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THE PRESENT STATE OF RESEARCH ON MECHANICAL TRANSLATION

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One of the interesting examples of the influence which a newly invented tool may exert in opening up fresh lines in theoretical research and in advancing new techniques for the solution of old problems is provided by the rise of electronic computers. They were originally designed to solve certain mathematical problems quicker than the human brain could but it soon turned out that their components, in which elementary logical and computational operations could be carried out at extremely high speed, might well be recombined to yield similar results in noncomputational fields.

When electronic computers were still in their infancy, in 1945, the question was raised whether a computer-like machine could not be designed that would automatically translate from one language to another. The story of this idea is told by the man who apparently conceived it first, Dr. Warren Weaver, Director of the Natural Sciences Division of the Rockefeller Foundation, in a memorandum of July 15, 1949. This memorandum aroused considerable interest, followed by some active research. Some of the first steps towards a solution of the problem of mechanical translation are described in another memorandum by Dr. Weaver, dated March 6, 1951.

The present paper summarizes the results achieved up to the end of 1951. They involve a clearer understanding of the aims of machine translation, of various possible divisions of labor between man and machine in a translation partnership, and of the preliminary steps that have to be taken before the final solution of the problem can be found. Some of these steps seem to have independent value and especially the task of providing for an operational syntax (see ref. 4) is a challenge that should appeal to structurally-minded linguists and give a new twist to their investigations.

AIMS

Interest in mechanical translation (MT) may arise through sheer intellectual curiosity concerning a problem whose solution, perhaps even attempted solutions, will in all probability provide valuable insights into the functioning of linguistic communication. Interest may also arise from many practical standpoints. One of these is the urgency of having foreign language publications, mainly in the fields of science, finance, and diplomacy, translated with high accuracy and reasonable speed: the scarcity of expert bilinguals is causing a log jam in scientific translation which is costing research an amount that can hardly be estimated but might well run into millions of dollars yearly, due to the fact that important scientific methods and results are not made available in time or perhaps not at all to research workers. Another is the need of high-speed, though perhaps low-accuracy, scanning through the huge printed output [of actual or potential enemies,] in newspapers, journals, propaganda leaflets, etc. These two aims are only partly overlapping, but a good method of achieving one of them would probably be of great help in attacking the other, since we apparently have here another case of a well-known situation where accuracy may be traded for speed, and vice versa.

PURE MT

It seems obvious that fully automatic MT, i.e. one without human intervention between putting the foreign text into the reading organ of the mechanical translator and reading off its output, is achievable only at the price of inaccuracy, if only for the reason that no method is feasible, for the time being, by which the machine would eliminate semantical ambiguities. Such an achievement would require

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either a knowledge of the relative frequencies of all word digrams (sequences of two words), trigrams, etc., or a knowledge of equivalent conditional frequencies of the foreign language (FL) on the part of the machine, a knowledge that is not even at the disposal of the human linguist (which is not at all astonishing in view of the fact that the number of digrams alone, say in German with more than a million words in actual use, will probably run into the billions); or else it would pre-suppose a "learning" organ, the construction of which is still in its rudimentary stage.

This fact, that high-accuracy, fully automatic MT is not achievable in the foreseeable future, has discouraged many thinkers from whom an interest in MT as a socially important, noncomputational application of digital computer-like machines might have been expected; it has discouraged them to such a degree that they have failed to see that, with a lowering of the target, there appear less ambitious aims the achievement of which is still theoretically and practically valuable.

Whether or not the inaccuracy involved in fully automatic MT will be so great as to make the "translation" completely worthless, as would be the case if a trained interpreter of the machine's output were unable to find out even roughly what the passage in question was about, will depend on the two languages involved and on the specific ways by which the completeness and the uniqueness of the translation is achieved. Only extensive experiments will be able to show whether there is any future along this line. Preliminary studies in this direction have been made by a Rand Corporation group, but the results achieved so far do not seem to be decisive.

