

### XIII. MECHANICAL TRANSLATION\*

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#### A. STRUCTURAL GRAMMARS

Any feasible machine translation program which is not to treat each successive word or sentence of the source-language text as a wholly new and isolated translation problem must embody some kind of syntax or grammatical analysis routine. Such a routine can be constructed only on the basis of a thorough knowledge of the grammatical structure of both source and target languages.

It is known that the sentences of a natural language cannot be generated by any finite automaton, such as an electronic computer with finite memory, but that at least as powerful a device as a Turing machine is required (1). We are also reasonably sure that the logical structure of any such device does not have any simple, well-known, or previously studied algebra as a basis, but requires an autonomous linguistic analysis for its description.

We might expect that a workable machine translation program would utilize routines that roughly correspond in internal structure to the logical plan of a grammar. Chomsky has shown (2) that the grammar of English sentences cannot be given in any natural, elegant, and detailed fashion by the exclusive use of bracketing, immediate-constituent analysis, or parsing, but that a new level of linguistic structure, a level of grammatical transformations, would be required. It is therefore of considerable interest to study grammars of languages other than English to see whether or not they also require these two distinct higher levels of syntactic description.

Following a suggestion of Chomsky and Lukoff (3), a scheme was constructed for generating all the verb phrases that appear in the independent clauses of German sentences. This scheme would, with a few minor changes, be an integral part of a complete German grammar. In this conception of grammar, each rule states how a partially developed sentence is to be rewritten as a more fully developed form, and the rules are to be applied successively until a complete sentence in pronounceable form is finally generated. The scheme must be so constructed that all and only the grammatical sentences of the language are produced, taking care at every stage to render each rule maximally general and nonredundant.

In the constructed scheme the basic constituents of the simplest type of verb phrase are first formed: the personal ending (to be conformed in a complete grammar to the subject of the verb), a sign of mood (subjunctive versus indicative), a sign of tense (past versus nonpast), auxiliary verbs, the verb base, and the separable prefix. Next, there

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are two transformation rules to produce the derived structure of passive phrases (in werden plus participle) and future/conditional phrases (in werden or würden plus infinitive). Finally, various rules affix all endings to their appropriate bases, introduce word boundaries at the proper places, select the proper auxiliary verb (haben or sein), reorder the words so that the nonfinite verb forms come at the end of the clause, produce the so-called double-infinitive construction when required, and the proper participle of werden (geworden or worden), and, finally, select the appropriate stem and affix forms in the correct combinations (e.g., sing, in nonpast; sang, in past; sung in participle, and so forth).

The exact details of the scheme and the limitations to which it is subject, so long as it is isolated from a complete German grammar, are given in an article which will appear in Mechanical Translation, volume III, No. 3.

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#### References

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2. N. Chomsky, The Logical Structure of Linguistic Theory (Preliminary Draft), M.I.T., 1956; Syntactic Structures, Janua Linguarum No. IV (Mouton and Company, 'S-Gravenhage, 1957).
3. N. Chomsky and F. Lukoff, Construction of the German verb phrase, Mechanical Translation Group Memorandum, Research Laboratory of Electronics, M.I.T., 12 Aug. 1955, pp. 5-7.