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MACHINE TRANSLATION IN WESTERN EUROPE: A SURVEY

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1. INTRODUCTION

Although work on machine translation in western Europe developed somewhat later than that in the Soviet Union and the United States, for a time it was equally prominent. Projects were undertaken in many countries. For some, i.e. Belgium, France, Germany, Great Britain, Italy and Sweden, at one time eight to fifteen research groups could be listed; for others, such as The Netherlands and Switzerland, fewer. Though some projects were carried out in close cooperation with projects in the United States, the greater part of the European research groups preserved their independence both with respect to linguistic theory and their methodology. In contrast with the American groups, which generally excluded the semantic component of language, the research groups at Cambridge, Milan, and Bonn took the semantic component into consideration. Moreover, while the larger research groups in the United States developed general analyzers that could process the grammar of any language, the research groups in western Europe, except that in Grenoble, developed language-dependent algorithms, which could process only a particular language.

Most of the European groups believed that high quality translation was not obtainable within a short time. Yet some set out to produce machine translation in a short time, reducing their requirements for quality. A few simply aimed to construct multilingual dictionaries for use in machine-aided translation.

These groups reacted variously to the report of the Automatic Language Processing Advisory Committee (ALPAC) of the National Research Council, which appeared in 1966. The report stated that large-scale support of machine translation research could not be justified on the grounds that machine translation was slower, less accurate, and more costly than that provided by human translators. Moreover, the report concluded that there had been no satisfactory machine translation of scientific texts and that none could be expected soon. On the other hand, the report recommended federal support for research and development for human and machine-aided trans-

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lation (National Academy of Sciences 1966). In response some European groups held that its conclusions were wrong (Hoppe 1967a); others concluded that its expectations were too great (Max Woitschach, of IBM-Deutschland in Gerwin 1967:11); others stated that the conclusions were based on false premises (Krollmann[2] 1967-68).

At approximately the same time as the report appeared, theoretical linguists began to deal with universal deep structures. Petrick had published his description of an algorithm that constructs for any transformational grammar with certain properties the corresponding surface grammar and reverse transformations (Petrick 1965). The effects of these developments on linguistic theory can be judged from a reappraisal of the possibility of machine translation (Schnelle 1967a).

The recommendations of ALPAC, however, had had a profound effect in Europe. Work in machine translation was sharply reduced. Many groups discontinued their activities because of lack of financial support. Some computational linguists began to direct their aims at non-practical goals. This effect was still apparent in the call for papers at the 1969 International Congress on Computational Linguistics, which disclaimed concern for 'problems within mechanical translation ... unless treated with linguistic methods' (whatever the implications of this qualification may be).

The European research groups which maintained their interest in machine translation cannot be classified as purely theoretical or practical; the theoretically-oriented LIMAS group at Bonn as well as the Centre d'Études de la Traduction Automatique (CETA) at Grenoble which has always held to practical achievements are both active. In a field whose theoretical bases develop rapidly, much of the older literature is dated; yet to provide a review of the general activities of the various groups in western Europe, statements will be made below about these as well as about the projects that are still in existence. It is too early to forecast what the prospects will be for further work, though in Germany interest and support seem to be increasing; and in France, CETA is continuing its activities, especially in the translation of Russian into French.

2. MT GROUPS USING SEMANTIC INFORMATION

Five research groups developed algorithms for translation by means of semantic information:

1. The Cambridge Language Research Unit (CLRU) at Cambridge, England;
2. Centro di Cibernetica e di Attivita Linguistiche, University of Milan;
3. IDAMI Language Research Section, Istituto Documentazione della Associazione Meccanica Italiana, Milan, Italy;
4. Centre d'Études de la Traduction Automatique, Grenoble, France (CETA);
5. Forschungsgruppe LIMAS, Bonn, Germany.

[1] Krollmann is director of the Mannheim 'machine-aided translation' effort, 'a considerably brighter prospect' according to ALPAC.

