language structure. The existing methods of language description have proved to be insufficient for language formalization to the extent which is required in MT.

So the search was launched for the ways of application of mathematical methods to the language analysis.

O. S. Kulagina, the worker of the Institute of Mathematics of the Academy of Sciences of the USSR, has suggested a set-theoretical conception of language.[6] This theory regards the language as a set of components or words. The finite number of words arranged in a certain order is called a phrase. Suppose that some set of phrases is given. The phrases that belong to the set are called "marked phrases." According to the criterion of interchangeability of words the whole multiplicity of words is split into groups of units equivalent to one another. A number of definitions that correspond to some traditional grammatical categories was obtained in terms of this system. The classification is based on a precise and strictly formal system of definitions and here lies the advantage of the classification. It is particularly efficient for the languages with a highly developed symmetrical system of word-forms (e.g., French).

For the languages, such as Russian, that do not possess the symmetrical system some other approach has to be found, and here the ideas of A. N. Kolmogorov and R. L. Dobrushin are highly valuable.[3] Their approach implies the subordination of words and classes, as a distinction from the notion of word equivalence that implies the possibility of mutual word substitution in the marked phrases. A word is considered to be subordinated to another one if in case of any marked phrase containing the first word a new phrase obtained through the interchange of the first and the second words is also marked. The back interchange is impossible. In terms of this concept the definition of case is introduced by Kolmogorov, and the definition of the grammatical category by Dobrushin.

Using the criterion of equivalence the relation among the classes of words can be defined.

The notion of configuration is introduced that is defined by O. S. Kulagina as a combination of not less than two words that belong to different non-intersecting subsets and this combination can be re-

duced to one component, under the condition that no marked phrase containing the above mentioned configuration loses its markedness. The introduction of configuration permits the recognition of the syntactical structure of the sentence.

The set-theoretical conception of language is strictly formal and deductive. However the formalization of language is attainable only to a certain extent. For example, the notion of the marked phrase (and the notion is indispensable for ascertaining the equivalence of the components and configurations of language) becomes less sufficient, when applied to all the fields of the functioning of language usage. At present MT is comprehended only within the limits of the scientific technical literature, and in this restricted area the notion is sufficiently precise and efficient.

The further theoretical study of this model and its comparison with real languages as well as the construction of some similar models seems to be useful.

DEVELOPMENT OF THE ALGORITHMS FOR TRANSLATING TEXTS FROM ONE LANGUAGE INTO OTHERS

The algorithms of translation can generally be subdivided into two types: binary and multiple ones.

A binary algorithm always implies two languages: the source language and the target language. The analysis of the source language is determined by the main grammatical categories of the target language.

A set algorithm always implies a whole group of languages and the translation can be done from any one language into any other language of this group. This is possible owing to the fact that the source language analysis is done independently of the target language.

In its turn the synthesis of the target language is independent of the source language. The results of the analysis of any source and any target language are recorded in terms of an intermediate language.

Let us now dwell on the algorithms of the first type. Two main approaches appeared in the work on binary algorithms—a "word-for-word" translation and a "configuration-for-configuration" translation.

The first algorithms that were developed in the Soviet Union belonged to a "word-for-word" type. In the end of 1955 the first experiment of translation from English into Russian was carried out on the computer BESM of the Academy of Sciences. The algorithm of the translation, dictionary and the program were designed by the workers of the Institute of Exact Mechanics and Computing Technique of the Academy of Sciences of the USSR—I. K. Bel'skaya, L. N. Korol'ov, I. S. Mukhin and S. N. Razumovskiy.[15,17,18] The experimental translations were based on the first variant of the algorithm. At present the algorithm is being improved and developed with the help of the workers of this Institute L. N. Bykova, A. I. Martynova and G. A. Tarasova.[10] A dictionary containing 2300 words was compiled.

Words appear in the vocabulary in their full forms as they usually appear in bilingual dictionaries. The whole algorithm is divided into

two main sections: the dictionary and the grammar, the latter consisting of the rules of grammatical analysis of the texts. The algorithms developed at the Institute of Exact Mechanics and Computing Technique are notable for a ramified system of vocabulary routines. For instance the dictionary of the English-Russian algorithm described consists of the following sections.

I. Dictionary of words that have only one meaning.
II. Dictionary of words that have multiple meaning called the dictionary of polysemantic words.

