

THE POSSIBLE USE OF DECISION PROCEDURESIN  
MECHANICAL TRANSLATIONby  
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(General Reference: "Report on the State of Machine Translation in the United States and Great Britain," by Y. Bar-Hillel, 15th February 1959.)

In his report on the work of the M.I.T. group, and again in Appendices II and III, Professor Bar-Hillel refers to the use of decision procedures in Mechanical Translation (M.T.), procedures which analyse the structure of given sections of text in order to test them for "sentencehood"\*. Appendix III contains his most recent views of the question: Bar-Hillel has originally asserted (Ref. "A quasi-arithmetical notation for syntactic description".) that a method of analysis based on the "Immediate Constituent Model" of sentence structure, that is, a method which regards a sentence as composed of "contiguous segments" only, would be sufficient to determine the syntactic character of any sentence which can occur. He now doubts whether, even supplemented by transformational operations(1) which take account of "non-contiguous" but "syntactically associated" elements, such a procedure would succeed in resolving and correctly describing all the sentence patterns of a language.

Bar-Hillel questions, on logical grounds, whether any form of analysis could give the desired result. He bases this claim on the fundamental assertion that it is impossible for any procedure, which, because it can only classify the elements of sentences according to a finite number of categories, can therefore recognise only a finite number of sentence types, to be capable of determining the infinite number of "meaningful" sentences in a natural language. That is, it is always possible to find sections of text which are sentences, according to the informal rules of the language in which they are expressed, but which are not sentences

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\* The word "sentence" is used to refer to what would in ordinary language be called a sentence. Where the reference is to particular kinds of sentences, this is indicated.

according to the criteria applied during the analysis. It is therefore always necessary to introduce new categories to describe the "irresoluble" elements of such natural sentences. Such open lists are incompatible with the finite nature of decision procedures. Bar-Hillel continues to assume, however, without offering any justification for such a far-reaching belief, that decision procedures of some kind which constitute a test for "sentencehood" must be a part of any M.T. programme. I feel that it is necessary, therefore, to consider both whether decision procedures must be inadequate, and, more fundamentally, whether they are relevant to M.T.

Before examining the general issue, it should be pointed out that Bar-Hillel has not shown that no decision procedure can be successful. He has only shown that the method which he describes can fail in too high a proportion of cases. Although apparently related to his logical objection, this criticism is in fact a practical one, and must therefore be refuted on practical grounds. The approach discussed assumes that the standard sentence consists of "contiguous segments"; any sentence for which this is not the case can be rearranged in standard form. It is possible, however, to construct perfectly reasonable sentences for which it is extremely difficult to find plausible transformations. To avoid these difficulties, it might be possible to develop a method of analysis similar in outline to that described, which takes non-contiguous elements into account from the start, and which would probably, therefore, be more flexible than that based on the "Immediate Constituent Model". The Appendix to this note contains a sketch of such a procedure, which is successfully applied to a "recalcitrant" example given by Bar-Hillel.

Although the logical argument still holds, its irrelevance would be shown by the practical success of the method. For although theoretical elegance, and even a "water-tight" logic might be required of an M.T. programme, it must essentially be judged by its practical efficiency. A programme of the type suggested might be criticised from such a practical point of view: it would almost certainly be too imprecise or arbitrary. Moreover, the difficulties involved in its application would be enormous: so many combinations of

elements are allowed that it would become wearisome to check them all. These problems are, however, irrelevant, as the present discussion is concerned solely with the possibility of a procedure which would be theoretically more satisfactory than that described. (That Bar-Hillel criticises his own method in these practical terms is contrary to his claim that he is only concerned with its theoretical consequences.) Finally, the point can be made that it might be possible to construct a method of analysis which would be so efficient as to reduce the logical objection, were it considered relevant, to triviality through there never being an instance to support it.

It should be noted that Bar-Hillel's logical assertion, that there is an infinite number of sentence patterns, is incompatible with his own belief in decision procedures. This again would seem to show that the logical point, although perfectly true, is irrelevant; thus Bar-Hillel's argument for decision procedures (whatever it may be), although highly general, cannot be a logical one.

It is obvious that part of any input programme must be concerned with obtaining syntactic information about the basic elements, say, words or chunks of the input text, whether they are regarded as individual units or as members of an integrated group, or both. Such information can be obtained by a dictionary look-up, for example; it could also be found by an analysis of the structure of the sections of the input text (2)(3): here a version of the procedure described by Bar-Hillel might well be useful. Obviously, such a procedure must be capable of obtaining a result in a finite number of operations. It is essential that the results of these operations should constitute a directive for further translation procedures. In its present form, Bar-Hillel's method can only result in a description of the sentential structure of the input, and is, to this extent, inadequate. Further, if used in this way, it is no longer a decision procedure.