MIXED MT

For those targets in which high accuracy is a conditio sine que non, pure MT has to be given up in favor of a mixed MT, i.e., a translation process in which a human brain intervenes. There the question arises: Which parts of the process should be given to the human partner? In principle, there are a large number of ways in which a machine and a human brain may collaborate. The following considerations are pertinent: First, the more the human partner does, the less complex the machine will have to be; second, the human partner will have to be placed either at the beginning of the translation process or the end, perhaps at both, but preferably not somewhere in the midst of it, according to a well-known principle of electronic computer handling; third, and perhaps most important, since the major bottleneck in translation lies in the scarcity of expert translators, the human partner should be required to know only one of the languages concerned, either the FL or the target language (TL). Even a tripartite partnership between two humans and one machine, where one human knows each language and the machine performs the transformation, might still have considerable practical value, though its theoretical importance might now be trivial. Even collaboration by a bilingual translator would not necessarily trivialize the task, provided this bilingual partner were required to put only a small fraction of the time he would have had to use to work for a completely autonomous translation, for example if a bilingual chemist together with a number of unilingual associates could use the time he would need for an autonomous translation of a Russian chemical paper for the translation of fifty important Russian papers, there seems to be no doubt as to the practicality of such a procedure.

Let us use the term pre-editor for the human partner who has to know the FL, post-editor for the man who knows the TL, bilingual editor for the man who knows both. The tasks to be performed by a pre-editor and by a post-editor are not symmetrical, contrary to what might be supposed at first sight. It would seem natural to have the pre-editor deal with the elimination of morphological and syntactical ambiguities and with the rearrangement of the FL text in accordance with a standard order in the TL following a set of instructions available to him in his own language. The main business of the post-editor would be elimination of semantical ambiguities, in addition, of course, to stylistic smoothing.

MT WITH A POST-EDITOR

It appears that a post-editor is indispensable for elimination of semantical ambiguities, so let us see first how, without a pre-editor, the post-editor will perform his task, then investigate how a machine could deal with the preliminary elimination of grammatical ambiguities and rearrangement of word order. The

post-editor, relying upon the machine alone, faces a formidable looking obstacle. Consider the relatively simple task of translation from German to English. Take a typical German sentence of 25 words. Assuming that the average number of translations offered for each German lexical unit in an ordinary German-English dictionary is only two (and this is probably a very conservative estimate), then, corresponding to the German sentence there will be a set of many tens of millions of English sentences. (For sentences of 60-word length, we would have quadrillions of correlates.) Is it conceivable that a human brain, even that of an expert, would be able to pick the pertinent correlate out of this astronomical number of offerings in a reasonable time? It is understandable that this situation should . have discouraged workers in the field of MT from continuing work along this line. This is exactly what happened, for instance to Prof. Erwin Reifler from the Far Eastern and Russian Institute of the University of Washington, according to verbal information. After having begun his investigations in MT by considering the case of a post-editor, he shifted to the case of a pre-editor, out of despair in the ability of the post-editor to solve this apparently super-human task.

The author, however, has been able to show experimentally that the post-editor's task is not super-human but, on the contrary, rather easy, if one assumes that a machine has eliminated all the grammatical ambiguities, and part or all of the so-called "idioms," and has rearranged the text in the TL word order. A sample output of a hypothetical German-English Mechanical Translator is given in the Appendix. The reader is invited to pick out of each column just one expression, to smooth the resulting word sequence stylistically, and then to compare his English sentence with one produced by someone else as a translation of the German original given on p. 1 of the Appendix. Another test would be to retranslate the English sentence into German and compare this product with the original.

The extremely interesting results achieved by Abraham Kaplan in a study made for the Rand Corporation (1) partially explain the human editor's success. This study was explicitly intended to be an auxiliary tool for rapid processing of foreign language material. Though it seems that the direct impact of this study on MT is not great, its indirect importance is high. For our purposes, let just one result be mentioned: The amount of ambiguity in meaning of a certain word within a given sentence is reduced, on the average, to something very near its minimal value through inspection of a context consisting of two neighbor ing words to the left and two to the right. The present author's interpretation of this result is that the ambiguity is not so much reduced by cumulative effect as by the occurrence of some one particular word which has a great chance of appearing in the given context. This means that in order to pick one word out of a column) in the above-mentioned example, only one other column in the near neighborhood of the first column has to be inspected, and this is certainly an easier task than a choice of one out of billions.

If one takes into account the fact that the post-editor will receive instructions, in his own language, for handling certain strange-looking combinations, that certain words with many possible translations might reoccur in the passage quite frequently in this same meaning so that time-consuming decisions will not have to be repeated, and so on, it should be clear that the burden on the post-editor will not be too heavy. He should be able to produce out of the raw output of this hypothetical machine a readable translation in a fraction of the time it would take a bilingual expert to produce a translation with the conventional procedure. If the machine can produce its part in a time span comparable with that of the conventional human translator, the machine post-editor partnership may well be able to compete in time and accuracy with an all-human translator. And even if the cost of a mixed translation should turn out to be higher, one should take into account, first, that there are certain practical situations where the cost-factor is secondary and, second, that the operation cost per man-hour is likely to rise in the future whereas the operation cost of the machine will, in all probability, be reduced as soon as such machines are produced on the assemblyline and new invention, such as the transistor, are efficiently incorporated.