Each dictionary is divided into two subsections:

Ia. Dictionary of terms;
Ib. Dictionary of general one-meaning words.
IIa. Dictionary of meaningful multiple-meaning words.
IIb. Dictionary of link-words.

The described type of translation makes it possible to translate one-meaning as well as polysemantic words by means of analysis of contextual connections. The conversional homonymy is one of the most complicated problems of MT from English and it is solved in the dictionary part of the algorithm. So each word that comes from the vocabulary has already got the indication of a certain part of speech. And after that the grammatical analysis follows.

There are the following "parts of speech" in the algorithm:

1. verbs;
2. nouns;
3. numerals;
4. adjectives;
5. adverbs;
6. prepositions;
7. conjunctions;
8. particles;
9. parenthetic words.

The grammatical analysis of the function of the word in the sentence must be founded on indications that characterize the place of the word in the grammatical system of the language. Those indications are given in the dictionary. The grammatical analysis consists of the following parts:

1. Analysis of verbs;
2. Analysis of punctuation marks;
3. Syntactical analysis of sentence;
4. Analysis of adjectives;
5. Analysis of nouns and numerals;
6. Changes in word-order in the output phrase.

The order of grammatical rules is conditioned by peculiarities of structure of English sentences. Rules of verb analysis are the first stage of algorithm. After the application of these rules the number of heterogeneous predicates in the whole phrase is stated. Dividing a phrase with a complex structure into simple components i.e. sentences becomes possible only when having obtained the necessary information

about the number of these predicates and consequently the number of simple sentences. The further analysis that is the identification of morphological and syntactical indications of other parts of speech is to be carried out within the limits of the singled-out simple sentences.

Such structure of the whole algorithm allows to achieve the automatic translation of an English phrase which is rather complex syntactically. There are various methods of text analysis: the morphological structure of a separate word, the relation of a given part of sentence to other parts of it and, especially, the contextual syntactical environment of a word are analysed.

The whole analysis of the English text is aimed at translating from English into Russian.

The binary German-Russian algorithm developed by the workers of the Institute of Exact Mechanics and Computing Technique, S. S. Belokrinitskaya and V. V. Parshin is based on the same principles, but the peculiarities of the analyzed language are taken into consideration. Like the English-Russian this algorithm is split into two chief parts: dictionary and grammar rules.

The look-up rules constitute a great part of the dictionary routine. The dictionary in the German-Russian algorithm is represented by a list of stems but not words in their full form. A special role in the system of German-Russian algorithm is played by "selection rules," which are meant to disregard the words that are not required at the present stage of work.

As for the rules of morphological analysis those of verb analysis are the most complicated and dismembered.

Verbal form classification is carried out by means of special rules "three verbal forms," and the identification of each form is performed in the section called "verb."

The whole complexity of syntactical construction of a German sentence puts into motion the rules of splitting the complex phrase into separate simple components, and also the rules of singling out independent isolated parts of the sentence and subordinate clauses. A special group of rules makes it possible to identify extended participle phrases, to recognize their starting and final boundaries.

The coding of hieroglyphs and the input phrase dividing into separate words is a grave difficulty for Chinese-Russian MT. As a preliminary step for coding, the system of "four angles" is chosen. Ten traditional grapheme groups are replaced with fifteen in the system in order to avoid the code homography. In dividing the Chinese phrase into separate words some form-words, formulas and punctuation marks are used.

The peculiarities of Chinese-Russian MT algorithm worked out by V. A. Voronin and A. A. Zvonov at the Institute of Exact Mechanics and Computing Technique of the Academy of Sciences of the USSR[2] are determined by individual features of Chinese grammar which is very poor morphologically.

This is why the analysis of the Chinese phrase is mainly reduced to the syntactical analysis. The following three sources of information

are used in order to get the full characteristics of the Russian equivalent:

1. Dictionary information about the given word which consists of a set of characteristics indicating lexico-grammatical properties of Chinese words and their Russian equivalents;

2. Grammatical information about words that are linked syntactically with the word in question;

3. Analysis of auxiliary words (or particles), united under the general heading "grammatical form-words," i.e. words that are not translated into Russian but that contain some grammatical information, such as verbal suffixes of aspect, a word-form "dj" separating attribute from the attributed word, etc.

