Machine Translation, Ten Years On: Discourse has yet to make a breakthrough

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Abstract

Progress in Machine Translation (MT) during the last ten years has been observed at different levels, but discourse has yet to make a breakthrough. MT research and development has concentrated so far mostly on sentence translation (discourse analysis being a very complicated task) and the successful operation of most of the working MT systems does not usually go beyond the sentence level.

To start with, the paper will refer to the MT research and development in the last ten years at the IAI in Saarbrücken.

Next, the MT discourse issues will be discussed both from the point of view of source language analysis and target text generation, and on the basis of the preliminary results of an ongoing "discourse-oriented MT" project .

Probably the most important aspect in successfully analysing multisentential source texts is the capacity to establish the anaphoric references to preceding discourse entities. The paper will discuss the problem of anaphora resolution from the perspective of MT. A new integrated model for anaphora resolution, developed for the needs of MT, will be also outlined.

As already mentioned, most machine translation systems perform translation sentence by sentence. But even in the case of paragraph translation, the discourse structure of the target text tends to be identical to that of the source text. However, the sublanguage discourse structures may differ across the different languages, and thus a translated text which assumes the same discourse structure as the source text may sound unnatural and perhaps disguise the true intent of the writer. Finally, the paper will outline a new approach for generating discourse structures, appropriate to the target sublanguage and will discuss some of the complicated problems encountered.

1 Machine translation ten years on - Work carried out at the IAI

Ten years ago was not only the date of the first Cranfield conference on MT, but also the date of the foundation of the IAI (Institut der Gesellschaft zur Förderung der Angewandten Informationsforschung an der Universität des Saarlandes), today one of the leading research institutions in MT and other multilingual language processing in Europe. Its first and main activity was the German part of the long debated EUROTRA project of the Commission of the European Union (CEU), which lasted in its concerted form until the end of 1992.

Taking over the long tradition of the University in Saarbrücken in "electronic language research" (realised by the SFB 100 and maintained today by many other specialised institutions in Saarbrücken), the Institute is carrying out today a number of application-oriented projects sponsored by the LRE and MLAP programmes of the CEU, German ministries and by private industry. Among them, there are projects using the most advanced techniques in NLP such as typed feature structures (eg. ALEP, the Advanced Language Engineering Platform), and others using the well tested CAT2 prototype for industrial validations.

CAT2 is a machine translation system embodying a unification-based formalism, similar to PATR-II, and software for the development of grammars, lexicons, and translation modules. It has been developed at IAI, as a sideline implementation to the Eurotra Machine Translation Project. Since 1987 it has been used in universities as a teaching device and for the definition and processing of language analysis, synthesis and translation. During this time, it has been used experimentally on languages as diverse as English, German, French, Spanish, Portuguese, Italian, Dutch, Greek, Russian, Bulgarian, Korean and Japanese, and for morphological description in Hungarian.

The translation mechanism is based on tree-to-tree transduction. A set of translation relations, called t-rules, describe how partial trees are transformed into partial trees. During transduction, a source tree is recursively transformed into a target tree, i.e. explicitly marked subtrees of a source tree are transformed into target subtrees, and each of these subtrees may include subtrees which are also recursively transformed. In this way, a constituent structure is transformed during analysis into a more abstract representation, called the interface structure; this structure may serve as a logical form, as an interface to a database query system, or as a form suitable for language translation. Similarly, t-rules transform the interface structure into a constituent structure during synthesis (i.e. generation). Language translation is defined as a transformation from the interface structure of a source language to the interface structure of the target language. Once again, unification (generalised as constraint resolution) is used to describe and process the transduction.

As a software development tool for language processing, the CAT2 system offers the usual functionality. Written entirely in SICStus Prolog, it has facilities for compiling grammars, creating and deleting linguistic objects, displaying, comparing, saving and restoring objects, and inputting source text and outputting (translated) target texts. It includes tracing and debugging facilities, and the rule compiler performs extensive syntactic and semantic checking.

