OUT OF THE SHADOWS

A retrospect of machine translation in the eighties

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The end of a decade is a traditional, even if somewhat arbitrary, time for looking back at what has been achieved, and for looking forward to what may come in the next decade. In the past, epochs of machine translation (MT) began and ended at the mid-points of decades. In the mid-1940s, Booth and Weaver first talked about the use of the newly invented electronic computers for translating natural languages; in the mid-1950s, a MT demonstration by IBM and Georgetown University prompted the start of large-scale official support in the United States and the Soviet Union; in the mid-1960s, the notorious ALPAC report appeared which effectively brought to an end projects in the United States and influenced MT funding throughout the world; and in the mid-1970s, the revival of MT began with increasing operational installations, commercial development and expansion of research activities. However, most of this revival has taken place during the 1980s. This is a general review of the last decade with some suggestions of what might or ought to happen in the next. It is neither comprehensive nor detailed, and full references to the systems mentioned are not given: these are to be found in Hutchins (1986, 1988), and proceedings of conferences in 1988 and 1989 (Carnegie Mellon University 1988, Maxwell et al. 1988, Coling 1988, MT Summit 1989).

At the end of the 1970s there were signs of a revival of MT after the quiet decade following the ALPAC report of 1966 (Hutchins 1978, Snell 1979). The US Air Force had been using Peter Toma's Systran system for translating from Russian since the early 1970s. The pressing translation needs of the European Communities encouraged its Commission to investigate computer translation of internal documents. In June 1975 the Commission arranged for a demonstration of the Systran English-French system and shortly afterwards signed an agreement for the development of versions for the Community. By this time also, the Systran Russian-English system had replaced the Georgetown system at Euratom and the Xerox Corporation had begun using Systran for translating technical manuals written in a controlled English. Three other initiatives by the Commission further stimulated the revival. One was the organisation in 1977 of a conference on "Overcoming the Language Barrier", which covered term banks for translators and nearly all current MT research projects; another was the commissioning of the survey of MT by Bruderer (1978); and the third was the publication in 1976 of an 'action plan' which promoted the development of Systran, the Eurodicautom term bank, and launched long-term research on Eurotra, an advanced multilingual MT system intended to eventually supersede Systran.

Otherwise, however, there were few research groups active at the time. In France there was the Grenoble GETA team with long research experience since 1961, and in Germany there was the Saarbrücken team established in the mid-1960s - although neither had yet put any systems into practical service. But in North America MT was still in decline: at the University of Texas the USAF support for the METAL system had come to an end in 1975, although later it resumed with funds from the German company Siemens; and at the University of Montreal, the TAUM project

was also coming to an end (in 1981), despite success with the METEO system installed in 1976. Operational MT systems at the time were mainly continuations of older (pre-ALPAC) designs. The future of MT was uncertain. It had not yet emerged from the shadows cast by the ALPAC report. For the general public and for many working in related fields MT was dismissed as one of the 'great failures' of research.

By contrast, the use of computer-based terminological databanks was growing. The LEXIS system at the German Bundessprachenamt had been producing text-related glossaries since 1965; the Community's term bank Eurodicautom had been established in 1963; Siemens' TEAM and the Canadian TERMIUM databanks had likewise already given a number of years service. The value to translators was clear and at the end of the 1970s it could be safely predicted that the use of terminology databanks would grow rapidly in the next decade. And so it has proved, new term banks have been established in many countries - but not in Great Britain, where proposals for an English-language databank failed to receive sufficient support.

Translators were very interested in the term bank developments and in the already apparent potentials of word processors and microcomputers in their work. They were intrigued about the Commission's commitment to Systran, but very sceptical about MT in general. This was not surprising: the only examples of MT systems at the time were 'batch' systems which produced output of such low quality that extensive post-editing was required before it could be passed as acceptable. Improvements were envisaged in two main respects: the quality of the MT output and the provision of on-line editing facilities. Both were desirable, the former entailed long-term linguistic research and the latter the development of appropriate microcomputer-based word processing software. However, this scenario was not one which appealed to translators, who - even if they believed that MT systems could be improved, and many did not - saw themselves as inevitably becoming no more than post-editing drudges.

The situation changed in the early 1980s with the appearance of the first machine-aided translation systems. In these systems the translators were clearly in full control; they could accept or reject the versions and the help provided by the systems as they wished. At the same time the threat of large 'batch' systems producing cheap MT versions and throwing quality translators out of business receded; these MT systems have been installed only in the largest translation organizations and services. The freelance translators have been scarcely touched; rather they have gained from improved word processing facilities, computer-aided translation and on-line access to term banks. Most translators have dropped their antagonism towards academic MT research and indeed wish research to continue on improving computer facilities and improving the general quality of MT output.