We shall deal only briefly with the first three groups for they did not reach the operational stage, nor are they at present involved in MT. Each of these attempted to perform semantic analysis without prior syntactic analysis.

2.1 At CLRU the problem of translation was formulated as a word-by-word translation in which ambiguous words had to be disambiguated. This was to be done by two methods: a) Words were classified by means of a thesaurus. It was assumed that ambiguous words would have the same descriptors as their environment, b) An interlingua, resembling pidgin English, was produced. By means of this interlingua, co-occurring descriptors were to disambiguate ambiguous words. Both methods required the recognition of 'phrasings', groups of words containing two stress points. An algorithm for locating phrasings in written texts by computer was developed. The algorithm has not achieved the aims proposed for it. Research is now concentrated on the recognition of syntactic elements by means of a new method of parsing texts.

2.2 and 2.3 The two institutes at Milan based their work on the semantic theory of network correlation which was developed by Silvio Ceccato. According to this theory, any sentence of a language can be represented as a hierarchical system of correlations. A correlation consists of a correlator and two elements, each of which may in turn consist of a single nominatum, a correlation of two nominata, or a net of several correlations. A nominatum is the meaning of a word. A correlator is the relation that links the meaning of two words. A correlator can be expressed by means of words like PREPOSITIONS, CONJUNCTIONS and other particles, or it may be implicit, that is, expressed by an affix or by the position of words. Ceccato assumed that the number of correlators in language is relatively few, between 200 and 800. Further, that they are common to all languages. Any given relation may be expressed by different correlators; moreover, a correlator may express different relations.

Each word in the dictionary is either a nominatum or a correlator. For each nominatum information is provided concerning the correlator with which it may occur; similarly, for each correlator information is provided on the type of nominatum with which it may occur. When a correlation has been established, the new correlatum may function as a new nominatum. An algorithm was devised to indicate the correlators with which a correlatum may occur.

Ceccato's work at the Centro di Cibernetica was continued by Ernst von Glasersfeld at IDAMI. He succeeded in analyzing a few English sentences by reading in the dictionary cards of the words in a sentence in the order they occur in the sentence. In October 1966 the Language Research Group at IDAMI moved to Athens, Georgia, U.S.A. Analysis of Italian, however, has been continued at Milan by Professor Terzi.

2.4 The two other groups with a comprehensive approach, CETA in Grenoble and LIMAS in Bonn, from the start have projected schemes for translation. Each has formulated its view of the activities involved in translation and developed a plan for carrying out these activities.

CETA projects translation in three stages, and proposes to carry out these stages by drawing on various kinds of linguistic theory, dependency and transformational as well as phrase structure analysis. The stages viewed in translation are: a) Analysis of input sentences; b) interlingual mapping; and c) synthesis of output sentences. Analysis is handled in three steps, each of which deals with a posited stratum: 1. Dictionary lookup; 2. syntactic analysis and interpretation; 3. semantic analysis. Since these strata are viewed as a series of levels, the output of each analytic step is input at the next higher stratum.

In dictionary lookup, a sentence, which is the input for the lookup program, is processed by means of a dictionary containing words, word parts and endings. The units recognized are replaced by their identification numbers and assigned an interpretation. Lookup ends when each word has been interpreted.

The word interpretations are then processed by the first part of the syntactic analysis program; this program uses a subscript grammar. For a brief account of subscript grammars, see Harman's (1963) "Generative grammars without transformation rules: A defense of phrase structure".

The output, consisting of one or more binary trees, is then processed by a program which derives from each binary tree a corresponding dependency tree; see Tesnière (1959), who has written the most comprehensive dependency grammar, in which an excellent introduction to the theory can be found. Since the grammar can deal with some types of discontinuous constructions, the word order derived need not correspond with the word order of the text.