The above mentioned peculiarities have conditioned the general principles of forming the whole system. Chinese-Russian MT system including a number of successively connected routines consists of two main parts:

(1) syntactic analysis of a phrase;

(2) determination of morphologic characteristics of the Russian equivalent of a Chinese word.

When the process of syntactic analysis and adding of corresponding characteristics is over, the determination of morphological indications of the word should be done.

In the Japanese-Russian MT algorithm constructed at the Institute of Exact Mechanics and Computing Technique by research workers M. B. Efimov and G. A. Volchek,[4] special attention is paid to the problems of coding, the problems of dividing the input text into words and dismembering of a Japanese phrase into separate sentences. Hieroglyphs are coded by means of an advanced system of "four angles," and the syllable alphabet is introduced by a special code. The separation of words in a Japanese phrase is attained by means of special three-graded rules. The rules of dismembering of a Japanese phrase into sentences are based on the analysis of a special final form of the verb and nouns with specific suffixes characteristic of the subject.

Besides binary translations the independent analysis of the Russian phrase is completed at the Institute by a research worker T. M. Nikolayeva. It is aimed at word-for-word translation. This method of Russian data processing is based on a deep study of a variety of Russian derivations, which has permitted build up of the whole algorithm in the form of pyramid. This means that the first to be analyzed are the word forms with monosemantic flections and then more and more complicated methods are applied to recognize different types of grammatical homonymy. All the Russian words having been processed according to the rules, each of them gets a full morphological and syntactical information; the relationships between separate parts of a compound sentence are also determined.

In the summer of 1956 the first translation of a phrase from French into Russian was obtained at the V. A. Steklov Institute of Mathematics on the Strela computer. The French-Russian algorithm de-

veloped by O. S. Kulagina and I. A. Mel'chuk [5,17] was aimed at translating mathematical texts.

The stems of words but not their full forms appear in the dictionary, and several stems are given in case when letter gradation takes place. Every stem in the dictionary is provided with a set of indications that form the dictionary information. The whole dictionary is divided into three parts :

(1) The foreign part of the dictionary containing the stems of French words and the necessary information about them;

(2) The Russian part containing the stems of Russian words and the information needed;

(3) The dictionary of idioms, i.e., word-combinations that cannot be rendered word-for-word.

The present division enables the use of one and the same Russian part while the foreign parts might be different.

Information added to Russian stems contains instructions as to how to build up various forms of the words.

The algorithm is aimed at translating text phrase for phrase. The process of translation includes three stages; look-up of the word in the vocabulary, analysis of the input phrase and synthesis of the output phrase. At the first stage for each word of the phrase the stem containing a maximum of letters and the information added to the stem are looked up in the dictionary. Then all the idioms of the phrase are looked up in the dictionary of idioms and the information previously added to the words constituting the idiom is replaced by the information from the dictionary of idioms. All the further translation is based on the information drawn from the dictionary without resorting to the words of the input phrase. The analysis of the input phrase begins with recognizing homonyms. There exist special rules that provide the analysis of different cases of lexicogrammatical homonymy. In the process of analysis the parts of speech are referred to in the following order: first verbs, then prepositions, nouns, pronouns, participles that are not processed together with verbs and adjectives.

Synthesis is the final stage of the work. Necessary stems are taken from the Russian part of the vocabulary, the required Russian word-forms are obtained through synthesis, the constructed words are placed in the required order and the phrase thus formed is printed.

The algorithm was realized by means of 17 programs through which a number of experimental translations was obtained. These translations make it possible to improve and make more precise both the algorithm and the programs.[7] At present the work is carried on by G. V. Vakulovskaya.

The algorithm for Hungarian-Russian MT was worked out by the worker of the Institute of Linguistics of the Academy of Sciences of the USSR, I. A. Mel'chuk. The instructions for looking words up in the dictionary imply the processing of compounds and verbs with separable prefixes that are widely spread in Hungarian. When the word is found in the dictionary the homonyms are recognized, then the parts of speech are analyzed in the following succession: postpo-

sitions, nouns, adjectives, verbs, numerals. A considerable difference between the word order in the Hungarian and Russian languages is the real reason for providing special rules of arranging output words. The order of Russian words stated, the synthesis of Russian phrase is going on in exactly the same way as in the case of translation from French.

