Types of Semantic Information Necessary in a Machine Translation Lexicon

David Mowatt
UMIST, Manchester, UK
dmowatt@fs1.ccl.umist.ac.uk | http://www.ccl.umist.ac.uk/ra/dmowatt/

Abstract

This paper describes research undertaken into assessing what types of semantic information (SI) are needed in a Machine Translation (MT) lexicon in order for ‘good’ translation quality to be attainable. We present a typology of semantic information, allowing the use of semantics in any MT system to be quantified in precise and absolute, rather than relative, terms. This typology was used to survey the SI present in twenty commercial and research MT systems. An automatically translated corpus was analysed to identify which types of semantics were necessary to achieve high quality translation. The survey and the analysis allowed us to conclude that four of the nine types of SI identified should always be included and that a further two complex SI types should be considered for inclusion pending further analysis. A formal lexicon specification incorporating these six SI types is presented.

1. Introduction

It is interesting to note that linguistic researchers have moved from primitive context free grammars (CFGs) to much more complex grammars such as HPSG, where the debate is not so much what syntax is encoded to how it is represented and how syntax interacts with other linguistic information, such as semantics and pragmatics.

The debate on how much or even which types of semantic information (henceforth SI) is needed (by rule-based natural language analysis systems) to disambiguate sentences has not however progressed to the same extent. The MultiLex project supports this assertion. The lexicon specification present within the report contained only the very minimum level of semantic coverage, “only the first step towards the building of a type system”. The authors agree that more semantics are needed, yet fail to provide an actual lexicon specification for them.

Our research aimed to provide a concrete lexicon specification for those wishing to use more complex semantics. In order to find out what types of SI the lexicon should be able to support, we first researched the existing semantic content of MT / NLP system lexicons as well as assessing the utility of each type.

2. Semantics in the Lexicon

The first aim of our research was to find out what types of SI should be included in MT systems – System Y uses SI types 3, 4 and 8, System Z just uses type 5. It was not to propose an answer to the (perhaps impossible) question of just what quantity of SI should be included – System X should have n amount of SI type 1, m amount of SI type 2…

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2 The is also true for the extensive EAGLES survey of semantics, cf. Sanfillipo et al. (1998).
3 Nirenburg et al. (1996) did attempt this reduction of SI in a system to mathematical figures, though their methodology again only allows one to quantify SI in MT systems in a particularly imprecise manner.
semantics in existing MT systems and in lexicon documentation (such as MultiLex, Eurotra, Systran, KBMT) in order to draw up a typology of SI. While the author is certain that other SI types could exist, the typology presented does seem to successfully account for every full-scale (non-theoretical) system.

2.1. A Typology of Semantic Information

The table below contains a typology of SI. Each type is accompanied by a description and, in column (\#), the number of commercial systems who claimed, when surveyed, to incorporate this type of SI. The order of the types was determined by their complexity (semantic primitives are generally yes/no attributes, whereas ontologies are complex interrelated structures), how they are used (subject domain information provides general indications whereas real world knowledge (RWK) allow complex semantic interpretations of sentences) and how commonly a type was incorporated into systems featured in the survey:

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Explanation</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_0$ None</td>
<td>No semantic information is used at all</td>
<td>1</td>
</tr>
<tr>
<td>$t_1$ Sense Order</td>
<td>The senses are stored in order of frequency: Plant $s_1$ = non-animate living thing Plant $s_2$ = factory</td>
<td>1</td>
</tr>
<tr>
<td>$t_2$ Sense Frequencies</td>
<td>Proportional measurements of frequency Plant non-animate = 0.8, Plant factory = 0.2</td>
<td>10</td>
</tr>
<tr>
<td>$t_3$ Subject Domain</td>
<td>The typical subject area(s) of a given sense: Plant $s_1$ (living) = General Domain Plant $s_2$ (factory) = Manufacturing Domain</td>
<td>18</td>
</tr>
<tr>
<td>$t_4$ Semantic Primitives</td>
<td>A limited set of primitives: abstract/real, +/-place, +/-time: Plant $s_1$ = real, living, non-sentient Plant $s_2$ (factory) = real, place</td>
<td>14</td>
</tr>
<tr>
<td>$t_5$ Collocations</td>
<td>Words commonly found together. No grammatical relation between words identified. Plant (life), (manufacturing) plant</td>
<td>15</td>
</tr>
<tr>
<td>$t_6$ Common Subjects and Objects</td>
<td>As with collocations, but with a grammatical relation. “grow $s_2$ object = plant $s_1$”</td>
<td>12</td>
</tr>
<tr>
<td>$t_7$ Frames(^v) / Real World Knowledge</td>
<td>Uses not just the triple (word1</td>
<td>grammatical/semantic relation</td>
</tr>
<tr>
<td>$t_8$ Use of an $IS_A$ Ontology</td>
<td>Semantic primitives are used to form a complex Plant $s_1$ $IS_A$ vegetative_lifeform Plant $s_2$ $IS_A$ industrial_place</td>
<td>2 small / 1 big</td>
</tr>
<tr>
<td>$t_9$ Extended ontologies</td>
<td>Nodes in the ontology use more than the $IS_A$ relation: Plant $s_1$ LOCATION garden Plant $s_2$ HAS_PART stem</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^v\) Frames were used extensively in the research of Hirst (cf. Hirst, 1987) to semantically encode events, and all the subevents and concepts of which they are formed. Currently, only a few systems use descriptions like frames to encode semantic information, such as Fujitsu’s Atlas, and Transparent’s Transcend.
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The typology presented is unique not because of the individual types identified, but because it the first attempt to present a method of identifying and classifying all types of SI with such a level of precision.