The dependency tree is thereupon analyzed at the semantic level, where words and their interpretations are processed with a semantic grammar by means of a transformational program. The resulting semantic tree, which is a dependency tree, displays the semantic relations that hold between any governing term and its dependent terms. It is translated into the corresponding structures of the output language. In this way the synthesis process is initiated.

Partial syntactic descriptions have been written for French, Russian, English and Japanese, and tested by computer. Although the segment of language dealt with is small, the experiments are of great interest for their versatile use of a variety of theoretical approaches. Computer output, which unfortunately has not been published, indicates remarkable translation capabilities for those languages, but notably Russian into French.

2.5 An approach totally different from those based on tree representations of sentences is being developed by the LIMAS research group at Bonn. From its inception, the LIMAS group emphasized semantic translation. Its descriptions of German and English accordingly incorporate semantic, as well as morphological and syntactic information.

As with other systems, translation is regarded as a three-stage process: analysis of input; matching; synthesis of output. Yet the LIMAS group is individual in its assumption that any sentence of a language can be represented by a 'factor formula' in the metalanguage of that language (there are as many metalanguages as languages). A factor formula can be regarded as a sentence of a metalanguage. Although the words of the metalanguages are common to all metalanguages, the factor formulas normally are not

Analysis in the LIMAS system seeks to establish the factor formula for a given sentence and to translate it into the corresponding factor formula of the target language. Analysis begins with lexical lookup, which assigns to words or word parts a syntactic interpretation by means of a dictionary containing semantic as well as syntactic information. .

After lexical lookup, the syntactic relations between words and the constituents of the sentence are specified. A context program looks up the syntactic interpretations in matrices; prepositional phrases, for example, are given their proper interpretations in preposition-noun matrices.

This stage is considered the interpretation of the morpho-sphere (syntactic component). In a further, second stage, the interpretation of the nomo-sphere (semantic component), the semantic features attached to dictionary words and to syntactic interpretations are used to reduce the number of interpretations, and finally to derive the factor formula of the sentence. Individual 'words' of the factor formula can be found at any level of analysis and can be immediately incorporated into the formula.

Among semantic information attached to nouns is that for groups of persons, groups of animals, abstractness; among information attached to prepositions is that for location and reference. Since nouns are also classified according to features associated with prepositions, syntactically ambiguous sequences of prepositions and nouns can be reduced to their proper interpretation.

The rules of grammar are represented by matrices whose columns and rows represent individual syntactic symbols or combinations of such symbols. Context programs recognize the individual symbols and check the corresponding matrices to determine whether the combination found is permissible. If it is, they specify its interpretation.

Transformations are possible on each of the two levels, the morpho-sphere and nomo-sphere (terms used by LIMAS which correspond to 'syntactic and semantic components'), and between the two spheres. The transformational operations fall into four types:

TRANSITION : the factor formula of the input sentence is mapped into the same factor formula for the output sentence.

EXPLICATION: a semantic factor which has no morphemic representation is made explicit in the factor formula. The lack of representation can be due to such phenomena as ellipsis or non-expressed context relations; for example, German *Er schüttelte den Kopf* corresponds to *He shook his head.* Since the literal translation is *He shook the head,* an 'explication formula' is devised to secure the correct English output.

VERBALIZATION: the expression of a factor explicated in the source language.

REDUCTION is the opposite of explication: the semantic factor is not verbalized, but only implied on the morphological level.

If there is no identical factor formula in the target language, the factor formula of the input language will be subjected to transformations on the nomo-level until a match is found. Since the factor formulas contain an indication of the underlying syntactic structure, in addition to semantic information and data on relation between constituents, a match can eventually be found that corresponds closely to the syntactic input structure.

The LIMAS system is also designed to recognize and translate metaphorical usage, idioms and discontinuities. It is general, so that any number of languages can be added to the system without causing changes in the description of earlier languages. Yet it is still in the theoretical stage. No translations, except for a small experiment, have been performed. When the proposed linguistic descriptions are completed, hardware is to be designed for the individual matrices. If computer logic can be arranged in accordance with linguistic patterns, interpretations encountered during analysis will initiate searches whose results will indeed be found with the speed of light.

