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Semantics and (machine) translation

This paper is about the dual relationship between the concepts of translation and semantics, and its implication for machine translation in particular.

I start by pointing out the close ties between the two tasks (namely, formal semantics of natural language (NL) and translation between two different natural languages), and proceed by making an overview of semantics in machine translation (MT). I will be specifically interested in the translation criteria given in the MT literature.

The point I want to make is that an equivalence criterion is too strong for translation. After describing briefly a set of entities with which the semantic analysis of a text in one language has to be concerned, I propose translation criteria connected with them. I then proceed to demonstrate in greater detail, for a simple case, that equivalence cannot be a translation criterion.

1 Translation in semantics

The concepts of meaning and translation are closely tied: On one hand, meaning in formal semantics is generally stated in terms of a translation into worlds, beliefs, a formal language; i.e., something outside language itself. On the other hand, the translation between natural languages is generally acknowledged to have something to do with meaning (to put it mildly...).

Actually, it is interesting to see how many of the arguments adduced in one discipline can be used in the other, as well as criteria and even definitions. Let me start by looking at what philosophers of language and linguists have to say about semantics regarding translation.[1]

To argue in favour of his principle of indeterminacy of translation, [Quine 60] uses the example of radical translation (i.e., of a language of a hitherto untouched people). Basically, he contends that a linguist in charge of such a task would have to make a number of analytical hypotheses, since

stimulus meanings never suffice to determine even what words are terms, if any, much less what terms are coextensive.

[1]For this overview I will base myself mainly on [Guenthner 78].

(...) the method of analytical hypotheses is a way of catapulting oneself into the jungle language by the momentum of the home language. (...) From the point of view of a theory of translational meaning the most notable thing about the analytical hypotheses is that they exceed anything implicit in any native's dispositions to speech behavior. [Quine 60, page 70]

[Wheeler 78] also supports Quine's principle of indeterminacy by pointing out that reference can be thought of as a theory of resemblance (between objects and concepts), or as a theory of causality (objects cause concepts (states of mind in the speaker)), in this latter case only definable in terms of physical things causally related. Since large portions of current NLs have kind terms with only nominal essences, the resemblance theory is then right for them and the indeterminacy true.

For [Cresswell 78], meaning is a relation between NL and sets of possible worlds, which are language-independent entities. However, to adequately treat NL devices such as indirect discourse and propositional attitudes, it is necessary to have a semantic account of "means the same as", and that is, according to him, precisely what is required to give an account of translation between NLs.

[Tymoczko 78] argued that meaning assignments are dependent on social and cultural factors, because important evidence necessary to differentiate among meaning assignments is not properly semantical: Two equally plausible meaning assignments can assign different truth values as long as this is compensated for by different theories of pragmatics. According to him, not only the contexts matter, but also the individual perspectives of the speakers, their beliefs. Therefore, to make translation between NLs, it is necessary to know, for each language, its environment, society and beliefs.

Finally, [Wallace 78] notes that a theory of meaning for a language needs to be more than a theory of truth. In fact, it requires at least some modal operator as "it is a matter of meaning alone". Understanding involves using one's own language (potentially all): the ability to translate does not by itself generate understanding; it can only transfer understanding from one language to another.

To argue for what he calls the division of linguistic labour: the fact that the criteria to identify some terms are only known to specialists, and the use of the terms by the other speakers depends on a structured social cooperation, [Putnam 78] resorts to two parallel communities, whose language is equal but whose world differs precisely on the extension of words whose meaning is not verifiable by a layman. Meaning is given in terms of a normal form description, consisting of a vector of syntactico-semantic markers, additional features of the stereotype, and a description of its extension. The first elements can be described as a psychological state in the mind of the

speaker, so to speak; however, the last one cannot.

Still, a speaker can have two synonyms in his/her vocabulary without knowing that they are synonyms (for example, in two different languages).

2 Semantics of translation

[Keenan 78] has argued against the argument that anything that can be said in one NL can be said exactly in another, showing how matters of efficiency in terms of communication play a part in how language users use their language.

