# A Survey of Soviet Work on Automatic Translation

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The Soviet literature on Automatic Translation is surveyed with the objective of acquainting English-speaking workers in the field with sources of information about relevant Soviet work.   The survey is complemented by a bibliography, which we believe to be comprehensive.   Limited machine facilities appear to have  restricted the range of concrete accomplishment, but much of the theoretical work is excellent.

RESEARCH ON THE linguistic and technological problems of automatic translation has been carried on for several years,   chiefly in the United States,   Great Britain and the   Soviet Union.   The journal <u>Mechanical Translation,</u> and the series <u>Current Research and Development in Scientific Documentation</u> issued by the Science Information Service of the   National Science Foundation already provide a ready guide to anyone interested in following work in the United States and Great Britain.   The purpose of this article is to survey Soviet work to date,   and to call to the attention of English-speaking workers the sources of published information on Soviet work in automatic translation.

The general impression left by a survey of the Soviet publications is that serious work of high quality is under way on a significant scale. Limited machine facilities appear to have    restricted the range of concrete accomplishment but much of the theoretical work is excellent.†   The available examples of accomplished translations are of such high quality,    and reflect such small samples as to suggest that they are the results of contrived "experiments"  of the same kind that received such extensive publi - city in this country.   There is not now,    and never was,  any question that automatic translation could be achieved if only proper rules could be developed.   Anyone  who wishes  to take the trouble can program a machine to produce perfect translations of any small set   of sentences.   The crucial problem is the formulation of rules and procedures adequate for the accurate and economical translation of large volumes of new material.   It is plain that this

is recognized by the Russians themselves.   For example,  Bel'skaja (A 3),  after   describing "some of the recent achievements of the machine translation research group of the  USSR Academy of Sciences" concludes "the principles have been proved reliable,  experimentally; it is therefore no exaggeration to state that the time has come to consider the opportunities for practical large-scale work in this field."   The principles in question are sound,  generally recognized as such, but not earth-shaking,    and anyone now working on automatic translation must agree with the final statement.

In analyzing the progress of automatic translation,  two dates seem particularly significant: May,  1957, and October, 1956. [1]  In May,  1957, a "Conference on the Problems of Development and Construction of  Information  Machines" (A 12) took place in Moscow.   In October,  1956, at a Session of the Academy of Sciences of the USSR on the Problems of Automation of Production (A   23),   considerable attention was given to automatic language translation.

From the brief report of the 1957 conference given by Mel'chuk in Voprosy Jazykoznanija (A 12),  it appears that great attention is now being given to "an automatic dictionary of unusually great capacity," (presumably to the development of large capacity storage devices) to problems of automatic character recognition, and to other questions of importance in information organization and retrieval,   as well as in automatic translation.   It appears that Soviet workers in automatic translation considered

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† For a survey of recent Russian work,  see V. Yu. Rozentsveig,  "Fourth International Congress of Slavicists Reports, " of this issue of MT (Ed.).

1. More recently (May,   1958) a Conference on Machine Translation took place in Moscow. The translated titles of the papers presented there are available from the author or from this journal.   The abstracts of these papers,  in the original and in translation,  are on deposit in the libraries of Harvard and M.I.T.

themselves hampered by the relatively small storage capacity and primitive input-output devices available with the <u>BESM</u> and <u>Strela</u> Machines,[2] although the <u>BESM</u> has an auxiliary magnetic drum and four magnetic tape mechanisms.[3]  While these limitations need not hamper,  and from all appearances have  not hampered,  conventional numerical computa - tions where the input-output problem is less serious, the demands of commercial data-processing have probably given the U. S. a lead in experimental work, although much of the theoretical basis of Soviet effort is of first-rate quality.