By the late 1970s it had become the generally accepted view that the 'direct' translation approach of 'first generation' MT systems (those developed before the 1966 ALPAC report) was inherently incapable of producing good quality output, that the 'interlingua' approach of systems such as CETA (Grenoble) and the Texas systems had been too ambitious given current levels of linguistic knowledge and computational expertise, and that the best prospects for improvement of MT quality lay in the development of transfer systems. At the same time there was a belief that developments in Artificial Intelligence (AI) had already begun to promise even higher quality in the more distant future.

The 1980s have therefore seen developments on many fronts. Firstly, there has been the research, development and in some cases implementation and commercial exploitation of transfer systems of

various kinds. Secondly, there have been implementations and improvements of earlier (basically 'direct') designs. Thirdly, there has been continuing research on artificial intelligence approaches and techniques and their application to MT system design. And fourthly, there have been explorations of alternative models, including not only innovative interlingua approaches but also applications of statistical techniques, the beginnings of experiments on speech translation and investigations of systems designed for non-translators.

The early 1980s saw the introduction of the first commercial systems. These were the ALPS and Weidner systems, both requiring considerable human assistance in order to produce reasonable output. They were rightly seen, and marketed, not as MT systems but as computer aids for translators. The ALPS system, which appeared on the market in 1983, has offered three levels of assistance to translators: multilingual word-processing facilities, automatic dictionary and terminology lookup packages, and an interactive translation program. ALPNET, as the company is now called, has expanded its operations by the acquisition of translation bureaux but it has also continued research on future computer aids. More successful on the market has been, however, the rival computer aided translation system from Weidner, later World Communications Center. This has appeared in two forms for DEC MicroVAX machines (MacroCAT) and for IBM PC/XT microcomputers (MicroCAT). Since it first appeared in the United States in 1981, there have been many language pairs offered on the market. Success continued worldwide after acquisition by Bravis, a Japanese translation company, but within the last year the company has closed trading and the future is now uncertain, although there are reports of former members of WCC setting up an independent company to continue development of systems.

In the course of the 1980s a number of other computer aided translation systems have appeared on the market in Japan. Most are systems for translating between English and Japanese; most are, like ALPS and WCC, low-level direct or transfer systems which limit analysis to morphological and syntactic information and restrict transfer operations to syntactic restructuring, with little or no attempts at lexical disambiguation. Such systems comprise essentially bilingual dictionaries, often restricted to particular subject fields, and they rely on substantial human assistance, often at both the preparatory (pre-editing) stage and the revision (post-editing) stage. Examples are Oki's PENSEE, Mitsubishi's MELTRAN, and Sanyo's SWP-7800 'Translation Word Processor', all Japanese-English systems, and Fujitsu's ATLAS/I and Sharp's DUET for English-Japanese. The considerable amount of pre-editing for Japanese texts is apparently acceptable to most Japanese operators who are accustomed to similar demands when using Japanese word processors with no translation envisaged - which means, of course, that users must know Japanese well to get any results. Like ALPS and WCC they are effectively enhanced multilingual word processors, a fact acknowledged explicitly by Sanyo.

Elsewhere in recent years there have appeared similar systems: the TWP system from Globalink (Fairfax, Virginia) for English into Spanish and other target languages running on IBM PC-compatibles; the various packages for English, French, Spanish, Swedish and Danish, from Linguistic Products (Houston, Texas), also running on IBM microcomputers; the Tovna system for English-French and later other languages; and the TRANSTAR system for English-Chinese translation from the People's Republic of China.

There is no reason to suppose that similar systems will not continue to appear in the next decade, on ever more powerful microcomputers. They are based on well-tested and familiar computational techniques of linguistic analysis, on familiar dictionary lookup and text processing facilities, and there is clearly a wide market for such products - in both the translation profession

itself and the larger, still untapped, market of non-translators. Nevertheless, as the WCC/Bravis example demonstrates, there are commercial risks.

However, not all systems on the market are as 'crude' in linguistic terms as these. A number of the Japanese systems, for example, are based on more sophisticated transfer and interlingua designs. Typically, analysis of Japanese is based on a case grammar approach - which is more appropriate for Japanese than the phrase structure analyses which have previously been widely used for English and some other European languages. The systems have also used semantic features to a great extent, in some instances as primitives or universal features in an 'interlingual' manner. Examples of such Japanese transfer systems are the Fujitsu ATLAS/II system for Japanese-English translation (available since 1985 in Japan), the Hitachi Japanese-English system (since 1987 in Japan), and the Toshiba AS-TRANSAC English-Japanese system (also since 1987). An example based on an interlingua design is the NEC PIVOT system for bi-directional English and Japanese translation (since 1986).