Since mid-1992, a pilot application project has been realised in which an industrial partner asked for new facilities to be added. Firstly, a full German morphological component was introduced; this component works on the basis of about 9,000 morphemes and is able to analyse up to 90% of current vocabulary correctly. Secondly, the system was modified to process unknown words (as all commercial systems do), making heuristic decisions about their morphological and syntactic properties and transferring them into the target sentence. Thirdly, an on-line "quick update" option was introduced which allows the user to interactively code unknown words and their translations in a shortened form, which is then valid for the entire session. A list of these codings automatically goes back to the development centre to be fully completed and integrated into the next system release. Fourthly, a fail-safe component has been added, which produces translations even in cases where the unification-based analysis fails; in the worst case (no analysis at all), the system produces a word-for-word translation showing all equivalencies of each source word in the target language. If a partial analysis succeeds, many of the possible translations are thereby disambiguated, so that only the semantically well-founded equivalencies are presented.

Being linguistically based, the system always produces the "best possible" translations, that is, it is not possible to generate the wrong word order or only one translation which is completely wrong. The claim is that the resulting methodology is more interesting for potential users than currently available systems because there is a greater chance of understandability.

The industrial system has been developed for a dictionary of about 3,000 entries (mainly in data processing) in the language pair German-English; for other language pairs (e.g. French-German/French-English), experimental versions are available. The system accepts free input, especially in the German-English source pair. It is an attempt to push a unification-based system in the direction of practical applications.

Other good examples of this development are small projects with Logos (MT evaluation for certain language pairs), the Danish software company WINGER (development of a small German-Danish PC-based MT system), the Italian Social Security Insurance (syntax checker), and in particular the Commission-founded projects with EDS (MT of email messages) and with RAMIT VZW, the University Hospital Gent in Belgium (ANTHEM, a multilingual environment for medical diagnoses).

The ANTHEM workplan, to be carried out by six partners over a period of 2.5 years, includes:

- The collation, structuring and tagging of corpora of the sublanguage of medical diagnosis.

- The modelling of this medical sublanguage using the Interface Structure (IS) of the CAT2-formalism, developed during EUROTRA.

- The representation of ICD expressions using some form of typed feature logic which by means of the inheritance mechanism will support a hierarchical classification of terms.

- The creation of a machine interpretable and processable terminological collection of medical terms in a format which also makes it accessible for other applications.

- The creation and integration in existing HIS of software modules able to analyse the sublanguage input and to create an abstract semantic representation (IS), to translate this input into Dutch, French, and German, and to generate the relevant ICD-9/10-CM codes starting from the IS level.

- Setting up a pilot study to test the ANTHEM-interface in a real world environment and to enhance it before final delivery.

The IAI contributes with the components of the CAT2 system; work will be carried out on German, French, English and Dutch.

This project may be the most concrete and product-directed of all current IAI activities; it addresses a relatively small domain, a fact which was always considered to be a guarantee for the success of NLP applications.

There may well be a successor on a larger scale (more medical applications, additional languages etc.) in the 4th Research Framework Programme for Telematics, organised by the Commission for the years 1994 - 1998; but the linguistic heart of the whole system will continue to beat here at the IAI.

On the other hand, the IAI has also made room for activities directed more towards basic research problems. Among others, a project was carried out which studied the implication of knowledge-based translation, the interaction between terminological ontologies and MT. Currently the IAI is also involved in the somewhat futuristic (German) VERBMOBIL project aiming at machine interpretation of spoken dialogues. This kind of work is normally done in co-operation with the Department of Computational linguistics of the University of Saarland or the German Research Institute for Artificial Intelligence as well as in the framework of invitations for guest scientists coming from other renowned institutions all over the world. One of the projects conducted now by a guest scientist at IAI concentrates on studying the feasibility of "discourse-oriented" MT, i.e.

MT which goes beyond sentence level. The preliminary results of the project are described in the following sections of the paper.

2 Machine translation: The urgent need for understanding more than a single sentence

The majority of existing MT systems can translate only single sentences. Once they have an input of two consecutive sentences, the result is often disappointing. In most of the cases the second sentence is translated as a completely isolated piece of information, without taking into consideration its preceding text.