Mel'chuk also reports a stress  on the creation of more educational and communication facilities  in the areas of mathematical lin - guistics and automatic translation:  "In the resolutions of the conference it is indicated that the development of work in mathematical linguistics and in machine translation,  as well as the timely and regular publication of results, have great significance for Soviet science and for the economy.   Therefore it was considered essential to establish a special publication (similar to the journal <u>Mechanical Translation</u> in the U.S.A.), to organize a corresponding sector in the Institute of Linguistics of the Aca - demy of Sciences of the USSR, and to prepare specialists in this area at linguistic faculties of the universities."[4]   In this respect, the Russians are following the lead of the United States, where graduate courses in mathematical linguistics have been offered at Harvard University since 1954.   More recently, Harvard established an undergraduate field of concentration in Linguistics and Applied Mathematics,  and the University of Michigan introduced graduate degree programs in the area of "Language Models and Logical Design," to cover problems which "on the one hand. . . involve language,  and on the other. . . require knowledge of the results and techniques of mathematics and engineering."

Mel'chuk's summary of a paper by Ljapunov presented at this  conference supports the idea

that Soviet results to date have been limited to small samples.   Ljapunov is reported to have suggested the use of automatic programming techniques for deriving translation algorithms which "would permit 'teaching' a machine independently to develop rules for translation, using parallel texts in two languages and a previously prepared dictionary."  This, in place of "empirical search (for rules) in every individual case."   The importance of developing generalized methods for formal linguistic analysis is stressed.   Stripped of the "teaching" verbiage, this idea has considerable merit, and some independent work in a similar direction is in progress also in this country.

Mel'chuk also mentions "one such generalized method" presented by O.  S. Kulagina. This method is based on "set-theoretic concepts, and permits the assignment of words in a language to some equivalence classes (analogous to 'parts of speech')."   Kulagina apparently presented a paper along the lines of one she gave   three months earlier at a meeting of the Seminar on Problems of Machine Translation (A 9).   The latter paper has considerable expository merit, and it is clearer and more sensible than similar papers on set-theoretic concepts in language which have sprouted like ungainly weeds in the lawn of our information-retrieval literature. The work is along somewhat different lines, and of lesser extent but of caliber comparable to that of the excellent theoretical work of Chomsky in this country.

However,  as in Chomsky's work, establishing a fruitful relation between the mathematical model and any concrete, natural language is left, so to speak, as an exercise for the reader.   It is in this exercise that the major problems (other than that of educating linguists) lie,   for, as Kulagina herself points out "as a matter of fact,  nothing new is done here, it is  simply that a different form of exposition is given, with a carefully drawn set of postulates."   The anguish of Soviet linguists when facing incomprehensible and not obviously useful mathematical apparatus has a familiar ring.   Witness the final comment of the chairman (V. Ju.  Rozentsvejg) presiding over the presentation of Kulagina's paper:   "Not everything presented earlier is clear to me, indeed,  one would like to have a translation of this terminology into our plain language."

More significant,  perhaps, are the remarks of G. V. Kolshanskij following Kulagina's paper, to the effect that all this is well and good for a finite vocabulary and a limited number of phrases, but that the problems of a living,  open-

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2.   Konferentsija <u>"Puti Razvitija Sovetskogo Matematicheskogo Mashinostroenija i Priborostroenija"</u> Plenarnye Zasedanija, VINITI Moskva,  12-17 Marta,  1956 g.

3.   Ibid, p.  34.

4.   The contents of the first seven issues of an informal <u>Bulletin of the Seminar on Problems of Machine Translation</u> are listed in Part D of the Bibliography.

ended language go beyond this. This point is amplified in a paper by Barxudarov and Kol-shanskij (A 2), apparently based on a presentation by Kolshanskij at the following meeting of the Seminar on Problems of Machine Translation. These writers feel that "the problem of machine translation at present is basically a linguistic problem, and that it is essential to seek its solution in this realm only." While not wishing to deny the potential practical value of automatic translation, they say "however, it is necessary to keep in mind that this mode of translation will perform only an elementary function, that it will play only a subsidiary role in translation, moreover only of special texts. When it is necessary to obtain a really good translation, a machine translation can be only raw material for a human translator-editor." This echoes comments of Zhirkov (A 24) to the effect that it will be difficult for a machine to choose, for example, between the synonyms lilovyj and fioletovyj for 'violet'.