Outside Japan, there have been other commercially marketed systems of greater sophistication than ALPS and WCC/Bravis. The earliest to appear was the Logos German-English system, first demonstrated in 1982; an English-German version came two years later. In design it is a mixture of the previous Logos 'direct translation' system for English-Vietnamese and later syntactic transfer and semantic feature approaches, and may be characterised as a 'hybrid' syntax-oriented transfer system. From the user's perspective it offers impressive facilities for dictionary upgrading and for text editing. Logos has sold almost exclusively within Germany, where it has had some measure of success. However, recently the Logos Company has been looking for future outlets; it is currently exploring the development of an English-French system for the Canadian Translation Bureau.

Within the last year, the METAL system has reached the market. Two language pairs are being offered: German-English and English-German. The system is based on the advanced research undertaken for many years at the University of Texas at Austin and since 1978 supported by the Siemens Company of Munich, West Germany, where some of the developmental work has also been done. METAL is perhaps the most sophisticated transfer system at present on the market, with AI components written in Lisp and running on a Symbolics machine. As with other commercial systems, facilities for translation revision (post-editing) and dictionary construction and updating are prominent features of the METAL package. Research and development is proceeding at present on other language pairs combining English and German with Spanish, French and Dutch, and involving teams in Barcelona (Spain) and Leuven (Belgium).

All these commercial systems, however 'advanced', generally require a considerable initial commitment by purchasers to adapt programs and dictionaries to local needs. In many cases this process of adaptation is undertaken by the vendor in collaboration with purchasers. In this sense, nearly all MT installations are tailored to particular environments, they are in effect 'in-house' systems which could not, without further adaptation, be transferred to another operational context.

The 1980s have seen the appearance of systems which have been explicitly designed for one particular situation. The Pan American Health Organization (PAHO) in Washington has developed two such systems in-house for medical and public health literature: SPANAM for Spanish-English translation (1980) and ENGSPAN for English-Spanish translation (1985). In both cases, the systems have been based on well-tested computational and linguistic techniques and have been developed by just two researchers: SPANAM was based originally on an essentially 'direct' approach but is now being revised in the light of experience with ENGSPAN which was from the beginning a syntactic transfer system making excellent use of an ATN parser. The quality of the

output is high, and the production of translations is expedited by text editing facilities designed specifically for translators. The PAHO systems show how much can be achieved without excessive expenditure, as long as known limitations are acceptable. It is surprising that other corporations have not followed the PAHO example.

The best known 'in-house' development is, of course, that of Systran in the Commission of the European Communities. Since 1976, when the English-French version was acquired, the translation service of the Commission has collaborated with the original designers (and the later owners Gachot) in the enhancement and development of Systran systems for many other language pairs: English into Italian, German, Dutch, Spanish and Portuguese, French into English, German, Dutch, German into English and French; and no doubt more in the future. A major effort - as in all such cases - is the enlargement and refinement of the dictionaries, upon which so much of the final quality of the output depends. Although intended for translations within the Commission, the systems have been adapted and used in other contexts: the French company Aerospatiale, the German Nuclear Research Center, and most strikingly, they have been made available on the French Minitel network. Various Systran versions have been developed by and for other users: the USAF is a long-standing user and developer of a very large Russian-English system, General Motors of Canada has an English-French system, and in Japan there are a number of large users of the English-Japanese system developed by the now independent Systran Corporation of Japan. One of the best known installations is at Xerox where since 1978 technical manuals written in a controlled English are translated into five languages: French, German, Spanish, Italian and Portuguese. Texts are written in a style and vocabulary which it is known the computer program can tackle with little or no need for external assistance or subsequent revision. The advantages of multilingual output justify the costs of preparing computer-acceptable input. There have been surprisingly few following Xerox's examples, although recently there has been a proposal for a controlled 'Small Japanese' for MT.

The use of controlled input to reduce problems of disambiguation and selection of target language equivalents has been the distinctive feature of another most successful MT company. The Smart Corporation has produced tailor-made systems for Citicorp, Chase, Ford, and largest of all (since 1982) the Canadian Ministry of Employment and Immigration. Smart provides a text editor for ensuring the writing of clear technical texts in English within a controlled grammar and lexicon - designed specifically for the client - and a translation system, which has been implemented to translate from English into French, Spanish, Portuguese and Italian. The aim is not perfect translation; post-editing of the output is accepted as necessary. European examples of Smart systems are expected within the next few years.

An earlier tailor-made restricted language system was, of course, METEO designed by the Montreal MT group TAUM in the mid-1970s for translating weather reports from English into French. Installed in 1976, METEO is still operating successfully. The other TAUM project (AVIATION) for the translation of a corpus of aircraft manuals into French proved ultimately a failure and led directly to the termination of the TAUM project in 1981. Subsequent single-corpus projects have been rare in the 1980s. One was undertaken at the Johns Hopkins University to translate a German medical textbook into English. Another has been the translation of Biblical texts into South American languages - not, however, from English but from one South American language into another closely related one. Just as more PAHO-type developments might have been expected, so might have been more Xerox-type (controlled language) and METEO-type (sublanguage) systems. Advances in computational linguistics and in artificial intelligence in the future may lead to more 'in-house' systems in the next decade.