2.2. Semantic Information in Actual MT Systems

The survey of SI in the systems revealed both the vast majority of systems surveyed (70%) relied heavily on types \( t_4 - t_6 \) for disambiguation: semantic primitives \( (t_4) \) and collocation information either with or without having identifying specific relations between words (types \( t_5 \) and \( t_6 \)). The ‘popularity’ of these three types comes from their tremendous power to disambiguate senses (cf. for example, Yarowsky, 1995:189).

Globalink, GMS, LOGOS are amongst those systems which claim to use more sophisticated types of SI. Globalink’s top of the range systems and GMS’s T1 systems are of comparable quality – though notably, despite their commercial success, they are both said to be under-performing because the SI present in the systems is not complex enough⁷; LOGOS is also highly reputed, yet their system differs as customers are expected to tailor lexica and grammars much more than other systems demand.

However, counter to the belief that more complex SI will necessarily yield better results, Systran is frequently accepted to be the world’s best performing MT system yet it only incorporates SI types \( t_1 - t_6 \), and some \( t_8 \). The survey also revealed though that they will be incorporating more SI (\( t_2 \)) to further improve translation quality.

No-one knows how well a system incorporating all nine identified SI types would translate because no-one has ever successfully developed a full system which can use this quantity of SI. This would require, according to researchers of KBMT, “all relevant domain knowledge” (Nyberg, 1992:3) – a near impossibility therefore for free text input. Full \( t_1-t_9 \) systems certainly do not exist yet⁶. Many have experimented with large levels of semantics, such as Memtah, only to abandon a full scale implementation in favour of a “only if needed”⁷⁷ basis only. The KBMT team themselves admit that such systems are currently only financially feasible in very restricted domains, Nyberg (1997:2).

3. Using Translated Corpora to develop a Lexicon Specification

Based on the assumption that a translation of certain sentences is only possible with a certain level of SI, we wanted to discover which types of SI could be said to be necessary in an MT lexicon so that we could incorporate them into our lexicon specification. As we were particularly interested in translation for assimilation⁸, we also wanted to be able to say that we felt types \( t_5 \) and \( t_6 \) did not merit the effort required to input them into each lexical entry because they did not significantly enhance translation quality. We wanted to propose a lexicon specification that would provide enough information for disambiguation without being inherently financially infeasible.

A 3000 word bilingual corpus of texts on the subject of the World Wide Web, containing lots of domain specific terminology, technical language and general language, was translated by a human, by Systran Professional and by Globalink’s French Assistant. Using knowledge about how MT systems worked, we attempted to deduce in each case why a system did not translate correctly (what we will term as a reverse-perspective evaluation). The error report thus contained:

⁶ Ann Devitt, Lernout and Hauspie, during Trinity College Dublin Computational Linguistics Seminar Series.
⁷ Dahlgren, 1988, claimed to have a text-understanding system that used up to type \( t_6 \), but with a vocabulary of only several thousand words, compared to the 360,000 words contained in Systran’s lexicons
⁸ ipc. Helen McKay, Adacel Technologies, 1998
⁹ Cf. Jordan, Dorr and Benoit, 1993:50
(1) the area where changes need to be made (the lexicon, the grammar or both)
(2) whether or not the MT system would be able to successfully translate the phrase it
got wrong if the new word / sense or new syntactic structure was added to the
existing lexicon / grammar
(3) if the existing specification was insufficient, what would need to be added to the
system for it to translate correctly?

A preliminary examination of the corpora revealed that too many mistakes were made in
the translations produced by the French Assistant software for there to have been value for the
project in analysing them:

Systran:  Les bruits et les films sont également possibles, cependant souvent trop grand
pour que beaucoup de gens téléchargent et pour entendre ou regarder.

Globalink:  Ses et cinéma sont aussi possibles, pourtant souvent trop grand télécharger
pour beaucoup de personnes et entendre ou voir.

All following observations thus relate only to the translation performed by Systran.

4. A Specification for the Semantics Section of an MT Lexicon

The results of the analysis were combined with knowledge of what SI types are already
used in MT systems to propose a specification for the semantics section of an MT lexicon.
Though many examples were used as evidence in the original analysis, we limit ourselves to
just one example per SI type in this paper - each example has incorrectly translated words
underlined, followed by the source language word and the correct translation in brackets.