Bar-Hillel's use of the "Immediate Constituent Model" and "Transformational Model" is far from being so uncontroversial. Their primary object, for him, is to provide the criteria

for a test of "sentencehood" which is applied to the given sections of the input text; here the method of analysis is a decision procedure in the strictest sense. Bar-Hillel again doubts whether such tests are sufficient to establish "sentencehood" in all cases, but again does not question the need for such a test. It is here that the real criticism of the use of decision procedures can be made: it is contained in the question: "Is it necessary to test sections of the input text in order to discover whether they are sentences?"

It can be argued that the aim of an input programme must be to "digest" the whole of any presented text. It can be queried whether it is the function of such a programme to act as a kind of literary critic, and to reject certain parts of a text on the grounds of syntactic, that is essentially, stylistic, deficiency. In defence of this normative view, it could be argued that it may be practically impossible to construct an M.T. programme which can assimilate or be capable of analysing any sentence pattern, and therefore that producing standard sentence patterns is necessary. (This could be done by pre-editing.) If this were true such a "standardising" operation might involve a test for "sentencehood" in order to discover whether any "indigestible" patterns exist. This last, however, is a practical point which must be considered in relation to a particular line of approach, though it can perhaps be said that an input programme which allowed only certain standard sentence types would probably condemn itself. The general assertion that a test is required remains unjustified.

A further point: the method of analysis based on the "Immediate Constituent Model" can only be applied to existing sentences. It could not, in its present form, break up a stream of unpunctuated text into its constituent sections; if it could, it might be a valuable aid to translation (4). Assuming (and to deny this would be somewhat extreme) that a translation programme needs the information that a particular section of the given text is a sentence, it is further assumed by most M.T. workers that this information can be mechanically obtained in a fairly efficient manner by some arbitrary means, say, by defining as a sentence the words between two "cut points" (e.g. full stops). The effectiveness

of the definition would be measured by the degree to which such defined sentences approximated to the sentences of the text. (It should be pointed out that the whole method described by Bar-Hillel is vitiated by the fact that the test for "sentencehood" can only be carried out on sections of text which have already been defined as sentences under some subordinate definition; and this would seem to make the test even more redundant.) Such an arbitrary definition of a sentence might produce sections which were not sentences for Bar-Hillel; but so long as the results of a translation based on these sections were reasonable, this would be a sufficient justification. It is an empirical one, but it avoids the logical difficulties and unfortunate practical consequence of a test. A text would then automatically contain nothing but sentences, and there would be no reasons for rejecting any of it.

Bar-Hillel considers the use of decision procedures in relation to the input stage of a translation programme; a test for sentencehood would be far more aptly placed in the output. Whether the input text consists of sentences or not, it might reasonably be required of the translation that it should. This implies that some part of the output programme must be concerned with the construction of sentences according to criteria which apply in the target language; for it is rarely the case that the syntactic structures of two languages are the same: the retention of the structure of the input could frequently lead to misrepresentative and incomprehensible translations. And it is taken for granted by most M.T. workers that an output programme will contain rules which ensure a "correct" translation (5); these might be very flexible: so long as the sense of the original was preserved, and the translation was comprehensible, there would be no emphasis on the finer points of grammar. On the other hand, such rules might be quite restrictive; for example, only allowing translation into the active voice. These different methods must be judged by their effectiveness. It is possible that it might be extremely difficult to construct such output programmes, and that the desired standard of "correctness" could only be achieved by post-editing, either human or mechanical. This would involve a test of the crude output sections in order to discover their deficiencies. But the use of such tests would be a feature of a

particular translation procedure, and not of translation programmes in general.

It is obvious, both for Bar-Hillel's logical reasons, and for practical ones, that rules which determine the syntactic structure of output sentences cannot be so wide as to generate all the varieties of sentence pattern which are allowed in the target language; they will exclude some which can in fact occur. Thus the consequence of a formalised (and therefore limited) translation programme is that translation cannot be carried through into a whole language, but only into some specified sub-language of it. But this in itself does not make the attempt to translate by mechanised procedures futile. The extent to which the translation rules and those of the natural language in question coincide is dependent on practical considerateness: as before, if the result is acceptable, this is the justification for the methods used to obtain it. And again, the logical criticism is inappropriate.(6)

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References:

- 1) N. Chomsky, "Syntactic Structures", S'Gravenhage, 1958.
- 2) 3) Such analyses of the structure of the input text are contained in two programmes by members of the Cambridge Language Research Unit; vide A.F. Parker-Rhodes, R.H. Richens, C.L.R.U. Workpapers.
- 4) This point is particularly relevant if translation of Chinese is to be attempted. For a discussion of the translation of Chinese, vide C.L.R.U, Workpaper, "Annexe V", and A.F. Parker-Rhodes, "An electronic computer programme for translating from Chinese into English", M.T. Vol III, No. 1, 1956.
- 5) R.H. Richens, C.L.R.U. Workpaper, "The Thirteen Steps"; here the bonding notation is designed to secure a correctly ordered output without difficulty.
- 6) For a fuller discussion of the position of syntactical analysis in translation programmes, vide M. Kay, "The relevance of Linguistics to Mechanical Translation".