Zhirkov also is concerned about the magnitude of the tasks facing linguists: "As soon as the question of the actual practical application of a translating machine arises, we must realize the necessity of developing detailed programs for those linguistic conditions and problems which the machine is expected to resolve. This is far from being a simple matter, especially since the task will devolve on linguists. Linguistic programs must be prepared in accordance with the properties of machines, and linguists until now have had no experience in this realm. There is no point in concealing the fact that they will find this a difficult task. "

All of these remarks support the notion that fully automatic translation, as an operating proposition, is probably as far from realization in the USSR as it is in this country. However, one must take into account the fact that criticism and pessimism on the part of linguists may not accurately reflect the progress made by groups led by mathematicians and engineers. Barxudarov, Kolshanskij, and Zhirkov persist in raising questions about 'violet', idioms, poetry and semantics, much in the manner of linguists such as Joos[5] in this country. The concepts of successive approximations, the

"fail-safe" principle, and the tolerance toward stylistic inelegance of which scientists and technicians are capable, are utterly foreign to some linguists.

Besides the papers already mentioned, several others of interest appeared in 1957. All merit careful reading by American workers in the field. While none give indications of spectacular, achievements, indeed modest disclaimers are the rule, they reflect considerable thoughtful work. The occasional novel ideas, and new formulations of known ideas, are generally lucidly expressed, but with gaps suggesting the absence of really significant large-scale machine experimentation.

Andreev, in "Machine Translation and the Problem of an Intermediary Language" (A 1), trots out the old chestnut about the number of algorithms needed to translate pairwise among $n$ languages growing as $n^2$, while use of an intermediate language would reduce the number of algorithms to $2n$. He discusses, quite elegantly, some criteria for a good intermediate language. Some interesting distinctions are introduced among "semantic," "formal," and "tectonic" symbols, which put into rather neat form a problem handled earlier but more obscurely by the Wundheilers.[6] He then defines measures for the lack of congruence between the structure of a string in one language and that of its translation in some other language. However, like most theoretical skeletons to date, this one has little flesh on it, and it is difficult to take translation among $n$ languages seriously until some satisfactory results have been obtained for at least one pair.

Moloshnaja's paper "Certain Questions of Syntax Connected with Machine Translation from English to Russian" (A 14), sketches in some detail a method for analyzing the structure of sentences, akin to the parsing once taught in the schools. A broad outline of this approach was given earlier by Panov, Ljapunov, and Muxin (A 17, pp. 182-192). Success in this direction would be of tremendous value, and one would expect to hear of further activity. Significant work, however, probably requires the prior compilation of a substantial automatic dictionary. The state of affairs at the time of publication is perhaps best summed up in Moloshnaja's own words: "The problem of choosing an index, i.e., of eliminating lexico-grammatical

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5. M. Joos, "Meaning in Relation to M.T.," Report of the Eighth Annual Round Table Meeting on Linguistics and Language Study, Monograph Series on Language and Linguistics, Georgetown University Press, 1957, pp. 13-18, and "Review of Machine Translation of Languages", Language, 32, 1956, pp. 293-298.

6. Luitgard and Alex Wundheiler, "Some Logical Concepts for Syntax, " Machine Translation of Languages, Wiley, New York, 1955, pp. 194-207.

homonymy in every given case, is very complicated. It requires additional work and more precision. . . . All the foregoing does not claim to be exhaustively worked out and complete. For the time being, it is a working hypothesis, whose verification on a large amount of material and with the aid of a machine is contemplated." It is reasonable to guess that until more has been heard about an automatic dictionary, the likelihood of successful verification remains small. This area bears watching, as capable of bearing fruit much earlier than the similar work of Kulagina (A 9), which is less directly coupled with reality.

The paper "Machine Translation from French to Russian" by Kulagina and Mel'chuk (A 10) is based on the analysis of 20,500 words of running text, and it is probable that the test material that was translated came from the same source.[7] The analysis of syntactic problems is generally sound and lucid, and in most cases should lend itself to generalization and verification on a large scale. However, one guesses that some important techniques described in the paper will not be adequate for large-scale work. This guess is supported to some extent by Kulagina's later switch to working in the mathematical stratosphere, in marked contrast to the down-to-earth approach in this paper, and by Ljapunov's concern with methods for generating translation algorithms. One feels that the mathematicians in the Ljapunov group became appalled by the wealth of detail to be considered in achieving practical large-scale results. This could account for the stand taken more recently by Barxudarov and Kolshanskij. However, the conceptual quality of the work is such as to suggest that the Russians have nothing to fear but fear itself. This paper is well worth reading. Like that reported by Moloshnaja, it is a product of the group working at the Steklov Mathematical Institute under the general leadership of Ljapunov. An outline of the same work may also be found in reference (A 23, pp. 182-192).