4.1. Subject Domains and Sense Frequency - \( t_1 \), \( t_2 \) - and Subject Domains - \( t_3 \)

We recommend that sense frequency and subject domain information should be included.
In the following example identifying the IT domain would have ensured correct translation of
three incorrectly translated words:

From a technical point of view, the WWW connects waiters (serveurs = servers) HTTP who send pages
HTML to stations (postes = terminal) equipped with a browser (navigateur = browser).

Subject Domain  =  \( \text{(Agriculture | Banking | Computers | etc.)} \) *
Sense Frequency  =  \( (0.0 - 1.0) \) ?

A full list of values for Subject Domain could not be specified as only the IT domain was
studied in this research, but we do though expect this field however to be dynamic in nature
and expand as more domains are added. Sense Frequency is intended to be a ‘last resort’
mechanism when all other disambiguation fails: SI type \( t_1 \) is here made redundant by type \( t_2 \).

4.2. Inheritance, IS_A Ontologies and Semantic Primitives – \( t_4 \) and \( t_8 \)

Virtually all MT systems use semantic primitives, though we found that using an IS_A
ontology \( t_8 \) can replace them, be more powerful and still be both computationally efficient and
easy to code into lexical entries.

By Web you can visit an exposure (exposition = exhibition), read your newspaper, learn English, control
(commander = order) a pizza pie.

Inherit  =  \( \text{(Word#Sense)} \) *

Stating all of the possible objects for commander or visiter would be time consuming and
ad-hoc – using an IS_A ontology provides the same semantic power but with much greater
ease. The top level ontology nodes can be used to encode features such as sentience,
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abstractness and movability and these can perform the same function as primitives (cf. Mowatt 1997 for a complete list). SI type $t_4$ is thus made redundant by type $t_8$.

4.3. Real World Properties - $t_7$ and $t_9$

RWK is generally accepted as being time-consuming to code and as necessary only when translating a small percentage of sentences, yet it is also accepted that using it sometimes provides the only way to translate certain sentences correctly.

En cliquant sur le nom de l’auteur d’un article vous pouvez ainsi avoir son adresse, sa photo…

While clicking on the name of the author of an article you can thus have his address, its (son == his) photograph…

“his photo” could either mean “the photo he possesses” or “the photo that pictures him”. The owner of the photo would have to be a human or an institution (i.e. a gallery might own the photo), and the picture in the photo (the content) would have to be a tangible thing. If this was encoded under the RWK categories of owner = sentient and content = real, then only “author” would be a plausible candidate – “nom”, “article” and “adresse” are ruled out.

RWProperty = <RWFieldName> <RWFieldValue>
RWFieldName = IsA | HasPart | Content | Duration | (etc.)
RWFieldValue = “Word#Sense”+ | <Ontology_Node>+ 
Ontology_Node = Profession | Body_Part | Male | NoSize (etc.)

Use of RWK cannot (yet) be definitively asserted as necessary for high quality translation, but we acknowledge its potential utility by including a possible way of encoding it in the lexicon whilst accepting that further research into RWK for large-scale systems is required.

4.4. Selectional Preferences – $t_5$ & $t_6$

Selectional preferences provide a way of stating the preferred subjects / objects etc. of a given word using semantic or collocation information. The correct translation of mondial, universel, global (in French or English) and world is most easily achieved by having a list of collocation objects, rather than complex semantic analysis:

Une dimension mondiale = A global (not world) dimension. Also: village planétaire = global village; guerre mondiale = world war, and similar words such as mortal / fatal / deadly.

SelPref = <ApplyTo> <Field> <Operator> <Value>
ApplyTo = Subject | Object 1 | Object 2 | Modified Unit
Field = (Any lexicon field) | <RWField> | (Text | Word#Sense)
Operator = Equals | Not Equals
Value = “Text” | (Appropriate field value)

The precise mechanics of how, given multiple selectional preferences for different senses, the parser is to weight each preference, is a problem that will not be discussed here. Our concern is to give the parser enough linguistic power and information to be theoretically able to disambiguate sentences, not to propose how it actually achieves it.

5. Conclusion and Further Work

We have presented a typology of semantic information which identifies nine individual types. When this typology was used in a survey of MT systems, it was revealed that no system currently in existence makes full use of sophisticated SI types such as real world knowledge $t_7$ and extended ontologies $t_9$, and few make use of IS_A ontologies $t_8$.

Our analysis of the translated corpora suggested that of the nine SI types, $t_3$, $t_5$, and $t_8$ should be incorporated into each lexical entry, and that type $t_6$ should be used as often as is
necessary. The analysis also strongly suggested that types t7 and t9 would be of value to the translation process and for this reason we have proposed a possible implementation in the lexicon.

Our current research is focusing on what quantity of SI types t7 and t9 is needed (in each entry) to achieve translation quality that is unobtainable using the other seven types alone. The results of this research should be available towards the end of this year.

6. Acknowledgements

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7. References