According to Keenan, some plausible criteria of adequate translation, such as sameness of speech act, sameness of truth conditions, and sameness of derived truth conditions, have to be violated in practice in some language pairs. He thus concludes that

The question of concern now should be not whether we can say anything exactly in one language that we can say in any other, but how much languages differ with regard to the exact types of information they encode. [Keenan 78, page 189]

Sometimes reference has to be sacrificed in translation (in cases of self-reference, such as described in [Burge78]).

[Grabski 90] notes that Situation Semantics distinguishes between Meaning and Content: meaning is a relation between the utterance situation and the properties of the described situation, while content is a property of the situation that is being described). He contends that, in translation, content may be preserved while sacrificing meaning. Thus there are two possibly opposed dimensions of transfer flexibility.

Finally, [Carlson 91] notes that some problems arising in translation between NLs (e.g. head switching) arise unilingually as discrepancies between syntax and semantics.

3 Semantics in machine translation

3.1 General overview

Even though translation between NLs is far from straightforward even at the theoretical level, the semantic component of machine translation systems is often naive, to say the least.

First, it is often assumed that, at the level of "semantic representation", meaning is language independent. In fact, meaning is always a function from observable linguistic objects to a semantic representation (or, in other words, a relation between NL expressions and their denotata), and thus language dependent.[2]

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[2]I am indebted to Lauri Carlson for pointing this out to me.

The claim that semantics should be used in machine translation is fairly usual: it describes the commonly held view that without understanding you cannot translate, and is frequently used to defend some approaches against others. Nevertheless, if we look more carefully at some MT systems that purportedly use semantics, "meaning" is often encoded in what is called "meaning representation languages", generally served without an explicit formal semantics (see for example [Doe et al. 92]).

However, [Schubert 88] argued convincingly that most knowledge conveyed in one language, and hopefully kept in the translation, is implicit. More controversially, he even pointed out that the primariness of meaning (in a form akin to the Meaning Representation Languages just presented) could be a factor of distortion in translation, thus defending that syntax should prevail over semantic and pragmatic rules.

Any text, of whatever style, can contain false claims, lies, unrealistic predictions and illogical utterances. The syntactic form, analyzed before any call to the knowledge bank, forces the semantic interpretation to go along the lines intended by the author and prevents the word expert system from destroying the text by rewording it according to some pre-formulated world knowledge. [Schubert 86, page 150]

Another interesting observation on the current use of "semantics" in MT is the fact that the kind of "semantic" problems MT systems typically try to cope with are often motivated by translation mismatches, instead of aiming at an actual understanding of one or every language involved.

In fact, most of semantics in working MT systems consists simply of annotating the syntactical representations with semantic features, percolated up in a compositional fashion during syntactical analysis (see e.g. [Isabelle 87] or Eurotra [Danlos 90]). But, as [Lepage 90] mentions, to use information of a certain level is very different from building a representation of that level. I.e., to use semantic annotations is not the same as build an explicit semantic representation.

Finally, knowledge of the world as opposed to linguistic knowledge proper is generally not distinguished, and gets treated under the label of "semantics" (see e.g. [Carbonell et al. 81]).

Fortunately, there is a number of exceptions to this situation: researchers who have used a formal framework for doing machine translation will be described in the next section. I will concentrate mainly on the criteria for translation, since a very important issue towards which many systems fail to take an explicit stand is the relationship bewceen meaning in one language and in the other.

In fact, even though some theories claim to seek (or to be) an "universal", non-language-dependent, framework, it is still necessary to account for the fact, as [Tsujii 86] argues, that there are meaning distinctions only perceivable in connection with other languages. Or, as [Lab 90] puts it, to have a linguistic description of two languages is not the same as having a linguistic

description of the translation among them, concluding therefore that a contrastive semantics is required.

It is in fact amazing to see how few broad contrastive studies there are as bases for actual machine translation systems. I will argue in the following that the task of translation is not simply to equate meaning. It is much more complex.