The paper by Razumovskij, "On the Problem of Automatizing the Programming of Translation from One Language into Another" (A 20), is interesting as one indicator of growing concern among workers on automatic translation with sophisticated machine methods. The

strong Russian interest in automatic programming is well known from manifestos by Ljapunov (A 23, pp. 118-121), from the attention paid to the subject in Kitov's book (A 6), from interesting papers by Janov (B 4, 5), and from descriptions of new books slated for publication (C 1, 2, 3). Razumovskij's paper is mathematically elegant, but contains nothing that is novel to anyone familiar with mathematical logic and its applications to computer programming. Its significance lies chiefly in the indication it gives that Russians are thinking along lines also considered potentially fruitful by workers in this country. It should be of value in research such as that contemplated by Moloshnaja, and in the practical execution of algorithms developed as a product of this research. Razumovskij is also credited with the development of the notation used by the Panov group to write down their translation algorithms. The notation is quite good, especially if used in conjunction with flow-charts.

Korolev's paper "Coding and Code Compression" (A 7) is much less significant. One may guess that it represents a very belated publication of results obtained as a consequence of great concern at early stages over limited storage capacity. Most of Panov's early papers mention this work. It is reasonable to guess that once the resolutions of the May 1957 meeting bear fruit, the tricks described by Korolev no longer will be used.

Many of the papers discussed in the preceding paragraphs were published after the October 1956 session of the Academy of Sciences, although some of the work had been done prior to that session, and reported there. Most of the work done under Panov at the Institute of Exact Mechanics and of Computing Techniques was published prior to the session, and will be discussed after some comments on the session itself.

In the proceedings of the Plenary Session of the Academy of Sciences on the Scientific Problems of Automation of Production (A 23) considerable space is devoted not only to a description of the work accomplished by the Panov and Ljapunov groups, but to discussions of the merits of efforts on automatic translation.

In the introductory remarks by A. N. Nes mejanov, the central theme of urgency about mechanization and automation is first sounded. Throughout the Proceedings, there are numerous allusions to the directives of the Twentieth Party Congress, in which automation of production is set up as a major task. Nesmejanov says: "Even such an area as translation from

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7. On this delicate point, which may also be raised about some work in this country, see the exchange between Denis Williams and I. S. Muxin, in the _Journal of the I. E. E.,_ January, 1957, p. 34 and February, 1957, p. 110.

one language to another is already an object (objective) of automation. Thus even for linguists the subject of our session should not be altogether strange."

V. V. Karibskij, in a commentary (pp. 59-65) on a paper by V. A. Trapeznikov entitled "The Role of the Technical Sciences in the Development of Automatic Control and of the Technical Means of Automation" (pp. 38-55) strongly criticizes the scientific organizations of the USSR for their lame effort in automation, in the face of reports from abroad of great progress in this area. He declares, for example, that "workers concerned with the design and construction of electronic calculating machines declare that they can apply any machine to the purposes of automation of production, but that they must have a mathematical description of the process to be automated. However, they consider that the mathematical description of these processes is a task for the technicians who are closer to production problems and who are more familiar with the technology and the equipment." He points out that the technicians do not have the necessary mathematical knowledge, but that meanwhile the scientists sit on their hands: "As a result, it happens that the scientists who have created the splendid contemporary mathematical machines in fact hold back the application of these machines towards the goals of automation of production." The parallel between these remarks and the more recently expressed attitude of Barxudarov and Kolshanskij is interesting.