CAT2 successfully translates many input sentences ([Mesli 94]), but may produce awkward translations when attempting to handle more than one sentence. For instance the system correctly translates the German sentence "Der Chef gibt seinem Mitarbeiter einen Computer" as "The supervisor is giving a computer to his employee" ([Mesli 94]). But it would have difficulties in translating the text "Der Chef gibt seinem Mitarbeiter einen Computer. Er funktioniert sehr gut " (the second sentence means "It functions very well") since the default translation of "er" would be "he".

High quality MT presupposes understanding of the source text which itself involves discourse processing. One of the important prerequisites for understanding the source text is the ability to disambiguate pronouns, i.e. pronominal anaphora resolution.

3 Anaphora resolution in MT

Everyone agrees that anaphora resolution is a complicated problem in natural language processing. Considerable research has been done by computational linguists ([Carbonel & Brown 88], [Dahl & Ball 90], [Frederking & Gehrke 87], [Hayes 81], [Hobbs 78], [Ingria & Stallard 89], [Rich & LuperFoy 88], [Robert 89]), but no complete theory has emerged which offers a resolution procedure with guaranteed success. Even if we restrict our attention to pronominal anaphora most approaches developed from purely syntactic ones to highly semantic and pragmatic ones, only provide a partial treatment of the problem.

Though anaphora resolution has its specific aspects within the domain of Machine Translation (MT), there has not been much work reported from this point of view. Preuß, Schmitz, Hauenschild and Umbach [Preuß 94 et al] describe work on anaphora resolution in an English-to-German MT system, whereas Mitkov, Kim, Lee and Choi [Mitkov et al 94] report on an extension of an English-to-Korean MT system to meet the needs of resolving pronominal anaphora.

Besides ambiguity resolution, often seen as the most important problem in MT [Hutchins & Somers 92], another major difficulty is the resolution of anaphora.

The identification of a pronoun involves the identification of the earlier noun phrase to which it refers, called the pronoun's antecedent. The establishment of the antecedents of anaphora is very often of crucial importance for correct translation. When translating into a language which marks the gender of pronouns for example, it is essential to resolve the anaphoric relation. Furthermore, the translation of the predicates connected with the pronoun (verbs, nouns etc.) may change according to different antecedents.

Consider an MT system with English as a source language and consider translating the pronoun "it" from English into the target language. If the target language is French, Spanish or Italian, the pronominal anaphoric reference has to be resolved before we decide which of the two possible pronouns - masculine or feminine - to use. In German, Greek and Slavic languages we have one more gender choice - neuter.

In some languages the pronoun is translated directly by its referent. In English to Malay translation for instance, there is a tendency to replace 'it' with its referent. Replacing a pronominal anaphor with its referent means, however, that the translator (program) must be able to identify the referent first.

Anaphora resolution reflects two essential topics in Machine Translation: ambiguity in an MT context and translation of discourse instead of isolated sentences. Anaphora can be viewed as a sort of ambiguity, in that the antecedent of a given pronoun might be 'uncertain' and referential relations are one of the means that constitute coherence of texts.

Some views advocate "optionality" of anaphora resolution in MT, if possible: there are certain language pairs which offer a number of cases in which anaphora resolution does not seem compulsory. "Optional" anaphora resolution means preserving anaphoric ambiguity in case no anaphora resolution is undertaken. It may seem that carrying ambiguities over translation is even more "authentic" from the point of view of having a mirror translation of the source text. Not resolving anaphoric ambiguity means that during the translation process the text is not fully understood. Generally speaking, however, analysis is aimed at producing an unambiguous intermediate representation [Isabelle & Bourbeau 85].

Moreover, a system strongly relying on the "ambiguity preservation" method, in addition to offering no computational advantage when ambiguity-preserving situations must be identified dynamically, is extremely vulnerable in situations where (i) the lexicon is growing while the system is in use or (ii) when additional languages must be introduced ([Nirenburg et al. 92]). Every new word sense added to the lexicon carries the potential of ruining the possibility of retaining ambiguity in translation for all previous entries. All this means that extra attention must be paid to the maintenance of the lexicons.