In order to eliminate grammatical ambiguities and to rearrange the words of the FL sentence in accordance with the standard order

of the TL, the machine will have to perform a syntactical analysis of the FL sentence. This may be more complicated than at first appears. In the case where the FL and the TL do not have the same syntactical structure, the task of the machine is more than recognition and elimination of ambiguities--note that ambiguities with respect to the TL need not at all be so considered by the native speaker of the FL. The task of the machine for languages of different syntactical structures would be that of a transformation of the original sentence that would keep its semantical contents intact and would enable identification of parts that belong to syntactical categories of the TL. For lack of space no detailed explanation of this process can be given here, but it appears that the minimum operations will be the following:

1. Mechanical analysis of each word in the FL into the stem (lexical unit) and morphological category. Since linguistic terminology is not unique, let us exemplify the required type of analysis, taking German as the FL. The German 'ging' will have to be analyzed into 'gehen' (past, singular, 1st or 3rd person), the German 'lieben' into 1) 'lieben' (infinitive) 2) 'lieben' (present, plural, 1st or 3rd person), 3) 'lieb' (adjective, plural) 4) 'lieb' (adjective, singular, genitive, dative or accusative-masculine). The analysis of 'lieben' is not complete and is even partly incorrect, but it is not necessary here to go into all the linguistic complexities.

2. Mechanical identification of small syntactical units within the given sentence on the basis of the morphological categories to which its words belong and, for most languages, their order.

3. Transformation of the given sentence into another that is logically equivalent to it, and rearrangement of the parts of the transformed sentence in accordance with some standard order of the TL.

The performance of these operations will encounter not only great practical difficulties, especially for operation 1, but will also require certain theoretical preparations, on a linguistic and logical level, of a kind that so far has been dealt with only more or less incidentally. To carry out operation 2, an operational (or instructional or analytic or sequential) syntax for the given FL will have to be prepared that will enable the machine (or, a human translator who does not know the FL) to identify the small syntactical units into which this sentence has to be broken up. This identification will be achieved by operating according to a definite sequential program on the set of sequences of the morphological categories to which the words of a given sentence might belong.

A considerable body of descriptive data about the language of the world has been amassed in recent years, but so far no operational syntax of any natural language exists with a sizeable degree of completeness, and the necessity of providing such a syntax has apparently not been recognized by linguists. To give an analogy: Just as even the most extensive knowledge of all imaginable properties of all chemical substances will not materially assist a student of chemistry in developing a method of analyzing a given mixture of unknown chemical substances, so even the most elaborate description of the properties of all morphological units of a given language will not enable a student of linguistics to find, in a reasonable time, a method of analyzing a given sentence-specimen of this language. Chemists have had to write, in addition to their general textbooks, special books instructing the student on how to proceed in a fixed sequential order (order which sometimes depends on the outcome of the preceding step) in his attempted analysis of a given mixture. Likewise special books will have to be written containing sequential instructions for linguistic analysis, i.e. an operational syntax.

An important step in this direction has been taken by Professor Victor A. Oswald, Jr. and Stuart L. Fletcher, Jr. (2) in an investigation made explicitly with MT in mind, under the auspices of the Institute for Numerical Analysis of the National Bureau of Standards at Los Angeles. In their report, there are very valuable suggestions and proposals and various routines are developed for elimination of morphological ambiguities, such as occur in the analysis of 'lieben' mentioned above, and of syntactical ambiguities, as in the determination of whether the phrase 'die Menge' functions as the subject or as the direct object in a given sentence. Oswald and Fletcher are fully aware of the incompleteness of these proposals, but apparently were not sufficiently

aware of the necessity of combining the different routines investigated into one sequential system. Such awareness has been shown by C.V. Pollard (3) who has developed a set of 11 rules to be followed in a certain sequence by his students of German. These 11 rules are sufficient, according to his claims, to assure satisfactory translation from German into English in almost all cases. Pollard's system presupposes, however, that morphological ambiguities are somehow overcome (an assumption that is not unreasonable for intelligent human translators); and he relies often and heavily, though not always consciously, on the fact that his students can and will use semantical shortcuts, a procedure that obviously does not stand at the disposal of a machine. It seems, however, that by making these tacit assumptions explicit and by incorporating the required additional rules into Pollard's system, an advance towards an operational syntax of German can be made.