Some remarks of I. S. Bruk in his paper "The Outlook for Applications of Control Machines in Automation" (pp. 131-148) indicate a slightly different attitude toward reports from abroad:

> "The theme of 'thinking machines' is hardly ever off the pages of popular publications abroad. Some speeches of well-known figures, some articles on the correspondence between the structure of the nervous system and calculating machines, were taken up by a press susceptible to sensationalism. The imagination of readers was taken by descriptions of guided missiles and other kinds of armament, about which so much is written abroad.
> "Doubtless all this helped to create false conceptions of the role of 'thinking machines', and of a fully automated industry without people. "

Bruk goes out of his way to indicate "how erroneous notions about the role of contemporary calculating machines can lead to an incorrect

evaluation of the prospects for their applications." He says: "It is necessary to say that in our country not everything in this area is satisfactory." He then devotes two paragraphs to pointing out that he considers automatic translation as an outstanding example of "the incorrect evaluation of the role of calculating machines, as it strikes the fancy of the public." The gist of his argument is that automatic translation is a poor illustration of the rational use of computers, principally because the job can be done well enough by people, with more complicated texts than "primitive, simplified and specially selected ones for machines" and also because the machine is not likely to replace people altogether.

A rebuttal by V. S. Pugachev (pp. 151-152) dwells chiefly on the importance of the algorithmization of speech in the development of automation, particularly with respect to self-organizing systems, speech-controlled automata, and the like. Pugachev dreams of using translating machines to permit conversations between two people speaking different languages. "The establishment of such lines of communication will have tremendous significance for the development of mankind."

A. A. Dorodnitsyn agrees that translation is an interesting problem, but says (p. 157), "I cannot agree that this task is one to which it is now essential to devote large forces and means." He does not think that it is an important job from the economic point of view, especially because he believes that the Soviet Union has adequate numbers of conventional translators, and even greater numbers of specialists who can read literature on their own speciality in the significant languages. He further believes that the distribution by the Institute of Information of copies of foreign journals will be more helpful to scientific progress in the USSR than the creation of specialized translating machines. "Besides," he says, "the problem of automatic translation is not sufficiently close to solution to warrant serious talk about the construction of translating machines."

A. N. Kolmogorov (p. 161) agrees with Bruk that for practical communication live translators or knowledge of foreign languages will scarcely be replaced by machines in the foreseeable future. However, he stresses the importance of the effect of work on automatic translation on the builders of calculating machines, especially with respect to broadening their ideas about the logical powers of machines, and on linguists, as a practical criterion so important in guiding the development

of theory.    The precision and completeness with which rules for automatic translation must be formulated leave no room for the vague phrases which humanists are inclined to call "laws."

These arguments have a very familiar ring. The presence of opposition, and knowledge that the session of the Academy would stress the need for achievement in automation, may also account for the multiple publication, loud drum beating, and excessive emphasis on American "achievements" associated with the relatively meager results achieved prior to the session. Publications since the session have been much more subdued, possibly because of greater confidence in support.    In this connection, the following quotation[8] may be illuminating.

"And what about these — friends of ours? Are they alive and well?" Lopatkin asked. "Well enough. . . .They are constantly praising their machine in the newspapers.    I think they are building a factory.    Shutikov has twice already been abroad. "
"You say they are praising their machine in the papers?  How can that be?  It means they are hiding something.   It can't be that everything is going smoothly with those machines.    So we can expect some more trouble, Nadezhda Sergeyevna."

This also has a familiar ring.

In the communication by M. V. Keldysh, A. A. Ljapunov, and M. R. Shura-Bura  (A 23, pp.  100-130) entitled "Mathematical Problems in the Theory of Calculating Machines" there is a brief mention of automatic translation as one among a number of applications which "at present are in the initial stages of investigation." Brief mention is made of some systems of automatic programming, some of which are described in greater detail by Kitov (A 6)   and about which more will very likely be said in forthcoming publications.  Automatic translation is mentioned in somewhat greater detail on pp.  121-124.   The IBM-Georgetown "public demonstration" of 1954 is mentioned briefly, and described as having been conducted with "a program of rather limited possibilities."   The material is  of no  great import,  since more technical detail is given in other papers already cited.    The work of the Institute of Exact Mechanics and Computing Techniques is characterized as empirical,  while that of the Stek-

lov Mathematical Institute is described as based on structural linguistics.