4 Our anaphora resolution model

A possible solution for CAT2 towards discourse translation (initially handling anaphora resolution), would be a simplified version of our integrated anaphora resolution model proposed in [Mitkov 94]. Full implementation of this model, including a centre tracking inference engine, seems too costly for the immediate goals of the system.

Given the complexity of the problem, we think that to secure comparatively successful handling of anaphora resolution, one should adhere to the following principles: 1) restriction to a domain (sublanguage) rather than focus on a particular natural language as a whole; 2) maximal use of linguistic information, integrating it into a uniform architecture by means of existing partial theories. Some more recent treatments of anaphora ([Carbonell & Brown 88], [Rich & LuperFoy 88]), ([Preuß et al 94]) do express the idea of "multi-level approach", or "distributed architecture", but their ideas a) do not seem to capture enough discourse and heuristic knowledge and/or b) do not concentrate on and investigate a concrete domain, and thus risk being too general. We have tried nevertheless to incorporate some of their ideas into our own proposals.

Our anaphora resolution model integrates modules containing different types of knowledge - syntactic, semantic, domain, discourse and heuristic (Figure 8 -1).

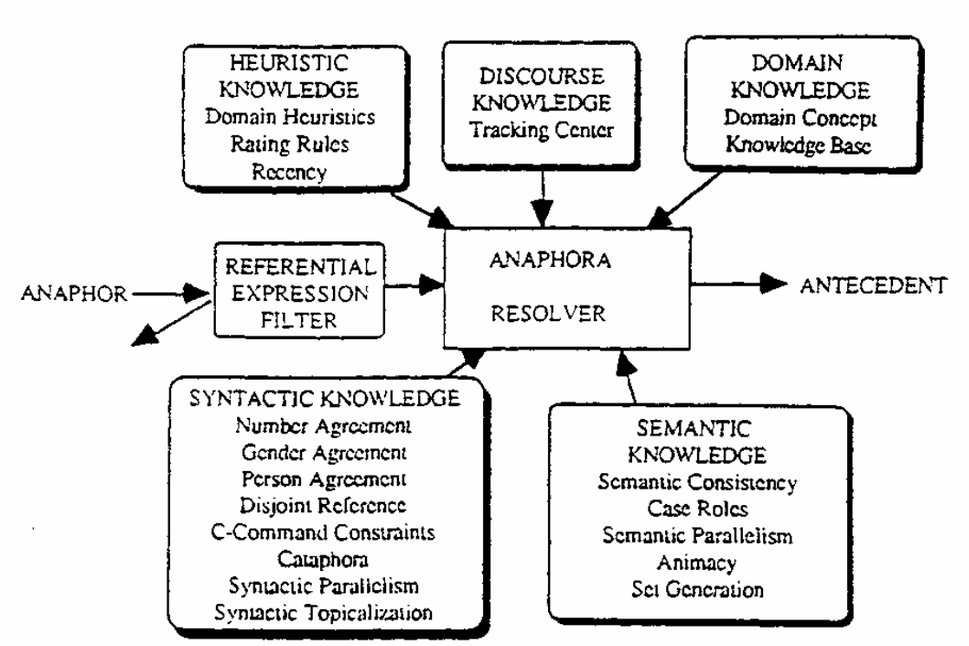

Figure 8 -1 Integrated anaphora resolution architecture

The syntactic module, for example, knows that the anaphor and antecedent must agree in number, gender and person. It checks if the c-command constraints hold and establishes disjoint reference. In cases of syntactic parallelism, it prefers the noun phrase with the same syntactic role as the anaphor as the most probable antecedent. It knows when cataphora is possible and can indicate syntactically topicalized noun phrases, which are more likely to be antecedents than non-topicalized ones.

The semantic module checks for semantic consistency between the anaphor and the possible antecedent. It filters out semantically incompatible candidates following the current verb semantics or the animacy of the candidate. In cases of semantic parallelism, it prefers the noun phrase, having the same semantic role as the anaphor, as the most likely antecedent. Finally, it generates a set of possible antecedents whenever necessary.

The domain knowledge module is practically a knowledge base of the concepts of the domain considered and the discourse knowledge module knows how to track the centre of the current discourse segment.