As it was mentioned above, another method of constructing a binary algorithm is worked out with the help of a configuration-for-configuration method. The English-Russian MT algorithm developed by the Steklov Institute of Mathematics of the Academy of Sciences, of the USSR worker T. N. Moloshnaya[13,14] differs from the above described by the fact that for the first time the configuration analysis of the structure of the input phrase was realized in it. The grammatical configuration denotes the combination of words representing certain classes of words that are arranged in a certain order and bear a certain morphological form.

The division of words into classes established in the algorithm differs from the grammatical division into parts of speech—19 classes of words were singled out in English, 17 classes in Russian.

The configurations in English were defined on the basis of the analysis of sentence-structure characteristic of English; they were provided with corresponding Russian configurations, and in case there were several correspondences the rules of choice were worked out. In each configuration a certain class of words was fixed to replace the configuration. All the configurations are split into 11 groups.

The dictionary for the translation from English is organized in the same way as the above described dictionary for the translation from French. The analysis begins with the search of the configurations of the first group in the input phrase. If any configuration is found, it is replaced by the fixed class of words. When there are no configurations of the first group left in the phrase, it becomes possible to proceed to the second group, etc. It is impossible to turn back from the superior stage to the inferior one.

As a result of replacing configurations by words the input structure is reduced to some minimum. All the groups passed over, the construction of the output Russian phrase starts. The structure, obtained through the analysis is replaced by a corresponding Russian structure which will gradually expand. In the process of gradual expansion those Russian configurations are used which correspond to the English ones involved at the respective step of reducing the structure.

This process results in obtaining the structure of the output Russian phrase, which contains the indications of word-order and morphological forms of the words.

The synthesis of words based on the structure obtained does not differ from synthesis in cases of translation from French or Hungarian. The multiple algorithms unlike the binary ones, realize translation from one language (A) into another (B) with the help of the third intermediate language (C), i.e. according to the scheme A-C-B.

There are different ideas of the intermediate language.

One of the ways of constructing the intermediate language was suggested by I. A. Mel'chuk (The Institute of Linguistics of the Academy of Sciences of the USSR).

The algorithm of analysis is provided for every language considered. The text in the given language is coded so that to every word in a given form and in a given type of context corresponds a sequence of symbols called "word information."

The information includes various word indications in symbolic form, for instance the indication of a definite meaning in case of polysemy; the precise indication of a morphological form in case of polysemantic morpheme; the indication of a syntactic function.[1] All these characteristics are effective only within the limits of a given language. They are based partly on the principles of traditional grammar, partly on methods of modern linguistics and sometimes are even arbitrary.

When such sequences of characteristics and corresponding algorithms are obtained for given languages the recognition of correspondences between successions of these languages informations begins.

Correspondences are recognized on three levels: lexical correspondences (between words and word combinations of various languages), morphological correspondences (between so-called non-syntactical morphological categories—number of the noun, tense and mood of the verb, etc. and some derivational categories); syntactical correspondences (between elementary syntactical constructions in different languages, i.e. configurations).

The sequences of units, corresponding to one another (words, types of syntactical relations etc.) serve as the units of intermediate language (words, types of relations, categories, etc.).

Multilinguage translation by means of intermediate language looks as follows. The process of translation includes two stages: analysis and synthesis.

The analysis embraces a number of operations, resulting in the transfer of the source language into the intermediate one. Every word or word combination of the text is supplied by reference to definite line number in the table of lexical correspondences of the intermediate language. This is done with the help of a special dictionary and a set of rules. The text is divided into elementary configurations, which are also supplied by the line numbers in the table of syntactical correspondences ; some morphol6gical categories are determined in the same way.

A kind of text deciphering takes place, since it has got many polysemantic elements (words, morphological forms, syntactical config-

[1] Replacing words with information makes possible the following thing: those word characteristics which in a real context are expressed non uniformly, vaguely and ambiguously, appear in information in a very precise, discrete and unambiguous form. Processing of words is simplified to a considerable degree if the words are replaced with information.

urations) and, besides, its syntactical relationships are expressed in an indirect, complicated and rather ambiguous manner. The information—the sequences of notions and their inner relations contained in a text—is extracted from the text; the information is fixed by a strictly unambiguous entry—the intermediate language.

The synthesis is the transfer from the record of a text in the intermediate language to its output form—the record in a target language.