3.2 Overview of formal approaches

[Dyvik 90] uses situation schemata [Fenstad et al. 87] as a means of representing the semantics of both languages, recognizing that they do not have to be exactly the same for the two languages: It is sufficient that they are compatible, and share relation names such as e.g. like', solution', and temporally-precede'. According to him, situation schemata are language-neutral enough to be useful as interlingual structures; especially because the key concept is compatibility, rather than identity, between structures. His data structures are feature-based, and compatibility is formally implemented as unification.

As a possible improvement to his system, Dyvik explicitly mentions the use of inferential components to add information to the feature structures, as well as the future incorporation of lexical semantics (replacing relation names such as like', etc.).

Using the multi-layered architecture of LFG, and the concept of correspondence functions between levels of description (and languages), in particular a correspondence function having as domain f-structures and another having as domain semantic structures, Kaplan et al. propose the following translation criterion:

for a target sentence to be an adequate translation of a given source sentence, it must be the case that a minimal structure assigned to that sentence by the target grammar is subsumed by a minimal solution to the transfer description. [Kaplan et al. 89, page 276]

The bulk of the paper is unfortunately devoted to the exemplifying of f-structure correspondences (i.e., the translation pairs that only require such a level of representation). No example of translation using semantic descriptions is given, even though (see below) the actual examples may suggest that semantics could be preferred.

Landsbergen is radical in arguing for a strong equivalence relation:

A sentence s' of L' is considered a possible translation of a sentence s of L if s and s' are derived from corresponding basic expressions by applying corresponding syntactic rules. [Landsbergen 87, page 353]

Meaning representations are logical derivation trees, i.e., trees of basic meanings annotated with the (unique) names of meaning rules, in a formalism inspired by Montague grammar and called M-grammars. Logical derivation trees play the role of intermediate expressions in the ROSETTA

translation system. The meanings (as well as the syntactic parses) of sentences in different languages are constrained by the grammar writers to be the same across languages, from those of the basic expressions to those of the meaning rules: thus we see here the most extreme form of equivalence. One interesting implication of this is that here, semantics is defined mainly in terms of contrastive data, which seems to be an original criterion of the MT system in question.

Beaven and Whitelock [Beaven/Whitelock 88], following Landsbergen, adhere to the principle quoted above, but use UCG as the semantic (and syntactic) representation formalism, introducing the notion of bilingual sign, where the source semantics and the target semantics are constrained to share their value. In addition, they require that, with the same markedness, there is no more specific sign in each language that unifies with that semantic description, and that, after the full derivation of the sign, the semantics continues to unify.

For example, they defend the unification criterion in terms of semantic representations, using as examples the predicates leg-of and human. This however immediately casts doubt on the independence of this semantic language. Why was for instance leg-of chosen and not perna-de and pata-de?, in which case there would be no need to use the condition human...

The designers of MiMo2 explicitly address the question of the translation criterion, defining the relation of "linguistically possible translation" as follows:
1. translation preserves truth-conditions; 2. moreover, it preserves as much as possible the way in which meaning is built compositionally; 3. it does not take world knowledge into account; 4. it does not necessarily preserve style; 5. it is defined only for grammatical sentences. [van Noord et al 90]
While the three last points are (in the paper) justified solely by pragmatic reasons, the two first suffice to assert that the relation is symmetric but not transitive, which is certainly an interesting point. [van Noord et al 90] use bilingual meaning equivalence postulates (BMEPs), to be interpreted as constraints on possible interpretations for the two languages. However, they end up by making translation ad hoc postulation, by the system designer, of what is (or is not) equivalent between two languages, by stating that
In translation, what counts is that two expressions are equivalent rather than what they mean.
(...) the MiMo2 system (...) is concerned only with the situation where the same meaning is expressed in both languages.