The primary aim of MT research is to develop techniques for the production of translations superior in quality to those produced by existing systems. By the late 1970s it had become generally accepted that the best prospects for improvement of MT quality lay in the development of advanced 'transfer' systems. It was also widely assumed that artificial intelligence (AI) could as yet contribute little in the construction of large-scale MT systems.

Such thinking underlay the decision of the European Community to support research for a multi-national multi-lingual system based on latest advances in computational linguistics. This was the Eurotra project, initially planned in 1978 and begun in 1982, which involved teams of researchers in each member nation of the Community. It has undoubtedly been the most ambitious project of the 1980s. Its general design owed much to the most advanced transfer systems of the time, the GETA-Ariane and the SUSY systems. All three are linguistics-based modular transfer systems intended for multilingual translation producing good quality but not perfect output. None make direct use of AI techniques, such as extra-linguistic knowledge bases and inference mechanisms; and none call upon human assistance during translation processes.

The GETA team has continued through the 1980s to pioneer many innovations in design structure: the attention to discourse features, the distinction between static and dynamic grammars, the development of software tools for linguists. It has continued to encourage other projects using GETA software, to train MT researchers, and to support MT research on an impressive variety of languages: Russian, French, German, Thai, Malay, Portuguese, Chinese, Japanese. GETA has often been criticised for failure to deliver an operational system. Its major problem has been and remains the lack of resources to build the substantial dictionaries which would be required. A major concern in the 1980s has been to demonstrate the practicality of the system. There was some hope that its Calliope project during the mid-1980s - in the French national computer-assisted translation project - might achieve this goal. Although ultimately no working system emerged from Calliope there were valuable extensive tests of the Ariane system which have led to further improvements in what is undoubtedly still one of the most important experimental MT systems.

The Saarbrücken team has almost an equally long record of achievement. During the 1980s the project has, like GETA, sought to show the practical application of the SUSY system. One was a collaborative project with the Kyoto University TITRAN system for German and Japanese translation of document titles; another was the SUSANNAH project to develop a prototype translator's workstation. Together these have led to the MARIS project and to the establishment of STS, the Saarbrücker Translations-Service which provides SUSY translations for a number of German information centres. Developments of SUSY itself have mainly resulted from the addition of English as a source language. However, the team has been involved in other projects. In the ASCOF project for French-German translation it has investigated newer parsing methods and the use of semantic networks for disambiguation. In the SEMSYN project it has produced a knowledge-based German text generation program which links to the semantic interfaces produced by the Fujitsu ATLAS/II system.

Eurotra itself shares much of the GETA and Saarbrücken philosophy. Its transfer design with multilevel interfaces of a high degree of generality, combining lexical, logico-syntactic and semantic information, has inspired innovative theoretical linguistic and computational-linguistic research, particularly in the Netherlands, Belgium, Denmark, Germany and Great Britain. These researchers have advanced substantially the theoretical foundations of MT and have contributed in general to syntactic theory (e.g. LFG and GPSG), formal parsing theory, discourse analysis. One of the aims of the Eurotra project was to stimulate such research, and in this it has succeeded. However, it has not yet produced a satisfactory working prototype. A major defect, readily

conceded by those involved, has been the neglect of the lexicon; indeed critics argue it is an ultimately fatal flaw. In addition Eurotra is basically a batch system with post-editing, and unable to incorporate interactive facilities. While at the end of the 1970s, Eurotra was seen as representing the best 'linguistics- based' design, at the end of the 1980s it is seen by some as basically obsolete in conception and objective.

Other influential advanced transfer systems of the 1980s have been the METAL system already mentioned and the Mu project at Kyoto University. This project (1982-) has pioneered many of the features now found in most Japanese systems, both commercial and experimental: dependency grammar, case relations, semantic features, etc. These are the commercial transfer systems mentioned earlier. The second phase of the Mu project began in 1986 with the intention of transforming the research prototype into practical system for Japanese and English. This is taking place at Tokyo University, the Japanese Information Center of Science and Technology and elsewhere.

Possibly least expected by any MT forecasts in 1979 would have been the revival during the 1980s of interlingua systems. It would have been accepted that interlingual components would feature in advanced MT systems of the transfer type which aimed for high quality output and it would have been accepted that AI-inspired experimental systems would be based on interlingual representations of some kind. But what would not have been widely anticipated would have been interlingua approaches in essentially linguistics-based systems. At the present time there are two such interlingua systems under development in the Netherlands: the DLT (Distributed Language Translation) project at the BSO company in Utrecht, and the Rosetta project at the Philips electronics company in Eindhoven. The two differ widely in both design and in objectives.