The work on the construction of rules for the independent analysis and synthesis in multiple algorithm for Russian, English, French and some other languages is carried on by the Institute of Linguistics jointly with the Electro-modeling Laboratory and the V. A. Steklov Institute of Mathematics of the Academy of Sciences of the U.S.S.R.

A large group of linguists and mathematicians under the guidance of N. D. Andreyev (Leningrad University) is developing translation schemes for a number of languages including some languages of the South Asia. At the same time a special language for recording these algorithms in symbolic form and their programming is being created. The intermediate language is built up so that the units common for the majority of languages under consideration appear to be its main structural units. It is believed that this will stimulate the increase in efficiency of a computer operating the algorithm.

Attention is paid to the question of working out experimental algorithms for solving some model problems (for instance, the transfer of decimal form of numbers into their initial forms and vice versa). The first stage of the work of the Leningrad University group is recounted in "Proceedings on Mechanical Translation," recently published by the University of Leningrad.

THE DEVELOPMENT OF ALGORITHM PROGRAMMING PRINCIPLES AND IMPORTATION CODING PROCEDURES IN THE COMPUTER MEMORY

Algorithm programming for mechanical translation is a rather complex problem requiring much effort and time to be solved. Thus the automatization of this part of work on machine translation is highly desirable.

A characteristic feature of MT programs is an extremely complicated logic structure, information transforming procedure in the computer memory being a relatively simple process. Consequently the main difficulty in preparing MT programs is associated with the development of the program logic diagram, the tracing of different approaches arising with various combinations of conditions encountered in an algorithm.

The automatic programming problem implies in the first place the elaboration of a special language for recording MT algorithms conformable to the following requirements. This language must be complete and flexible to such an extent that various MT algorithms may be recorded in it; it must be precise to such an extent that the transfer from this record to the program may be performed according to

completely simple rules so that it may be performed by the computer; it must be compact enough to permit a simpler way of describing than the programming of the algorithm; finally this language must be so simple symbolically that no great technical difficulties might arise in mastering it.

The study of the algorithms prepared indicated that despite the apparent variety of programs all of them may be presented as a sequence of some standard routines for information handling check operators or operators of some other routines—the number of different types of them being comparatively small.

The investigation of programs prepared for machine translation from French into Russian allowed O. S. Kulagina to single out 16 operators in terms of which all the programs of the analyzing part of the given algorithm as well as the analyzing part of other algorithms may be described.[7]

However the recording of MT algorithms in terms of operators requires certain understanding of computer work, of information arrangement in computer memory. The preparation of an algorithm directly in terms of operator symbols would be difficult enough especially for a linguist having no knowledge in the computer field.

So besides operators another method of algorithm recording—so called "simple rules,"—was devised. Nine simple rules were established each of them being a certain generalized instruction prescribing the performance of a routine either on the text to be translated or on some of its equivalent or on the simple rules themselves.

The simple rules are put into word phrases each of them having a fixed formulation, in which concrete values of parameters are to be inserted. By changing these parameters it is possible to arrange a simple rule for operating with certain attributes of a given word or certain simple rules as well as for making simple rules work in definite sequence. The recording of simple rules requires no special knowledge in the field of computer operation and is independent of the type of computer on which the translation will be performed.

The record of the algorithm presented in the terms of simple rules is translated into the record of operator symbols; this transformation may be called operator programming.

In this case every simple rule is replaced with one or more operators; some operators are also inserted which are associated with the information arrangement in the particular computer memory and have no analogues among simple rules. Each operator as well as each simple rule have some parameters and it is possible, by attributing definite values to these parameters, to establish the concrete form of the operator which is desired in a given case. The sequence in which the operators are to work is presented in the operator record of the algorithm. The transformation of this record into the MT program is performed by the computer itself with a special compiling routine, which utilizes program "blanks" prepared for all operators.

Besides the operator record and the indication of parameter values for all operators in the compiling routine some data about information arrangement should be inserted in the compiler memory.

The proposed system of operators has been tested in the algorithm for translation from Hungarian into Russian described above. The analysing part of this algorithm has been programmed using the above described operator system. The preparation of an operator record is considerably less laborious than the preparation of a program.

N. D. Andreyev,[9] S. N. Razumovskiy,[17] and M. Beletskiy have also proceeded to work on the development of various forms of algorithm recording.