[Dorr 92] separates two levels of (so-called) semantic knowledge: aspectual and lexical semantical, which is in turn separate from syntactic processing. At the lexical-semantical level, LCS [Jackendoff 90] is used as the interlingual structure, and divergences between languages are parameterized. However, a closer look reveals that English is certainly the closest to LCS, so divergences boil down to divergences to English.

At the aspectual level, Dorr's proposal is that coercion functions are defined interlingually in terms of transformation of the values of the aspectual features, while the actual morphosyntactic ways of realizing them are language dependent. This is in some way a dynamic view of language interpretation: it is not an internal representation, but functions from interlingual values to interlingual values that are required to be unchanged. Further thought though reveals that rather strong assumptions are presupposed, namely, among others, that the aspectual features and values, originally motivated for English, apply as well to other languages; that there are similar coercion mechanisms in all languages. But even without questioning these assumptions, it is not clear using such a model what translation actually is.

Even though [van Eynde 88] is concerned with a transfer system, he proposes an interlingual semantical approach to handle the translation between the tense and aspect systems of the EEC languages, stating that identity of meaning is by definition what an interlingual MT system is about. However, later he writes that

If one of these forms is not present in the language, its meaning may be expressed by another form (...) whose basic meaning is the least distant from the meaning to be expressed. [van Eynde 88, page 703] [3]

Van Eynde seems also to assume that the distribution of work is done equally in every language, in that if a language expresses a meaning with one morphosyntactic device, there must be a corresponding one in the other language. However, in what regards division of labour between tense and aspect, he introduces the notion of degrees of compositionality, treating combinations of tense and aspect form syncategorematically.

4   A preliminary translation model

I will start by listing what the representation of the meaning of a text in one language may contain. The following list is not exhaustive, nor do I claim that all elements should necessarily be invoked for any specific piece of text.

1. extralinguistic entities (formalized using e.g. model theory), to represent the meaning of words like *table*;

2. concepts defined prototypically, whose meaning also encompasses their extension, as defended by [Putnam 78], to represent the meaning of words such as *water*;

3. abstract concepts not analysable extensionally (thus indeterminate in reference, as argued by Wheeler and above), for words like *beauty*;

4. truth-values (for example with respect to possible worlds);

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[3]Incidentally, there is no univocity in this criterion, nor any independent justification for the ordering presented.

5. presuppositions, statements and derived consequences (roughly, separating statements actually and explicitly expressed, and others who are implicitly (pragmatically) understood or inferred, without being mentioned.

This list was presented with the goal to propose, for each item, a translation criterion which is different from simple identity. I will be concerned solely with the relation of **possible translation** (see [Landsbergen 87]) between (the pieces of text in) A and B, defined as follows:

1. the extralinguistic entities mentioned in A and B should have a non-null intersection, instead of denoting the same set (or structure of the model). (Example: both *rivière* and *fleuve* are correct French translations of English *river*, neither term, however, encompasses the whole set of what in English are called rivers.[4])

2. The prototypical concepts mentioned in A and B should have a maximal intersection (which is not going to be defined precisely in this paper, but which should account for non-identical beliefs towards a concept while still accepting its translation).

3. The abstract concepts mentioned in A and B should have been a priori defined as mutual translations, through the compared study of two civilizations. (In here, bilingual dictionaries are supposed to be the only source of knowledge, and no other concept than pre-defined translation will help us.)

4. truth values of A and B are not contradictory. (Example: even though I am not claiming that the words actually correspond to the boolean connectives, the best example is the common translation of *or* by *and*, in contexts where the (intended) truth value is true.)

5. The set of the presuppositions, assertions and derived consequences of A and the corresponding set of B have a maximal intersection and their union is not inconsistent. (That is, we may need to make explicit in one language something that it is only presupposed in another; however, we cannot accept for translation two texts which contradict each other, even if they only do it through the derived conclusions that speakers of each language are bound to make!)