The six-year DLT project began in 1985 (after a feasibility study 1982-85) supported by the BSO computer software company and a Netherlands ministry. DLT is designed as a multilingual interactive system operating over computer networks, where each terminal acts as a translating machine from and into one language only; texts are transmitted between terminals in an intermediary language. As its interlingua, DLT has made what was for many a surprising choice: Esperanto. Monolingual analysis is restricted primarily to morphological and syntactic features (formalised in a dependency grammar), i.e. the establishment of potential parses of sentences of source texts and the identification of potential ambiguities. There is no semantic analysis of the input. Disambiguation takes place in the central interlingua component, where semantico-lexical knowledge is represented in an Esperanto database. The 'word expert' system SWESIL utilizes linguistic and extra-linguistic information to compute probability scores for pairs of dependency-linked interlingual words. A significant effort has been made to confront the major impediment to good translation: large, well-constructed lexical databases. A recent suggestion is the building of a Bilingual Knowledge Bank from a corpus of (human) translated texts in the two languages of the prototype system, English and French. After initial scepticism, the DLT project is now seen as one of the most innovative of the present time.

In another respect the Rosetta project at Philips is equally innovative. This experimental system, involving three languages (English, Dutch and Spanish), has opted to explore the use of Montague grammar in interlingual representations. A fundamental feature is the derivation of semantic representations from the syntactic structure of expressions, following the principle of compositionality, i.e. that the meaning of an expression is a function of the meaning of its parts. For each syntactic derivation tree there is a corresponding semantic derivation tree; and these semantic derivation trees are used as interlingual representations. The task of the project is to attune the grammar rules for each of the languages so that they produce derivation trees which represent

equivalent semantic operations. Whatever the ultimate success of Rosetta, it will have explored and tested a conception of grammatical formalism which is currently attractive to many researchers in the fields of MT and of computational linguistics in general.

For many observers of MT development it has appeared that the most likely source of techniques for improving MT quality is the research on natural language processing within the context of Artificial Intelligence (AI). The involvement of AI researchers in MT-related projects began in the mid-1970s with Wilks' work at Stanford University on 'preference semantics' and the 'semantic template' approach, and with the research of Schank and his colleagues at Yale University on 'conceptual dependency' representations, 'scripts' and 'schemata'.

The 1980s have seen continued and increasing activity in research on AI approaches to translation. A major centre has been established in the United States at Carnegie-Mellon University, where work continues on a knowledge-based interlingual MT system begun initially at Colgate University in 1983. This research builds upon the substantial expertise at Carnegie-Mellon on natural language processing in AI and on speech recognition and parsing systems. Particular attention has been paid to the structure of the interlingua representations and of the knowledge bank, to interactive dialogue for MT systems, to speech translation and to problems of text generation. Given the high level of AI research in North America it is not surprising that many other experimental projects are concerned with aspects of MT, e.g. at the universities of California, New York, New Mexico, Texas, British Columbia, Montreal, Toronto, etc. There is also growing interest in the commercial sphere: the LMT (Logic-programming-based Machine Translation) project at IBM, and the Martin Marietta Corporation collaboration with the Korean Advanced Institute of Science and Technology on an interlingual English-Korean system which adapts the EQUAL database interface system to produce representations from which Korean text can be generated.

In Europe, interest in AI work directly or indirectly related to MT is also growing. The Eurotra project itself has stimulated research, in particular the CAT2 project based at Saarbrücken and the NASEV projects at Stuttgart, Berlin and Bielefeld. As in the United States small-scale projects have multiplied, and there is non-academic research also, e.g. at Cap Sogeti Innovation in France. Japanese AI research of relevance is perhaps even greater; certainly the MT implications are often clearer. Notable examples are the LUTE project at NTT (Nippon Telegraph and Telephone) which began in 1981, a knowledge-based system for bi-directional English and Japanese translation; the LAMB system at Canon; and the research at the Electrotechnical Laboratory (ETL) on an ambitious Japanese-English translation system, where texts will be 'understood' using information from a concept dictionary and interface representations will be language-independent and paragraph-based.

This ETL research is linked to the Japanese CICC (Center of the International Cooperation for Computerization) project for the construction of a multilingual interlingua-based system for translation between Japanese and other Asian languages: Malay, Thai, Indonesian and Chinese. As with Eurotra, this nine-year project (1987-) has also political and technological aims: the encouragement of computer technology in the expanding markets of the Pacific region. Still in its early planning stages, the CICC project will be followed in the 1990s with as much interest as Eurotra has been in the last decade.