Some methods of improved word coding in the computer memory were devised by L, N. Korol'ov,[17] as well as by G. S. Zeityn, I. L. Bratchikov and S. Ja. Fitialov.[9]

There was suggested a method of code compression in which numeric code of a word coded alphabetically is divided into sections that are summarized. The compressed codes require relatively small area in the computer memory, the distinction between codes of different words being preserved (provided that the length of the sections which depends on the number of words in the dictionary is chosen correctly).

Specific character of work on machine translation consists in the close interlacement of linguistic and mathematical problems. Only the joint efforts of mathematicians, engineers and linguists will make it possible to solve successfully numerous problems in this new field of sciences.

The variety of methods and approaches suggested by different researchers will provide in future the selection of those of them which would ensure successful realization of machine translation idea.

REFERENCES

1. Andreyev, N. D.,
"Mashinni Perevod i Problema posrednika," Voprosy Yazikoznaniya, No. 5, 117-121 (1957).
2. Voronin, V. A.,
"O Mashinnom Perevode S Kitaiskogo Na Russkii Yasik," Moskva, ITM i VT AN SSSR, 1958. str.
3. Dobrushin, R. L.,
"Opit Opredeleniya Ponyatiya Grammaticheskoi Kategorii," Tezisi Konferentsii Po Mashinnomu Perevodu, Moskva, Ministerstvo Visshego Obrazovaniya, ImgpIIYa, str. 37.
4. Efimov, M. B.,
"Nekotorie Voprosy Mashinnogo Perevoda SS Yaponskogo Yazika Na Russkii, Moskva, ITM i VT AN SSSR, 1958, 26 str.
5. Kulagina, O. S., Mel'chuk, I. A.,
"Mashinni Perevod S Frantsuzskogo Yazika Na Russkii," Voprosy Yazikoznaniya, No. 5, 111-121 (1956).
6. Kulagina, O. S.,
"Ob Obnom Sposobe Opredeleniya Grammaticheski Ponyatii Na Baze Teorii Mnozhestv," Problemi Kibernetiki, vip. I, 203-214 (1958).

7. Kulagina, O. S.,
"Mashinni Perevod S Frantsuzskogo Yazika," Izvestiya Vuz' Ov (Matematika), No. 5(6) (1958).
8. Lyapunov, A. A.. Kulagina, O. S.,
"Ispol'zovanie Vichislitelini Mashin Dlya Perevoda S Odnogo Yazika Na Drugoi," Priroda, No. 8, 83-85 (1955).
9. Materialy Po Mashinnomu Perevodu, Sbornik I, Leningrad, LGU. 1958.
10. Mashinni Perevod, Sbornik Statei, Moskva, ITM i VT AN SSSR, 1958 g, 122 str.
11. Mel'chuk, I. A.,
"Model Yazika-Posredinka Dlya Mashinnogo Perevoda," Tezisi Konferentsii po Mashinnomu Perevodu, Moskva, 1958,str. 20-22.
12. Mel'chuk, I. A.,
"O Mashinnom Perevode S Vengerskogo Yazika Na Russkii," Problemi Kibernetiki, VIP. I, 222-264 (1958).
13. Moloshnaya, T. N.,
"Nekotorie Voprosy Sintaksisa v Svyazi s Mashinnim Perevodom s Angliskogo Yazika Na Russkii," Voprosy Yazikoznaniya. No. 4, 92-97 (1957).
14. Moloshnaya, T. N.,
"Voprosy Razlicheniya Omonimov Pri Mashinnom Perevode s Angliskogo Yazika Na Russkii," Problemi Kibernetiki, Vip. I, 215-222 (1958).
15. Mukhin, I. S..
Opiti Avtomaticheskogo Perevoda Na Elektronnoi Vichislitel' noi Mashine BESM, Moskva, 1956, 28 str.
16. Nikolayeva, T. M.,
Analiz Russkogo Predlozheniya, Moskva, ITM i VT AN SSSR, 1958, 23 str.
17. Panov, D. Yu, Lyapunov, A. A., Mukhin, I. S.,
Avtomatizatsiya Perevoda S Odnogo Yazika Na Drugoi, Sessiya AN SSSR Po Nauchnim Problemam Avtomatizatsii, Moskva, Izdatel'stvo AN SSSR, 1956, 30 str.
18. Panov, D. Yu,
Avtomaticheskii Perevod, Izdatel'stvo AN SSSR, Moskva, 1959, 45 str.