The paper by Panov,  Ljapunov, and Muxin (A 17),  presented at these  sessions,  summarizes work done by both groups,  and with the exception of a few points of detail,  adds nothing to the contents of the more specialized papers by members of these groups represented in the bibliography.   In particular,  the section describing the work at the Institute of Exact Mechanics and Computing Techniques is almost identical to five other publications by members of the group (A 4, 8, 15, 18, 19).   Some of the differences in detail are of interest to specialists, and Muxin's paper (A 15) in particular is somewhat more detailed than the others.   His flow-chart for the translation of  'of'  has an error which will lead to a correct translation of "... the result of experiments ..." but to an incorrect translation of "... the result of simple experiments. . ., " a weakness typical of ad-hoc programs based on intuition and the study of small samples.   However, there is no reason to doubt that continuing effort by this group will have led to considerable progress by now.

The papers by Moloshnaja et al. (A 14) and by Kuznetsov et al. (A 11) are general surveys, again of some interest to specialists, but not particularly significant for this review.

In conclusion, it is worth giving special notice to the book of A. I. Kitov "Electronic Digital Machines" (A 6) which superficially describes Soviet work on automatic translation, but which is most noteworthy for a very good chapter on automatic programming, in which a system suggested by Ljapunov and elaborated by Janov (B 4, 5) is described in some detail probably for the first time.

For the sake of completeness,  some interesting papers on information organization and retrieval and on automatic programming, subjects with which automatic translation has some kinship and which are of great importance in their own right,  are listed in section B of the Bibliography.

The third section of the Bibliography (C) lists some books scheduled for publication in 1958.   It is evident that the meetings described earlier in this review are having some effects. The Table of Contents of the first seven issues of the <u>Bulletin of the Seminar on Problems of Machine Translation</u> is given in part D of the Bibliography.  This publication is also available in the Harvard and M.I.T.  libraries.

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C. Forthcoming Publications †

1. N. A. Krinitskij and A. I. Kitov, <u>Ehlektron-nye Tsifrovye Mashiny i Programmirovanie</u> (Electronic Digital Machines and Programming).

2. Ju. Ja. Bazilevskij (Ed.), <u>Voprosy Teorii Matematicheskix Mashin</u> (On the Theory of Mathematical Machines).

3. A. A. Ljapunov (Ed.). <u>Problemy Kiberne-tiki</u> (Problems of Cybernetics).

4. M. A. Kartsev, <u>Arifmeticheskie Ustrojstva Ehlektronnyx Tsifrovyx Mashin</u> (Arithmetic Units of Electronic Digital Machines).

5. M. R. Shura-Bura and others, <u>Metod Stan-dartnyx Podprogramm</u> (The Method of Standard Subroutines).

6. <u>Matematika v SSSR za 40 Let</u> (Mathematics in the USSR over 40 years), Section 16: "Matematicheskie Mashiny" (Mathematical Machines) by A. A. Ljapunov.

7. N. A. Arxangel'skij and B. I. Zajtsev, <u>Ehlek-tronnye Tsifrovye Mashiny</u> (Electronic Digital Machines).

D. Table of Contents of the <u>Bulletin of the Seminar on Problems of Machine Trans-lation</u> (mimeographed).

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<u>Number 1 (Meeting of December 24, 1956)</u>

V. Ju. Rozentsvejg, "Vstupitel'noe Slovo" (Introduction).
I. I. Revzin, "Nekotorie Voprosy Formali-zatsii Sintaksisa" (Some Problems in the Formalization of Syntax).
Debate: I. Eh. S. Raxmatulova, A. A. Ba-laban, G. V. Kolshanskij, V. V. Ivanov, V. Ju. Rozentsvejg, L. S. Barxudarov, T. A. Amiro-va, A. V. Dogopol'skij, G. M. Strelkovskij, T. K. L'vova.

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<u>Number 3 (Meeting of February 21, 1957)</u>

O.S. Kulagina, "Ob Odnom Sposobe Opre-delenija Lingvisticheskix Ponjatij" (On a Method for Defining Linguistic Concepts).
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II. Revzin, "Dobavlenie k Dokladu 'Neko-torye Voprosy Formalizatsii Sintaksisa' " (Additions to the Paper 'Some Problems in the Formalization of Syntax' ").

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G. V. Kolshanskij, "K Voprosu o Vozmo-zhnostjax Mashinnogo Perevoda" (On the Question of the Possibilities of Machine Translation) .
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