## APPENDIX

This Appendix is concerned with an attempt to show that a decision procedure other than that discussed by Bar-Hillel might be theoretically more satisfactory.

The notation, and most of the operations, are taken over from Bar-Hillel's method, but the procedure outlined introduces a fundamental expansion of the bracketing involved in the "Immediate Constituent" and "Transformational Models". "Non-contiguous", but "associated" elements are not eliminated, but are included from the start.

This is only the sketch of a procedure. No attempt is being made to establish a new method. The object of the experiment is to show that an alternative approach to that of Bar-Hillel may be more successful. The test is carried out on a sample piece of text which is ordinarily accepted as a sentence, but which cannot be satisfactorily resolved by Bar-Hillel's method.

### Notation

With some additions the same as that given by Bar-Hillel in Appendix III.

A sentence is regarded as the result of a successive series of combinatory operations: the basic units are words which can be combined and the resulting units can again be combined, and so on. Both words and word groups are classified according to their syntactic properties. This classification is into two categories - arguments and operators; the former is represented symbolically by  $n$ , the latter by a composite symbol representing on the one hand its operand, and on the other the category of the result of the operation. A unit which can be a sentence is represented by  $s$ . Thus an operator may be assigned the symbol  $s/n$ ; that is, a sentence results from the combination of the operator with an argument to its right.  $s \backslash n$  would indicate an operand to the left. Both are possible, as in  $n \backslash s/n$ . Also, the result of an operation may still be an operator, as in  $n \backslash s // n$   $s$ , the use of the double slash being obvious. It should be noted that any word can be classified in as many ways as are appropriate.





follows:

Operator elements may be symbolised thus:  $n \setminus s$ ,  $n \setminus s$ ,  $n \setminus s \setminus n$ ,  
 $n \setminus s \setminus n \setminus s$ ,  $n \setminus s \setminus n \setminus s$  and so on.

The symbol  $\setminus$  or  $\setminus\setminus$  indicates that the operator in question can combine with the indicated operand whether the operand is contiguous or not on the appropriate side. The additional combinatory procedure consists of applying the operator to all available operands in turn, whether these are first stage elements, or represent the result of previous bracketing,

Example:

The sentence to be bracketted is: He looked it up.  
 The words in the sentence can be reasonably classified as follows:

|    |           |    |                                       |
|----|-----------|----|---------------------------------------|
| He | looked    | it | up.                                   |
| n  | n \ s / n | n  | n \ s \setminus n \setminus s         |
|    | n \ s     |    | n \ s / n \setminus n \setminus s / n |
|    |           |    | s \ s / n                             |

When all possible bracketting alternatives have been tried,\* it can be seen that only one gives the desired result, as follows:

|                      |           |   |                                       |
|----------------------|-----------|---|---------------------------------------|
| n                    | n \ s / n | n | n \ s / n \setminus n \setminus s / n |
| └──────────────────┘ |           |   |                                       |
|                      | n \ s / n |   |                                       |
|                      | s         |   |                                       |

Taking  $\setminus\setminus$  as combining with the next element but one in the appropriate direction

some failures are, for example:

1. 

|                      |           |   |                                       |
|----------------------|-----------|---|---------------------------------------|
| n                    | n \ s / n | n | n \ s / n \setminus n \setminus s / n |
| └──────────────────┘ |           |   |                                       |
|                      | s         |   |                                       |

Here  $\setminus\setminus$  has the same value as above, but the left hand bracket is done first, and therefore second stage bracketting is impossible.

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\* too many to present here.

$$2, \quad n \quad \frac{n \setminus s \quad n \quad n \setminus s}{n \setminus s} \setminus \setminus n \setminus s$$

Where  $\setminus \setminus = -1$

$$3. \quad \frac{n \quad n \setminus s}{s} \quad n \quad n \setminus s \setminus \setminus n \setminus s$$

Where  $\setminus \setminus 1, -1, \wedge -2$ , but the left hand bracket is done first.

The procedure indicated has therefore been able to give a correct result. From a theoretical point of view, the procedure can be said to be more successful than that described by Bar-Hillel; it in fact includes the latter. From a practical point of view, its application would present enormous difficulties as so many combinations of elements must be tested. (This was not very apparent in the example discussed as the possibilities of combination were quite small. But the addition of further classifications to the elements even in such a sentence would lead to intolerable complexity.)