3. MT GROUPS USING SYNTACTIC INFORMATION

Three centers have been involved in mechanical translation by means of a language-dependent algorithm without using a semantic component:

1. The National Physical Laboratory, Teddington, Middlesex, England. The report by McDaniel and colleagues (1967) indicates that an MT system requiring post-editing from Russian to English was produced. The level of the output was favorably evaluated by W.L. Price (1967) in his article "Computer translation — is it worthwhile?" Further work, however, was discontinued through lack of support.

2. IBM-Deutschland, Sindelfingen, Germany, has produced an MT system for translating IBM manuals from English to German.

3. The Joint Nuclear Research Center, Ispra Establishment, Italy, Scientific Data Processing Center (CETIS) has been using the most sophisticated of language-dependent algorithms. The underlying theory is discussed more fully below.

In addition to these three centers a fourth may be in the process of establishment: the Deutsche Forschungsgemeinschaft (the German equivalent of the National Science Foundation) has sponsored a program to translate from Russian into German, which was developed by Peter Toma, formerly of the Georgetown Automatic Translation Group. Toma programmed the algorithm to analyze the Russian input; the program to produce the German output is being written at the University of Saarbrücken.

IBM-Deutschland and CETIS are continuing their research in MT, using in general the following theoretical approach.

Language-dependent algorithms like those used by these groups exhibit a similar logical structure. We shall give a short description of the most sophisticated of them, SLC (formerly for 'Simulated Linguistic Computer'), developed by A. Brown, who began his work with the Georgetown Automatic Translation Group and then transferred his activities to Ispra. SLC is a general language processor which can be used to analyze various languages. It has been used for the translation of French into English. It may be called language-dependent because it processes grammatical statements which contain language-dependent programming operations. Originally produced for French-to-English translation, SLC has been developed into a general translation system for processing the text of any source language and translating it into an equivalent target language text after the necessary operations and grammatical descriptions have been carried out.

SLC permits the writing of operations necessary for analysis, translation, and synthesis of sentences as independent operations (sub-routines) which are executed only when they are listed in an 'item'. An item is the information furnished by the dictionary for each lexical element in a text. It consists of four types of information: the target language equivalent of a source language element (word or stem); an identification number of the source language element; codes to indicate syntactic and paradigmatic information; and optionally, instructions.

The instructions are the names of operations which must be executed during the translation of the sentence. An item may also contain a complete operation of its own, called local instruction. Local instructions cannot be referred to in other items.

When analysis is undertaken, every sentence is assigned a zero item as its leftmost 'word'; this zero item also functions as the last 'word' of the preceding sentence. It contains all the instructions necessary for analyzing any sentence in the language. Moreover, each instruction is assigned a priority number for its sequence of execution. An instruction can replace, delete or add items, codes or instructions; it can also rearrange items. Any instruction is removed from an item after it has been executed. When all instructions have been executed, the target language equivalents are printed out.

The programming algorithms are divided into two basic sections: the source language section, which analyzes the text to be translated, and the target language section, which synthesizes the target language, producing the translation.

Each section is sub-divided into sub-sections, or modules, which are determined by linguistic structures:

Programs dealing with word recognition and interpretation;

Programs called syntagmatic, dealing with phrase recognition;

Programs called syntactic, dealing with recognition of sentence structures, that is, with main and subordinate clauses and their syntactic elements.

Any of the modules may be modified, or used in various ways, without affecting others in the algorithm.

Moreover, because they are modular, these programs are not applied in a rigid order. Rather, individual parts of sub-sections are selected and used, to assure complete analyses of any given input and correspondingly complete syntheses of the output.