The basic justification for AI approaches is the argument that since translation is concerned primarily with conveying the content or 'meaning' of a text in one language into a text in another language any MT system must be able to 'understand' the meanings of texts. Without understanding, it is argued, no system can be expected to be able to decide which of possible target

language expressions correspond most closely to the meaning of the original text. AI research claims to tackle this problem directly and is thus seen as likely to improve the quality of MT output.

However, it raises a general problem, which is bound to be more widely discussed and debated in the 1990s, namely the role of ‘understanding’ in translation. There is both a theoretical question and a practical one. The theoretical question centres on whether human translators do or do not need to fully understand what they are translating. Often it seems that they do not: when translating a scientific text at the forward edge of research it is unreasonable to expect a translator to understand as much as the scientists involved in the research itself. The basic requirement is to know 'enough' to cope with the terminology and general context. The practical question concerns how much a MT system can be based on linguistic information and how much on extra-linguistic data. The former is necessary in any case in order to analyse and generate texts, it is implicitly incorporated in the lexical and grammatical information of systems, and includes sublanguage information specific to the subjects of texts. It is the prerequisite for any understanding of text. Extra-linguistic knowledge is that which is or might be brought to bear in interpretation and disambiguation when linguistic knowledge is insufficient. It can be of two kinds: knowledge of the general and subject-specific 'background' of the text, and knowledge acquired in the course of reading and understanding the text itself, i.e. dynamically acquired knowledge. However, the boundaries of these different kinds of knowledge are very fluid: what has been dynamically learned from one text may be applied as background knowledge in reading another, and sublanguage knowledge is inextricably bound up with subject expertise.

The specific question is how far MT systems should go in the direction of programs for Natural Language Understanding (NLU) which have been developed in artificial intelligence. In general NLU programs have been designed for one particular language and for specific domains and purposes (e.g. data retrieval, paraphrasing), and are concerned above all with the content of texts and not the specific linguistic (discourse) framework in which the content is conveyed; once the 'message' has been extracted, the linguistic 'form' can be disregarded. But MT cannot ignore the 'surface' discourse form. The sequence and manner in which the content is presented must be retained, and fundamental differences between the lexical and semantic structures of languages cannot be ignored. While much scientific terminology can be standardised across languages, there is a basic body of non-scientific vocabulary and linguistic knowledge occurring in all texts which can only be defined language- specifically; thus, although some knowledge and text understanding is language-independent (universal), much is specific to particular languages.

Furthermore, the ultimate success of AI methods is still very difficult to assess. Experimental systems are necessarily on relatively small scales and are almost inevitably restricted to small corpora and limited domains. The latter restriction is not necessarily significant since many MT systems on the market are designed for specific subject fields and sublanguages, and many experimental MT projects designed on more ‘traditional’ computational linguistics approaches are equally restricted. However, the small-scale nature of NLU projects is pertinent: past experience in MT is not encouraging, many successful experiments did not fulfil their promise when expanded to large-scale systems.

For such reasons many MT researchers believe that MT systems should build upon well-founded and well-tested 'linguistics'-oriented approaches, with extra-linguistic knowledge bases as additional components alongside morphological, lexical, syntactic, semantic and text-grammatical information. The assumption through most of the 1980s was that this should be the advanced transfer model as exemplified by the GETA, SUSY, METAL, Mu and Eurotra systems. Many

Japanese projects have in fact taken this line; they and others embodying AI features have already been mentioned. In the 1990s other models are also likely: DLT points to one alternative - an interactive interlingua approach with a knowledge-based disambiguation mechanism.

Although the tendency for AI-base systems to produce 'paraphrases' rather than 'translations' may restrict the full implementation of AI methods in practical MT systems of the traditional kind, i.e. where the output text (whether post-edited or not) should correspond reasonably closely to the original text in both form and content, there are undoubtedly many situations where paraphrase is quite acceptable. The most obvious examples are those of conventional business correspondence, hotel reservations, etc. Three projects, at Carnegie-Mellon, at UMIST (NTRAN) and most recently at Grenoble (LIDIA), have indicated the possibilities: senders of messages would be interactively prompted to compose texts in forms which the system could 'understand' and then reformulate according to the linguistic and cultural conventions of the recipient. It is a development which could probably not have been foreseen in the late 1970s, as it arises from recent progress in expert systems, data retrieval, dialogue systems, text editing and composition aids (e.g. the Smart 'expert editor' and IBM's CRITIQUE program). The possibility of 'paraphrase translation' systems for non-translators will certainly be pursued in the 1990s, probably in a variety of models. There is a large latent market which will surely not be ignored.