The heuristic knowledge module can sometimes be helpful in locating the antecedent. It has a set of useful rules (e.g. the antecedent is to be located preferably in the current sentence or in the previous one) and can forestall certain impractical search procedures.

The use of common sense and world knowledge is in general commendable, but it requires a huge knowledge base and set of inference rules. At the present stage of our project, however, we do not envisage the development of this module.

The syntactic and semantic modules usually filter the possible candidates and do not propose an antecedent (with the exception of syntactic and semantic parallelism). Usually the proposal for an antecedent comes from the domain, heuristic and discourse modules. The last plays an important role in tracking the centre and proposes it in many cases as the most probable candidate for an antecedent.

The referential expression filter plays an important role in filtering out the impersonal 'it'-expression (e.g. "it is important", "it is necessary", "it should be pointed out" etc.), where 'it' is not anaphoric.

Based on empirical studies from the sublanguage of computer science, we have developed a statistical approach to determine the probability of a noun (verb) phrase to be the centre of a sentence. Unlike the known approaches so far, our method is able to propose the centre with high probability in every discourse sentence, including the first one. The approach uses an inference engine based on Bayes' formula which draws an inference in the light of some new piece of evidence. This formula calculates the new probability, given the old probability plus some new piece of evidence [Mitkov 94].

Initially, we envisage the implementation of the syntactic, semantic and heuristic modules which, together with the referential expression filter alone, are helpful in solving practically most of the cases in the majority of sub languages.

5 Understanding beyond sentence level. Do we stop there?

In the previous section we discussed the determination of anaphoric links which are necessary for correctly understanding a source language discourse segment. However, discourse-oriented MT should be regarded also from the other angle: how to synthesise the target text taking into account its discourse structure.

It is well known that most of the MT systems perform translation sentence-by-sentence. Only a few try to translate paragraph-by-paragraph and in these cases, the discourse structure of the output text is identical with that of the input text. However, we have shown that the discourse structures across the different sub languages are not always the same for any pair of natural languages [Mitkov 92b].

Paragraph-by-paragraph machine translation seems to be, at least now, a complicated task for practical needs. It involves the complete understanding of the paragraph, the determination of discourse topic(s) goals and intentions so that the output can be produced in accordance with the respective discourse rules and purposes. However, recognising topic, goal, intention by a computer program seems to be a very tough problem. Moreover, analysing a paragraph is itself a complicated task which does not always yield satisfactory results.

On the other hand, translating sentence-by-sentence with the sequence of the original sentences preserved is a general approach, which guarantees in most of the cases an understandable output. However, in order that a translated message sound as natural as possible, it should be conveyed in accordance with the discourse organisation rules of the target language. If we examine more closely the work of a professional translator, we shall inevitably note that he/she does not follow always the order of sentences in the source text.

Taking into account the complexity of paragraph understanding and the necessity of observing the specific target sublanguage rules, we have proposed a practical discourse-oriented MT approach (within an English to Malay MT system) which analyses a source paragraph as a schema of rhetorical predicates and generates the target text as possibly another schema of rhetorical predicates [Mitkov 92a]. Towards this end, we have developed a Text Organisation Framework

Grammar which maps source paragraph structures of rhetorical predicates onto the specific target paragraph structures of rhetorical predicates.

5.1 Selection of text organisation approach

We have studied different approaches which so far have been used to describe the organisation of a given text (paragraph). From a practical point of view we argue that the most appropriate approach would be the "schemata-based approach" introduced by K. McKeown [McKeown 85] and used by other researchers .

Though some researchers point out the relative inflexibility of this approach, we found this approach more suitable for the needs of MT. The plan-based approach [Mann & Thompson 87] seems to be too complicated and unrealistic to be implemented in an MT system, because its rhetorical relations are dependent on an expected effect on the hearer achieved by their combination. In an MT system, as already mentioned, it is very hard, if practically not possible, to recognise automatically, in a paragraph, the goals and intentions of the speaker.