[4]Jan Engh has called my attention to the existence of correct translations of terms denoting physical objects, which have a null intersection, but which have the same use in the two language communities. (An example is Norwegian *stålull* (lit. steel-wool) and Portuguese *palha-de-aço* (lit. steel-straw), both denoting a tool for cleaning saucepans etc. made from steel fibers. Material and purpose are the same; still, they are different.

This may mean that still a finer distinction should be made at the level of terms denoting extralinguistc entitles, maybe involving man-made versus natural objects.

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5   Example

We will present a practical example of translation in the domain of tense and aspect between English and Portuguese, which are relatively closesy related languages, both historically (they belong to the same language family) and socioculturally (they originated and are still spoken in Europe; the two language communities have had contacts for centuries inside and outside Europe).

Tense and aspect was chosen because it is acknowledged that time is an extralinguistic entity (it passes by without being influenced by language). Moreover, time is a phenomenon which is intuitively easy to model: By a time line where at least a partial order is defined. It can therefore be classified as belonging to the first class in the list above, which seems to be the easiest case to translate (and/or to model semantically). By showing that even in this case it will be necessary to resort to a concept weaker than identity, I hope to demonstrate that identity is no good as a translation criterion in any case.

For the sake of illustration, I will use the formal framework proposed in [Santos 92]. It can be briefly described as follows: Lexical aspect is represented by clauses with temporal variables, while tense and grammatical aspect is formalized by implications. The meaning of a text is what can be deducted in the classical way, using first-order predicate logic (at least in the example analyzed here). On purpose, I will use an example which will not introduce questions of intensionality, and which can thus be formalized in a wholly extensional way.

5.1   The translation complexity

I start by presenting a picture of possible translation pairs, to show the translation problem and at the same time to motivate a semantic analysis versus a syntactic one.

> I have lived in London for two years. *Vivo em Londres há dois anos.* (now) *Vivi em Londres durante dois anos.* (once)
>
> I have left for ten minutes. *Saí por dez minutos*
>
> I have met Einstein. *Conheci Einstein.*
>
> I have met E. twice. *Estive com Einstein 2 vezes.*
>
> I have often eaten rice in India. *Comi muitas vezes arroz na Índia.*
>
> I have bought many books in Cairo. *Comprei muitos livros no Cairo. Tenho comprado muitos livros no Cairo.*
>
> I have met him lately. *Tenho-o encontrado ultimamente.*
>
> I have bought many books lately. *Tenho comprado muitos livros.*
>
> I haven't seen Mary lately. *Não tenho visto a Maria.*

I have never been in Moscow. *Nunca estive em Moscovo.*

I have just bought a peacock. *Acabei de comprar um papagaio.*[6]

He hasn't just beaten, he has almost killed him. *Ele não lhe bateu, ele quase que o matou!*

By looking at these translation pairs, the reader can see translation rules based on existence or inexistence of specific words and/or morphosyntactic features, as most working MT systems do, are cumbersome to read and obscur the semantic insights that explain the translation choices. For lack of space, I will not pursue here any specific example of how to handle this syntactically, nor how to describe the semantic parallels.

5.2   A possible formalization

Let me just concentrate on the first translation pair, and give it a detailed analysis. In the English sentence "I have been in Lisbon for two years", the temporal-aspectual constituents are the following

PresPerf: P —> final(t,T) & t ≤ T2 & Q(T2) & Stat(Q) & inside(T2, now)

for: P(T) --> dur(T,Y)

for two years: P(T) --> dur(T, 2 years)

be-in (state): be-in(T)

By applying Modus Ponens, we may get

be-in-for two years: be-in(T) & dur(T, 2 years)

be-in(T) & dur(T, 2 years) & final(t,T) & t ≤ T2 & Q(T2) & Q(T3) & inside(T2,now)

or, with a different order of application,

PresPerf-be-in: be-in(T) & final(t,T) & t ≤ T2 & Q(T2) & Q(T3) & inside(T2,now)

be-in(T) & final(t,T) & t ≤ T2 & Q(T2) & Q(T3) & inside(T2,now) & dur(T, 2 years)