To be sure, the problem still remains of finding a sequential system of rules that will be reasonably effective and enable the machine to finish the analysis of an average sentence in a few seconds at most.

At the end of their paper, Oswald and Fletcher point out that they postponed the accomplishment of a complete mechanical syntactical analysis until certain other problems (connected with our operation 1) have been solved. This seems rather unfortunate. It is not clear why there should exist a functional dependence of an operational syntax on counts of the relative frequencies of members of certain syntactical categories within large samples. Important as these investigations might be in themselves, their value for MT is very slight and their influence on the construction of operational syntaxes is almost nil. It is however, exactly with such counts that the UCLA group, now centering around Prof. William E. Bull and Prof. Oswald, is occupying itself at the moment, under a grant from the Rockefeller Foundation.

One motive for this preoccupation with frequency counts lies in the fact that our operation 1 requires, at least under certain assumptions, a huge storage organ of a not-too-large access time. For the complete German language, the number of words actually or potentially in use today is probably between one and two million. It is indeed true that no system exists at the moment in which such a large memory can be scanned in a short time within reasonable limits of expenditure for equipment; yet the time span that can be allocated for comparing a word stored in an electronic register with the corresponding key-word in the storage organ has to be measured in tenths of seconds, at most. This state of affairs seems to have discouraged the UCLA-group from continuing their investigations into operational syntax and induced them to look for ways of reducing the required storage capacity by a considerable factor. They apparently hoped that insights into the relative frequencies of the syntactical categories will somehow enable such reductions.

Now it is true and well-known that a large part of every discourse of sufficient length will consist of repetitions of not too many words belonging to the most frequently occurring words of the given language. A storage of 10,000 suitably chosen words would certainly enable a German-English mechanical translator to identify and translate more than 90 percent of the words appearing in any average text. One might now be led to conclude that such a translation would be satisfactory insofar as an intelligent editor should be able to interpolate the remaining 10 percent or less. There can, however, be little doubt that this widely-held view is false. And this for the following reason: The remaining few percent of words will be of rare occurrence, some of them probably extremely infrequent. For this very reason, they will be least predictable and highly loaded with information. Their interpolation would at the best be very difficult and time-consuming and sometimes, probably in the most decisive places, not possible at all. The result is that, so long as the machine, and not a pre-editor, is required to perform the syntactical analysis and no human bilingual expert is available to take care of the infrequent "remainder", the problem of constructing huge storage-organs has to be faced and solved.

Before we go on to discuss this fact, let us remark that the cheapest and theoretically simplest, so simple as to be almost trivial, solution of the MT problem from, say, German to English will be in using both pre- and post-editors and, in addition, a bilingual expert to deal with the "remainder". The instructions for the pre-editor would, in this case, be, in

all probability, so simple that by using existing machinery a translation could be provided that would not take, altogether, more time nor cost any more money than the translation produced by a good bilingual expert, and it would be of considerable practical importance insofar as the bilingual expert would have to spend on this type of translation only a fraction of the time he would have had to spend on a completely autonomous translation. It might therefore turn out that, for this method of translation, namely that making restricted use of a bilingual expert plus pre- and post-editors, the UCLA frequency counts will prove to have some practical value, insofar as they might point to certain constructions in the FL that occur so infrequently that one should not complicate the machine in order to deal with them but should leave them to the bilingual editor.

To return to the storage problem, there is no reason to assume that it will not be solved satisfactorily. Many possibilities present themselves, from simple gravitational non-scanning devices to magnetic, electronic, or photo-electric devices, or any combination of such, scanning or semi-scanning. Further experimentation in this direction for use in fields quite independent of translation is under way with results expected in the near future.

Under the assumption that the storage problem has been solved, then the possibility of providing the machine with the results of a complete morphological analysis arises. It should be remembered, however, that there is in principle no reason for the machine's not being able to perform this analysis by itself. This is the method which will have to be used if sufficient storage is not available.