Since the syntactic programs scan a text and try to establish relations between words which can be separated by a number of other words within a sentence, sentence boundaries must be recognized in order to prevent words in one sentence from being related to words in another.

Separation routines are essential in the language-dependent approaches to machine translation. They prevent mismatches across boundaries; they also economize on computer time by setting definite limitations to areas which are to be processed by subsequent syntactic operations.

After each word has been identified, and syntagmatic and syntactic analyses completed, one alternative is selected from among the English translation equivalents of a Russian word in the lexicon. This selection is based on the syntactic environment in which the Russian word occurs, and leads to the translation.

The procedure for carrying out translation consists of:

Synthesis, which provides the English equivalents of the Russian words and their proper inflections:

Word insertion, which inserts words into the English text which have no overt representation in Russian;

Rearrangement, which puts sentence elements into proper English word order.

For some time SLC has been used at Ispra. Recently it was acquired by the Atomic Energy Commission at Oak Ridge, Tennessee, and is used for in-house translations. (Translation cost at Oak Ridge is $7.30 to $13.00 for one thousand translated English words; the cost at Ispra is $4.55. In the ALPAC report the cost of 1,350 English words is given as $36.00 (Krollmann 2/1968:45).) In spite of the considerable difference in these figures, the Oak Ridge accounting system takes into consideration all costs, including key-punching of input material and computer costs.

4. MACHINE-AIDED TRANSLATION

Three organizations have recently started to perform machine-aided translation:

The Federal Armed Forces Translation Agency, Mannheim, Germany;

The Department of Terminology of the European Coal and Steel Authority (CECA);

Centre de Linguistique Automatique Appliquée, Free University of Brussels, Belgium.

In the Mannheim system, the human translator underlines the English words for which he needs the German equivalents. The underlined words are then punched by a key-punch operator in their canonical form. Three to four text-related glossaries can be produced by computer in ten minutes. These are then given to the human translator for his use in producing the final translation.

The other two systems contain sample sentences for a particular word and the various translation equivalents of the word in actual translated sentences. Whenever equivalents of a given word are requested the computer prints out the list of sentences in which this word occurs. The sentences are stored in five versions: French, German, Dutch, Italian and English. Sentence dictionaries with French and Dutch as input have already been established. Sentence dictionaries with German and Italian were to be operating in 1966 according to *Current Research and Development in Scientific Documentation* No. 14.

5. PILOT STUDIES

Finally we may note a small number of research groups which seek to perform analysis or synthesis of natural languages with the aim of essential application to machine translation or machine-aided translation.

Bonn University, Institut für Phonetik und Kommunikationsforschung der Universität Bonn: Structural Analysis of German;

Freiburg University, Englisches Seminar: Automatic Analysis of English and Automatic Synthesis of English;

Köln University, Seminar für Vergleichende Sprachwissenschaft: Automatic Analysis of Hebrew;

Saarbrücken University, Germanistisches Institut, Institut für angewandte Mathematik: Analysis of German;

Belgium, Royal Museum of Central Africa: Syntactic Analysis of Bantu Grammar;

Netherlands, Netherlands Mathematics Center: Mechanical Linguistics.

With the possible exception of the last, these groups employ language-dependent algorithms; the groups at Köln and Freiburg started out with the intention of constructing general language processors.

The research group for quantitative linguistics (KVAL), Sweden, has concentrated on statistical investigation and mechanical syntactic analysis. It regards these as indispensable preliminaries to mechanical translation, but no direct mechanical translation project has been planned.

6. CONCLUSION

The groups which have maintained themselves in western Europe will probably continue their work. Their existence is not influenced by overly optimistic expectations nor by overly pessimistic conclusions with respect to their results. These groups are gradually increasing the scope of data to be processed so as to include more and more semantic and even factual information in their analysis procedures. These groups are gradually improving their control of MT and the quality of their output. Their confidence may be spreading, as one may assume from the recent publication *Computational linguistics at RAND* (Kay 1969).

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