For the Portuguese sentence "Estive em Lisboa durante dois anos", the constituents are

estar (estado): estar(T)

perfeito: P—> final(t,T) & t ≤ agora

durante: P e Q —> dentro(P,Q) & Q(T)

durante dois anos: P —> dentro(P,Q) & Q(T) & dura(Q,dois anos)

and the derivation is

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[6]This kind of translation pair was handled in [Kaplan et al. 89] by pairing f-structures.

estar-durante-2-anos: estar(T) & dentro(P,Q) & Q(T) & dura(Q, dois anos)

estar(T) & dentro(P,Q) & Q(T) & dura(Q, dois anos) & final(t,T) & t< agora

perfeito-estar: estar(T) & final(t,T) & t< agora

while for "Estou em Lisboa há dois anos", we have

estar (estado): estar(T)

presente: P → Stat(P) & P(T) & dentro(agora, T)

há: P → t2 < t=agora & dura(t-t2, Y) & P(t2)

há dois anos: P → t2 <, t=agora & dura(t-t2, 2 anos) & P(t2)

producing

estar-há-dois-anos: estar(T) & t2< t =agora & dura(t-t2, 2 anos) & estar(t2)

estar(T) & t2< t−agora & dura(t-t2, 2 anos) & estar(t2) & Q(T2) & dentro(agora,T)

presente-estar: estar(T) & dentro(agora,T)

5.3   Discussion

On purpose, I did not use the same metalanguage for the sentences in the two languages, which is rather uncommon. There are several reasons for this: on one hand, I am explicitly arguing for a different semantics for the two languages, so there is no reason why primitive metalanguage relations/symbol names have to be the same. On the other hand, it seems an interesting pragmatic requirement: Grammar developers in every language would certainly benefit from using a metalanguage closer to their intuitions. (E.g., I would object to use a Japanese-inspired metalanguage to describe what a Portuguese sentence means). Moreover, there is an increasing use of on-line dictionaries, thesauri and corpora to semi-automatize language processing, which consequently implies that the metalanguage used has to be somehow related to the original language. Finally, and even if we conclude that we can identify the metalanguage symbols used (in this example or in others), it seems to me that this exercise can be useful to call the attention to possible non-explicit assumptions concerning the meaning of translation.

To be able to compare the two metalanguages, we have to give them a model which makes identical the interpretation of final and final, of < and <, of now and agora, of inside and dentro, of dur and dura. But also, and this is more delicate, do we need to require that the interpretations of be-in and estar coincide, or that the aspectual classification of state and estado have the same translation[6]?

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[6]In fact, I used the latter assumption in [Santos 92], namely, that the aspectual classification described is valid for English and Portuguese, but that should be investigated.

Let us assume nevertheless that we can do this. We still have to face the fact that the translation pairs do differ in size (in number of things asserted and/or presuposed and/or derived), and in the number and type of the temporal entities mentioned. This last fact is particularly important if we remember that discourse factors are an extremely important ingredient in language understanding (and that the close connection between tense and aspect and discourse interpretation has been acknowledged for a long time). The temporal variables used above can be seen as discourse entities that can be referred and co-refer within the rest of the text.

6   Conclusion

The comparison of the meaning of two texts in different languages, in other words, the translation criteria, cannot be based on equivalence between meanings of a whole text, given that this is not possible even in the simplest cases, involving only extralinguistic entities.

It was already an assumption for this whole paper that it does not make sense to talk about equivalence between the meanings of forms belonging to linguistic subsystems, such as lexical semantics, tense or conjunctions, given that, for each language, there is a distinct division of labour among those factors. (For a preliminary contrastive study that clearly shows this, see [Santos 91].) I believe this to be fairly non-controversial nowadays; however, it should be stated clearly.

The conclusion I want to draw is that it is necessary to resort to more flexible translation criteria, and I propose among others the use of deduction, the substitution of non-null intersection for identity, and the acceptance of translation pairs whose import stands at different levels in the linguistic system.

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