Milestones in Machine Translation no.3

Bar-Hillel's survey 1951

In May 1951, Yehoshua Bar-Hillel took up a research position at the Massachusetts Institute of Technology to do research on machine translation (MT). It was to prove to be one of the most significant appointments ever made in this field. Bar-Hillel was in fact the first person to be appointed anywhere specifically for MT research. He had originally come to the United States on a fellowship from the Hebrew University of Jerusalem in order to pursue his philosophical studies, going first to Chicago where he studied under Rudolf Carnap (and learnt about Shannon's information theory) and then to MIT, where he met Norbert Wiener, whose book on cybernetics had been a great influence. When his fellowship money ran out, he was appointed at MIT to a two-year post in the Research Laboratory for Electronics, with the task of investigating the possibilities of machine translation and planning future research.

In October 1951, Bar-Hillel visited the few places in the US where research had started on machine translation, at the Rand Corporation and UCLA in Los Angeles, and at the University of Washington in Seattle. After the tour, it was decided to hold a conference at MIT in June 1952. For this conference, Bar-Hillel wrote a 'state of the art' survey*, in which he clarified the major issues, identified where the main problems lay and suggested what the principal lines of inquiry could be.

He began by stating practical aims: "the urgency of having foreign language publications, mainly in the fields of science, finance and diplomacy, translated with high accuracy and reasonable speed", and also "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."

With remarkable prescience, he realised that MT was an instance of "a well-known situation where accuracy may be traded for speed, and vice versa." For Bar-Hillel it was already "obvious" that "fully automatic MT, i.e. one without human intervention… [was] achievable only at the price of inaccuracy." The major obstacle to fully automatic translation was that there were no obvious methods "by which the machine would eliminate *semantical ambiguities*."

However, he stressed (in words, which are as valid today as when he was writing,) that "with a lowering of the target, there appear less ambitious aims the achievement of which is still theoretically and practically viable". In particular, he advocated "mixed MT", i.e. a translation process in which "the human partner will have to be placed either at the beginning of the translation process or the end, perhaps at both…" With human and machine collaboration, he contended, "high accuracy" could be achieved.

The revision of the output of a MT system by a 'post-editor' was "indispensable for elimination of semantical ambiguities." But the task could be "astronomical" if, in a word-for-word translation, all possible equivalents were output. This was why Erwin Reifler (at the University of Washington), when first considering the difficulties,

believed a 'pre-editor' was also essential. The task envisaged for the pre-editor was to mark the source text for its parts of speech, "using a universal artificial system of morphological and syntactical categories", and to reduce ambiguities by marking the specific subject context for every ambiguous source word. But Bar-Hillel thought the method was inefficient and laborious and furthermore that there would still need to be a post-editor.

On the other hand, he did think that the post-editing task could be made "rather easy", if the system had already eliminated "all the grammatical ambiguities" and had arranged the text in correct target language order. While under no illusions that this would itself be easy, he was able already to suggest some possibilities. There was the statistical approach described the year before by Abraham Kaplan (Rand Corporation), which isolated the specific meanings of polysemes from an examination of immediate context, which need be no more than two words to the left or right. Then, he suggested that a post-editor could be given specific instructions for dealing with "strange-looking combinations" arising from literal translations of source language idioms. For example, he could be instructed that *he/she/it gives* might originate from German *es gibt*, and should be changed to *there is.* And post-editors would get used to some changes: "certain words with many possible translations might reoccur… in this same meaning, so that… decisions will not have to be repeated." In sum (and, rather over-optimistically), Bar-Hillel thought that a post-editor "should be able to produce out of the raw output… a readable translation in a fraction of the time it would take a bilingual expert to produce a translation with the conventional procedure."

However, it was Bar-Hillel's conviction that machines could go further, that systems could incorporate grammatical analysis. He thought there would be three components: (a) "*mechanical analysis* of each *word* in the FL [foreign language, i.e. source] into the *stem (lexical unit)* and *morphological category*…"; (b) "*mechanical identification* of small syntactical units within the given sentence on the basis of the morphological categories…"; and (c) "*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 [target language]".

In overall conception this plan was a remarkable anticipation of what came to be known later as the 'transfer' approach to MT system design, one that lies at the heart of many current systems, both commercial and experimental. The main problem he envisaged was that systems would 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" – and in the early 1950s current linguistics had little to offer MT research.

However, there were some pointers for syntactic analysis. There was the research in Los Angeles by Victor Oswald and Stuart Fletcher, who had suggested various routines for identifying German syntactic structures, but – Bar-Hillel stressed – they had not combined them into "*one* sequential sequence", i.e. in a form suitable for a computer program. Furthermore, they assumed that successful morphological analysis had already been achieved, but for this all they could suggest were frequency counts of categories in large text corpora. Not only would this demand "a huge storage organ of a not-too-large access time", which did not exist at the time, but Bar-Hillel was

very sceptical of the value of statistical methods. (Within a few months of writing this survey, Bar-Hillel put forward his own system of analysis, a 'categorial grammar' based on work of logicians Carnap and Ajdukiewicz.)

He drew a clear distinction between "specific MT" (translation between just one source and one target), and "general MT" (from any language into any other). He believed that systems for "specific MT" could be developed on a simple trial-and-error basis. Indeed, many of the earliest MT research groups were to do precisely this: rules developed to deal with one set of sentences were tested on a new set, revised to deal with new problems, tested on a third set, revised again, and so forth. However, he thought that "general MT" required the "establishment of a *universal*, or at least *general grammar*, perhaps even the construction of a whole artificial exchange-language" (or interlingua, as it would now be called). Although past efforts to build universal languages were not encouraging, Bar-Hillel's positivist training led him to think that "empirical open-mindedness, mathematical logic, and modern structural linguistics" could provide better foundations – as indeed, was demonstrated by later MT researchers, with greater or lesser success.

A final section of the survey represented a further significant anticipation of later MT, a discussion of MT with "a restricted vocabulary or a restricted number of sentence-patterns or perhaps both." He had in mind Basic English, artificial languages such as Esperanto, and the "codes" used by pilots and meteorologists. In the latter case, he believed that "sentence-pattern translation might be an effective method…The theoretical difficulties of such a type of MT are clearly less formidable." Furthermore, Bar-Hillel foresaw the control of vocabulary and grammar in order to assist automatic translation: "restricting, by voluntary convention, the richness of expression… to such a degree that sentence-pattern translation might easily and quickly be applied." With these words, he may be said to have predicted not just sublanguage systems such as Meteo for weather forecasts in Canada and the successful application of controlled language input in many present-day implementations, but even the more recent development of example-based MT.

In 1951, MT research had not begun on even very modest scales. Bar-Hillel's perspicuity was all the more remarkable, since he identified many of the problem areas (obviously, not all) that still concern researchers, and he outlined many of the basic strategies for the construction of practical MT applications. His emphasis on the non-feasibility of fully automatic translation and his comments on the value of limited systems were commendably realistic, and ought to have been heeded much more in subsequent years than they were.

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* The present state of research on mechanical translation. *American Documentation* 2 (4), 1951, pp.229-237.