It is unlikely that in the late 1970s anyone would have predicted a revival of statistical approaches to MT. There has obviously always been a place for statistical methods in data collection for MT system construction; and for the application of statistical information during disambiguation and target language selection processes. The DLT project and a number of Soviet MT systems, e.g. AMPAR and NERPA (now united in ANRAP) and SILOD, have made significant use of statistical information. What would not have been expected is the exclusive use of statistical techniques for translation. At the IBM Research Center (Yorktown Heights, N.Y.) a project has begun within the last two years to construct an English-French system based on lexical and grammatical equivalences derived from statistical analyses of large text corpora.

The inspiration for the approach has been the success of automatic speech recognition systems based on statistical methods. The last years of the 1980s have in fact witnessed the establishment of a number of projects devoted to research towards telephony translation. The British Telecom (BT) project in Great Britain is designed to match the caller's spoken input against a highly restricted set of phrases used in standard business communication, to check with the speaker that the one selected conveys the intended message, and to translate it into an equivalent in another language for oral generation at the recipient's telephone. A much more ambitious project has begun in Japan without the BT restrictions. This is the research at ATR in Osaka and Kyoto on an 'automatic translation telephone', based on previous MT research at NTT and current research on knowledge-based dialogue and natural language understanding. It is long-term project with no operational prototype expected for 15 years. In the meantime, however, we can expect more developments on the lines of the Automatic Translation Typing Phone of Toshiba, the Systran service on the Minitel network and the recent Fujitsu ATLAS-MAIL for a networked translation service.

Automatic speech translation is one example of the integration of MT and telecommunications. Another example which will undoubtedly feature in the 1990s is the link with information retrieval systems. The possibilities have already been demonstrated by Sigurdson and Greatrex at Lund, and by the Japan-Info project of the European Community which provides on-demand translations of Japanese abstracts retrieved from the Japan Information Centre for Science and Technology database (the translations are produced by Systran Japan and the Fujitsu ATLAS systems). Full integration of MT and IR is the next step. A related but more distant prospect must be to combine

translation and summarization. The idea of producing summaries of foreign language documents is certainly more attractive to administrators, businessmen and scientists than rough translations of full texts. There have been small-scale experiments on summarization in restricted domains, but it is already apparent that the complexities of the task are at least equal to those of MT itself.

More immediately desired by translators, translation agencies and any other potential users of translation systems must be fully-compatible integration of MT and computer-aided systems with automated office systems, local communication networks, optical character readers, publishing systems, etc. Hardware incompatibilities often seem to exacerbate the problems of integration; greater efforts towards global standards and protocols are essential if translation systems are to serve the translation profession - and even more so, if they are to be accessible to the general public.

In this regard the availability of Systran on the French Minitel network is a pointer to what may become commonplace in the next century if not earlier. Probably the greatest expansion of MT services in the coming decade will be the provision of unedited translations for those with some knowledge of the subject content and prepared to overlook grammatical and stylistic inadequacies. These are translations which would not have been done at all without MT, and in this respect MT will be fulfilling urgent needs. But such public accessibility has its dangers. The limitations of MT systems may not be appreciated by those who are ignorant of translation or of source languages. As long as MT systems are bought and operated by translators, translation bureaux and by companies with experience of translation, the recipients of unrevised MT output will be or should be alerted to the limitations of unrevised MT output. However, as MT systems become more widely used by non-professional translators there is the more general danger that users and recipients will adapt to poor quality, particularly that of the cheaper commercial microcomputer-based systems, and if the sales are adequate there may be little incentive for vendors to improve quality.

With the increasing variety of systems and the widening range of possible modes of interaction and integration, it is imperative that every MT researcher and developer should have clearly defined objectives. In the past, and still too often today, much MT research has been undertaken with no clear idea of who might use the system and in what way. There is still a remarkable reluctance to discover or identify the real needs of potential recipients of translations. Do they want high-quality translations, when and in what circumstances? Do they want rough translations for information purposes only (where raw MT output may suffice)? Do they want lightly post-edited versions, as the European Community has discovered with some recipients of Systran translations? Or do they want to revise translations themselves? and if so, do they want to revise on-line or not? Such different needs and purposes indicate different system configurations and different levels of complexity in linguistic and computational processing.

During the 1980s the earlier antagonism of translators towards MT has decreased. Whereas once MT systems were seen as direct threats to their livelihood, unless they were prepared to become post-editors, they have recognised the genuine advantages to their own translation productivity and standards resulting from computer-based aids. Machine aids for glossary construction, word processing software for non-Roman scripts telecommunication links for document transmission and for accessing remote term banks -all developments of the 1980s - have revolutionised the ways in which many translators now work. They have recognised that MT has not replaced them, that they can work with MT systems, and that there will always be a need for good quality translation which cannot be satisfied by computer translation. Nevertheless, it is unclear what they require for the actual processes of translation itself. Translator's workstations have been much discussed, and the integration of the various translation aids is probably desirable - Melby’s three level design appears

broadly acceptable. However, it is unclear whether the kinds of interactive systems presently available are what they would really like. Certainly translators want to see improvements in the quality of MT output - although what this often means is the elimination of those irritating grammatical mistakes, wrong pronouns, misplaced or omitted articles, inappropriate use of tenses and modals, etc. which MT systems find so difficult to deal with. The more immediate questions concern what kind of semi-translated output they would like to work on, whether pre-editing is acceptable and how much post-editing can be tolerated.

