

# Long Time No See: Overt Semantics for Machine Translation

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## Abstract

In this paper, we show how a computational semantic approach is best fitted to address the translation of highly isolating languages. We use Chinese as an example and present the overall process of translation from Chinese to English, within the framework of Knowledge-Based Machine Translation (KBMT), using an overt semantics while de-emphasizing syntax. We focus here on two particular tasks: Word Sense Disambiguation (WSD) and compound translation.

## 1 Introduction

In this paper, we present results of a theoretical and an applied investigation on the translation of a highly isolating language, such as Chinese. “Long time, no see” is a very concise way of expressing the more analytic expression “I/we haven’t seen you in a while/in a long time”, in English. Chinese expresses both expressions by “very long, no see.” Because Chinese is among the most, isolating languages, it presents a challenging situation for Natural Language Processing: grammatical functions can be irrelevant; morpho-syntactic markers are sparse, and are very often elided (Li & Thompson, 1981). We argue that for isolating languages syntactic analysis can be spared, or should, at the very least, be de-emphasized to let semantics overtly take over in the process. By de-emphasizing syntactic analysis, we mean that there is no need to produce the N-best syntactic parses. In the case of an isolating language, one could not avoid generating the exhaustive list of combinations for an ambiguous parse because of the lack of morpho-syntactic clues. In this paper, we show how an overt semantics along with lexico-syntactic dependencies coded in the lexicon can account for a syntactically ambiguous parse. The study presented here has been conducted within Mikrokosmos, a KBMT system between Spanish and Chinese to English (Nirenburg *et al.*, 1996).

In section 2, we briefly present the type of information encoded in the lexicon. In section 3, we present results on the task of WSD. In section 4, we focus on compound generation, showing how to recover the relation between words from the semantics of the co-occurring words.

## 2 A Brief Overview on Our Computational Lexicons

The information encoded in the Mikrokosmos lexicons is distributed among various levels of lexical information (Meyer *et al.*, 1991), relevant to phonology, orthography,

morphology, syntax (SYN), semantics (SEM) (as first introduced in Nirenburg and Defrise, 1991)<sup>1</sup>, syntax-semantic linking (SYNSEM), stylistics, paradigmatic and syntagmatic information, and also database-type management information, (see Viegas and Raskin (1998) for more details on the format and content of the lexicons).

We illustrate below relevant aspects, for this paper, of a lexicon entry via the description of one sense of the Chinese word 削减 (reduce) (Figure 1.), which is an EVENT, and the noun 配额 (quota) (Figure 2.), which is an ATTRIBUTE.

**削减** -V1  
 syn:  
     root:          0  
     subj:          1  cat:      NP  
     obj:           2  cat:      NP  
 sem:  DECREASE  
     agent:         11  Human  
     theme:         21  Object  
 synsem:  
     subj:          1  sem:     11  
     obj:           2  sem:     21

Figure 1: Sense Entry for the Chinese lexical item 削减.

**配额** -N1  
 syn:  
     root:          0  
     mods:          1  cat:      NP  
 sem:  QUOTA  
     domain:        11  Object  
     range :        21  Any Number  
 synsem:  
     domain:        1  sem:     11  
     range :        2  sem:     21

Figure 2: Sense Entry for the Chinese lexical item 配额.

**The SYN Zone** essentially amounts to an underspecified piece of a syntactic parse of a sentence using the lexeme.

**The SEM Zone** maps to an underspecified Text Meaning Representation (TMR) as described in Nirenburg and Defrise, (1991). The TMR is composed of a combination of concepts and/or speaker related information (such as the attitude of the speaker with respect to what is being expressed, as in *good*). We use the concepts as defined in the Mikrokosmos ontology (Mahesh, 1996).<sup>2</sup> The Mikrokosmos ontology is a large collection of information about EVENTS, OBJECTS and PROPERTYs (subdivided into

<sup>1</sup> The semantics is expressed as a frame as in, for instance, Fillmore (1985).

<sup>2</sup> See <http://crl.nmsu.edu/Research/Projects/mikro/htmls/ontology-htmls/onto.index.html>.

RELATIONS and ATTRIBUTES) in a domain. We give below two extracts of concepts for the EVENT DECREASE and the ATTRIBUTE QUOTA.

Concept Name: DECREASE  
DEFINITION: a change in quantity where the final value is lesser  
than the initial value  
IS-A: CHANGE-IN-QUANTITY  
SUBCLASSES: SUBTRACT-FROM  
DIRECTION-OF-CHANGE: NEGATIVE  
AGENT: HUMAN  
THEME: OBJECT  
TYPE-OF-CHANGE: MENTAL PHYSICAL SOCIAL

Concept Name: QUOTA  
DEFINITION: a specified amount of something  
IS-A: AMOUNT  
DOMAIN: OBJECT  
RANGE: ANY-NUMBER

**The SYNSEM Zone** provides the syntax-semantic linking. For instance, in Figure 1, we know that the SUBJ:1 is linked to the semantics AGENT:11 of type HUMAN. It is better, for acquisition purposes, to leave this information transparent for the user.

To summarize, the lexicons include selectional restriction type information (expressed by the concepts defined in the ontology), along with semantico-syntactic dependencies per word.