5.2 Sub languages and schemata

In the sub languages we have studied, however, we found out that schemata of rhetorical predicates could not always be uniquely defined. There are sub languages where more than one typical schema should be defined and consequently used. We examined numerous texts on which basis we defined "stable schemata". The schemata S1, S2, .., SN can be considered "stable" if 1) SI/N_d, "I and 2) SSI/N_g where N is the number of all examined texts, d, g are numbers in the interval (0,1) which we call "individual contribution minimum" and "global contribution minimum" respectively. The idea behind this mathematics is that schemata can be considered as "stable" if they as a whole represent a significant portion of all examined texts and yet every "stable" schema should itself be representative.

For translation from L1 into L2, if more than one stable schema is available in the respective sublanguage of L2, the stable schema, which is closest to the input of L1, is chosen. For determining closeness, special metrics have been developed which take into account not only the number of displaced predicates, but also the size of the displacement and the maximal length of matched sub-strings from the input and output schemata of rhetorical predicates [Mitkov 92a].

We have studied the discourse structure of a few sub languages and from our investigations on these sub languages we have drawn three main conclusions:

1) The stable schemata in any pair of natural languages are not always identical and do not occur equally frequently

2) For some sub languages there are more than one stable schema

3) For some sub languages there exists no stable schema

These conclusions are important for MT because in the second case there is no need for discourse transition rules and the translation should be undertaken sentence-by-sentence.

5.3 Rhetorical predicates are not easy to handle

During analysis, rhetorical predicates should be recognised. In certain sub languages this can be done by means of key words and other clues [Mitkov 92a]. However, in general this seems to be a very complicated problem and extensive world knowledge and inferencing mechanisms are needed. How can a program recognise a sentence (proposition) as an amplification, attributive etc.

rhetorical predicate? For our sublanguage-based MT needs, we are considering two approaches for the identification of rhetorical predicates.

One approach would be to define "verb frameworks" characteristic of a verb within the sublanguage. Each verb should be associated with possible rhetorical predicates and the predicate should be identified on the basis of the logical structure of the analysis. However, this approach may not be powerful enough in certain cases. Consider the sample text from [Kodansha Encyclopaedia] describing Kyushu Daigaku (Kyushu University):

> "A national, coeducational university in the city of Fukuoka. Founded in 1910 as Kyushu Imperial University. It maintains faculties of letters, education, law, economics, science, medicine, dentistry, pharmacology, engineering, and agriculture. Research institutes include the following: the Research Institute of Balneotherapeutics, the Research Institute of Applied Mechanics, the Research Institute of Industry and Labour, and the Research Institute of Industrial Science. Enrolment was 9,425 in 1980".

It will be quite difficult, however, using only the verb framework, to recognise the first, the third, fourth and the last sentence as rhetorical predicates. A useful approach in this case would be to use domain knowledge which would enable the recognition of the rhetorical predicate after semantic analysis. For instance, a proposition describing entities which are in 'sub-part' relation should be classified as a constituency predicate. This 'sub-part' relation could be easily recognised, being already described in the domain knowledge base. In our case, if there is a knowledge base describing the concepts and their relations from the sample text, from the 'is-a' relation ("Kyushu Daigaku"- "University"), from the respective 'sub-part relations' ("university"-"faculty", "research centre") and the 'has' relation ("university" -"enrolment of students"), the program could assign to the above sentences identification (1st sentence), constituency (3rd, 4th sentences) and attributive (last sentence) predicates, respectively.

Consider, however, the second sentence. Is it "amplification"? If yes, how is the program supposed to conclude that this sentence is an elaboration of the first one? How feasible is in general the computational recognition of the rhetorical predicates? The important question is: how much domain and world knowledge, as well as AI inferencing techniques, are needed?

And if yes, does it not seem that "amplification" is not refined and precise enough? (I can give many examples which could be assigned the rhetorical predicate "amplification", because they simply do not fit the definition of the rest of the predicates.) Should one not introduce an additional predicate called e.g. "initiation" which would be associated with the act of founding, setting up, opening, organising etc. something? This gives rise to a second important question: Is the set of rhetorical predicates given in [Grimes 75] , [McKeown 85] or [Shepherd 26] sufficient and precise enough to describe the real world? But if we propose additional predicates, how far can we go?

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