Until the late 1970s most MT research activity was undertaken in academic environments with relatively little regard for immediate or even long-term potential applications. During the 1980s there has been a remarkable shift: some research, particularly on advanced AI systems, is still based in universities and institutes, but most is now undertaken by independent companies mainly in the electronics and computer business for short- or long-term commercial interests. This has had an impact not only on the pace of development but also on the range of languages covered. For the first two decades of the history of MT, systems were developed primarily for the use of scientists to keep abreast of technological activity. Research concentrated on translation from Russian, or - in the case of Soviet MT research - from English. In the 1970s systems were designed for the pressing needs of bilingual Canada and the multilingual European Community. In the 1980s the demand has been for systems covering the major commercial languages of the world: English, French, German, Spanish, and Japanese, to which have been added in recent years Arabic, Chinese and Korean.

One of the major motivations for MT research has always been to improve the communication of ideas and knowledge across language barriers. There is urgent need for translation of scientific, technical, engineering, agricultural, economic documents, textbooks, and manuals, etc. from the 'major' languages of the developed world into the languages of the underdeveloped countries. Yet these languages have been relatively neglected in MT research. There are exceptions: the GETA group has been active, and among the principal objectives of the multinational Eurotra and CICC projects is the stimulation of research on some of these neglected languages. Before Eurotra Danish, Greek and Portuguese had previously been ignored; and the CICC project is to bring MT to Malay, Indonesian and Thai. However, major languages of Africa, India and Southeast Asia (with the short-lived exception of Vietnamese) have never been the subject of MT research; it is to be hoped this situation will improve in the 1990s. MT research should above all be international.

Collaboration between MT groups across national and linguistic boundaries ought to be the natural mode of operation in the field of machine translation. Yet until the late 1970s it was relatively rare. This has changed in the last decade. International cooperation in MT research has grown substantially. The most prominent example has been the Eurotra project, now being followed by the Japanese CICC project. However there have been many other examples: the continuing Systran and European Community collaboration, the various GETA projects, the support by Siemens of the Texas METAL project and the involvement of Belgian and Spanish groups in development; the collaboration between Fujitsu and the Saarbrücken group, and between a number of Japanese and Korean groups, e.g. Fujitsu, NEC and the Korean Advanced Institute of Science and Technology; the collaboration between the Martin Marietta Corporation and the same Korean institute, and the new IBM initiative involving Israel, Finland and Spain.

Cooperation would also seem desirable for the continuing major requirement of all MT systems: the need for comprehensive, consistent MT dictionaries. The Japanese are demonstrating what might be achieved in the establishment of the Electronic Dictionary Research Institute in 1986, with support from government agencies and from companies engaged in MT research. The aim is to develop two types of dictionaries for MT (primarily for the interlingual CICC project), for

information retrieval and for speech recognition systems: word dictionaries and concept dictionaries for 'basic' vocabulary and for information technology in Japanese and English. A similar European project would be a worthy objective for the 1990s.

With the variety and wealth of activity which this survey has outlined it is difficult to summarize the changes during the last decade. Major features would have to include: the shift from large-scale batch systems to microcomputer-based interactive systems, the impact of artificial intelligence, the development of controlled language and of sublanguage systems, the revival of interlingua and statistical approaches, the commercialisation of MT development, the growing internationalisation of MT activity, and above all the emergence of Japanese systems on a field previously dominated by American and European systems. The rapid growth of MT in the last decade and particularly in the last five years (Hutchins 1988) means that there are almost certainly more researchers and developers active in the field than there were at the height of the 1960s before the ALPAC report appeared. The question which is frequently asked is whether there will be another 'ALPAC' in the 1990s. It would seem most unlikely. A 'failure' of the Eurotra project might prompt an investigation, but any impact would probably be restricted to academic research in Europe, and perhaps in the United States. On commercial development the effects would be minimal. The market for MT has now been established; there is scope for expansion of existing types of systems for translators and translation services and there must be scope for new products designed for the latent market of systems for non-translators. The demand for translation is growing at a pace well beyond the capacity of the translation profession. The need for MT and computer aids is indisputable, and yet it still accounts for less than 2% of all translation in the world. In these circumstances the future of MT is secure. Machine translation is no longer a slightly suspect academic pursuit (as it was until the mid-1970s), it has established itself as an important branch of applied science (computational linguistics and artificial intelligence) and as a technology-based industry of international dimensions.

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