MT WITH A PRE-EDITOR

Prof. Reifler (4), as already mentioned, has occupied himself mainly with MT involving a pre-editor only. He discusses at great length various possibilities of actually eliminating grammatical ambiguities and rearranging by the pre-editor. Besides a discussion of such devices as addition of diacritical marks to the original text, vowel-signs in Hebrew and Arabic where books and scientific papers are usually printed without them, artificial stress-signs to distinguish, in English, between 'convict' and 'convict', etc., he also has some interesting though somewhat speculative and not too specific remarks on using a universal artificial system of morphological and syntactical categories. The gravest problem for this method is obviously the elimination of semantical ambiguities. Reifler envisages, for this purpose, a "mechanized dictionary," i.e., a device that will give the pre-editor, for every word in the FL, a set of interpretations in the FL that will stand in bi-unique correspondence to the translations usually given in some ordinary bilingual dictionary. When the pre-editor sees, for instance, that the German word 'Hahn' is used in a certain context referring to a weapon, he would tag this occurrence of 'Hahn' by the numeral '2' if the following set of "association" is put before him:

Hahn 1.(Tier)... 2.(Gewehr)... 3.(Wasser)...
corresponding to the entries in a German-English dictionary
Hahn 1. cock 2. hammer 3. faucet

It is hard to foresee whether this method can be made to work quickly and efficiently, but if it can, the pre-editor can take upon himself a larger part of the whole translation process than can be put on the shoulders of a post-editor, with a corresponding reduction in the complexity of the machine.

Reifler makes a clear distinction between general MT, where translation from any language into any other language is considered, and specific translation where only two languages are treated. Obviously, certain methods that depend heavily on the close syntactical relation of two languages will be useless for general MT. This latter problem is, therefore, of a higher order of complexity.

UNIVERSAL GRAMMAR

Whereas specific MT will, in all probability, continue to be mainly an application of trial-and-error investigations, general MT will require the establishment of a universal, or at least general, grammar, perhaps even the construction of a whole artificial exchange-language. Prior attempts in this direction have failed completely and brought the whole topic of a characteristica universalis or even a grammatica universalis into disrepute. The usual combination of metaphysical preconceptions, Aristotelian logic, and complete innocence of any knowledge with respect to the so-called exotic languages is not a very promising mix-

ture. Empirical open-mindedness, mathematical logic, and modern structural linguistics may perhaps prove to be a better one. There is good reason to believe that a combination of the methods developed by K.A. Ajdukiewicz (5) with those developed by Zellig S. Harris (6) may lead to the beginnings of a universal system of syntactical categories. Other contributions have been made by Rudolph Carnap (7), Hans Reichenbach (8), and the author (9). Professor Stuart C. Dodd's system (10) is highly interesting and has been experimentally tested but is not yet in its final form.

The construction of a universal grammar is, at the best, a long-term project, and specific MT should by no means be postponed until its succesful accomplishment.

Somewhat less ambitious are investigations into so-called transfer-grammars, i.e. systems in which the grammar of one language is stated in categories appropriate to some other language. This method, too, is old and now unpopular, but it is by no means clear that important achievements cannot be reached with a careful use of it. Preliminary results have been achieved by Harris and his pupils, but little, if anything, has been published.

MT BETWEEN RESTRICTED LANGUAGES

So far, only MT between complete natural languages has been treated. There are situations, where perhaps a restricted vocabulary or a restricted number of sentence-patterns or perhaps both, are used or might be used.

This is true of "basic" languages such as Basic English, artificial international auxiliary languages such as Esperanto, Interlingua etc., and also with regard to the pilots' Q-code or the code used by meteorologists. These codes are so restricted that pilots and meteorologists are simply required to learn them as they are, but situations are conceivable in which the richness of information to be transmitted might be so great that a memorizing of the corresponding code should not be required of a pilot, for instance, whose responsibilities are already exceedingly arduous and complex. Some mechanical translation system from the pilots' native language into the international code and another system for translating from this code into the control tower operator's native language might be of great help.

In such cases, word-for-word translation is not obligatory since the number of all admitted larger syntactical units, even of all admitted sentences, might still be relatively small. Sentence translation or sentence-pattern translation might be an effective method here and is already in use, to a certain degree. The theoretical difficulties of such a type of MT are clearly less formidable and are included in the difficulties of ordinary MT so that no special treatment is necessary here.

More important, perhaps, might be the possibility of restricting, by voluntary convention, the richness of expression in writing abstracts of technical papers, for instance, to such a degree that sentence-pattern translation might easily and quickly be applied, perhaps not directly into any other language but first into some exchange language, natural or artificial.

HARDWARE PROBLEMS

Little thought has been given so far to the problem of the type of machine that should do the mechanical part of a translation; so long as the various alternative possibilities had not been explored to a sufficient degree, experimentation in the uses of computer-like machines was not warranted. It seems, however, that the stage has been reached where experimentation could be started. The main problem is whether general-purpose computers or special translation machines would, in the long run, be more satisfactory with regard to the speed-accuracy cost ratio. The major operations to be carried out by the machine seem to be comparison and identification, shifting and transferring, unconditional and conditional selection, but not specifically arithmetical operations.

It seems that for reasons of cost MT will have to be undertaken on a large scale, if at all, It will be justified only if the equipment operates on a full-time basis. Reasons of economy also dictate that the equipment be as well adapted as possible to its special task. Computers in their present form are not ideally suited for MT. Nevertheless certain preliminary experimentation can be carried on with them.

SUMMARY

Practical interest in MT has arisen from

the desirability of very rapid, but low-accuracy, and provisional translation of large amounts of material in foreign languages, for the purpose of high-accuracy translation of mainly scientific material, and for various other purposes. On the other hand, engineers have been impressed by the possibilities inherent in various components of electric computers and are now looking for further practical applications in noncomputational fields of new combinations of these components. MT seems to them to be promising since its basic logical operations are of a kind already carried out in existing computers.

Active investigation in the use of MT for rapid mass-translation is going on in the Rand Corporation; research in the use of MT for high-accuracy translation is being done by the author at the Research Laboratory of Electronics of M.I.T.; and certain bordering problems are being investigated by a group at UCLA. Reifler's valuable contribution has been somewhat isolated, and no further research has been undertaken by him. No additional information on progress made by an English group centered around A.D. Booth and R.H. Richens could be obtained, but to all appearances no new important results have been achieved. The author's own results, only a small part of which are incorporated in this interim report, will be published separately.

The following tasks seem to be of great importance for their own sake and sufficiently independent of each other to permit their undertaking by separate groups:

1. The compilation of a word-index for each language, giving the (unique or multiple) analysis of each word into stem and morphological category.
2. The construction of a permanent large-scale storage organ, of medium or low access-time, for utilization of the word index.
3. The construction of a mechanical bilingual stem-dictionary. It seems rather obvious that radical departures from ordinary dictionaries will be necessary.
4. The construction of an operational syntax for each language, giving a complete sequential program for the analysis of every sentence.
5. Experimentation or relative speed, accuracy, and cost of translation by pre-editor, post-editors, pre- and post-editors, part-time bilingual translators, etc.
6. Construction of various universal grammars and comparison of their efficiency in translation.

Though these tasks may be quite independent, MT must be based on the completion of most of them. Hence organization and synchronization are important and require the establishment of some coordinating organism, if real progress toward MT is to be made.

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APPENDIX

Sample output of a German-English Mechanical Translator for sentence B. below

if	a	modern	electron super microscope	be	judge	with regard to	its	
when		new		Pres.	estimate		his	
whenever		fashionable			criticize		her	
though					interpret			
					understand			
					review			
					Part. Past			

optical	capacity		so	the	question	stand	almost	always	in the	foreground
	efficiency		thus		problem	be	nearly	ever		
	ability to perform		then		demand	become				
	productive power				inquiry	fit				
						be upright				
						Pres.				

till	to	which	magnitude	down	small	detail	be	prepare	in
until		what	quantity	downward	little	particular		produce	
up to		who	size	down here	short		Pres.	manufacture	
			amount		narrow	Plural		exhibit	
								present	
								describe	
								Part.Past	

faithful	form
true	shape
	cut
	size
	usage
	mold
	frame

A. Original German Passage

Wenn ein modernes Elektronenübermikroskop hinsichtlich seiner optischen Leistungsfähigkeit beurteilt wird, so steht fast immer die Frage im Vordergrund, bis zu welcher Grosse herab kleine Einzelheiten in getreuer Form dargestellt werden.

B. German Passage Rearranged for English Translation

Wenn ein modernes Elektronenübermikroskop wird beurteilt hinsichtlich seiner optischen Leistungsfähigkeit, so die Frage steht fast immer im Vordergrund, bis zu welcher Grosse herab kleine Einzelheiten werden dargestellt in getreuer Form.