### 3 An Overt Semantics for WSD

In the following, we address the task of WSD on Chinese sentences, using an overt semantics, that is, a rich well-structured ontology of concepts, and a semantic processor which perform WSD at a very high percentage of correctness and can identify relations between words in compounds. We first go through a simple example to exemplify the process of WSD. Consider the Chinese sentence:

**美 单 方 削 减 中 国 纺 织 品 出 口 配 额**

*The US unilaterally reduced the export quota of Chinese textile.*

This example is simple from a WSD viewpoint because we only have one word **出口** which is ambiguous in the lexicon (export) with two senses (OPENING ISA OBJECT which means the place to exit and EXPORT ISA EVENT which means to export). The word **出口** was correctly disambiguated. The f-structure below shows the syntactic parse for the sentence above.<sup>3</sup> Note that the compound is left ambiguous: all modifiers (MODS) are at the same level. It would be expensive and vain to produce the exhaustive list of combinations inside the compound, whereas only some of them would be

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<sup>3</sup> We thank the University of Maryland for providing us with the f-structures used by the Mikrokosmos analyzer.

semantically valid. This is why we let the semantic processor decide on the relations expressed between the words as will be further discussed.

```
(( (SUBJ ((ROOT 美) (CAT N) (GLOSS "US")))
  (MODS ((ROOT 单方) (CAT ADV) (GLOSS "unilaterally")))
  (ROOT 削减) (CAT V) (GLOSS "reduce")
  (OBJ ((MODS ((ROOT 中国) (CAT N) (GLOSS "China")))
        (MODS ((ROOT 纺织品) (CAT N) (GLOSS "textile")))
        (MODS ((ROOT 出口) (CAT N) (GLOSS "export")))
        (ROOT 配额) (CAT N) (GLOSS "quota" ))))
```

**削减** (reduce) subcategorizes for a SUBJ and an OBJ in its lexicon entry and is mapped to the concept DECREASE (see Figure 1.). SYNSEM links the SUBJ to AGENT: HUMAN and OBJ to THEME: OBJECT. Moreover the grammar of Chinese tells us that the last N in a compound can be identified as a head, as discussed in Huang, (1997).<sup>4</sup> Therefore DECREASE will try to match the semantics of the last N (quota) as the OBJ (grammatical object) of the V which expects a semantics of type OBJECT. Note that “quota” is of type ATTRIBUTE, and will still be selected thanks to inferences, as shown below in INFERENCE63.

In this sentence we had 7 open class words, out of which 5 had only one sense. The number of senses left after syntactic binding was 8, out of which 6 had one sense. In other words, the semantic processor was left with 2 senses for one word, which it disambiguated correctly. 100% of the words were correctly disambiguated. Obviously this was a simple example and only one word was 2-ways ambiguous; see below results on up to 4-ways ambiguous.

The semantic analysis (the result of which produces a TMR) of the sentence above is given below. We use a frame-based representation for TMRs.

```
proposition-59   time:   time-58
                 head:   decrease-51
proposition-61   time:   time-60
                 head:   export-57
decrease-51      agent:  united-states-of-america-54
                 theme:  quota-52
quota-52         theme-of: decrease-51 inference63
                 RELATION: export-57 fabric-55 china-56
unilateral-53    domain: decrease-51
united-states-of-america-54
                 agent-of: decrease-51 inference65
fabric-55        RELATION-OF: quota-52
china-56         RELATION-OF: quota-52
export-57        RELATION-OF: quota-52
INFERENCE63     type:   METONYMY
                 object64   DOMAIN-OF: quota-52
INFERENCE65     type:   METONYMY
                 human66    MEMBER-OF: united-states-of-america-54
```

The natural language output produced by the generator is as follows:

*The USA unilaterally reduced China's textile export quota.*

<sup>4</sup> [For nouns], “Heads are final with respect to modifiers.” (Huang, 1997).

We refer the reader to Beale *et al.* (1995) for the details on the semantic disambiguation process. Briefly it operates as follows: i) Derive selectional constraints from the lexicon and the ontology for each pair of syntactically dependent words, in both directions; ii) Check each constraint by finding the "distance" between the pair of concepts in the ontology (Onyshkevych, 1997); iii) Combine the results in an efficient constraint satisfaction algorithm to select the best combination of senses for all the words in a text (Beale, 1997).

The above description gives a general view of our approach to the application of selectional constraints during processing, and some insight into our approach to computational semantics. Results on the WSD for Spanish can be found in Mahesh *et al.*, (1997). Note that the semantic processor does more than matching selectional constraints or finding the distance along ISA links. The search inside the ontology also involves looking for metonymic type links, as identified in INFERENCE65 where *US* is in a metonymic relation with HUMAN, and INFERENCE63 where *quota* is an ATTRIBUTE with a DOMAIN: OBJECT, which enables it to "match," via relaxation, to the grammatical object of DECREASE which has a semantic type OBJECT. Also note that the semantic analyzer signals when there are RELATIONs between the Ns inside the compounds, although, at this point, it does not further go down the hierarchy of concepts to recover the most specific one which could apply between the Ns. The generator takes care of the recovery on a needed basis (e.g. when an English compound cannot be used), as discussed further.

Finding out which relation holds between words with a good confidence in retrieving the right one from the ontology requires to first get a high confidence rate on the WSD in general and on the words entering in the relations in particular. We present below results on WSD on a very complex sentence with 28 words.

在 第 21 届 东 新 澳 中 央 银 行 组 织 行 长 研 讨 会 上 中 国 人 民 银 行 副 行 长 殷 介 炎 就 资 本 大 量 流 入 情 况 下 宏 观 经 济 政 策 的 协 调 问 题 发 表 意 见

*At the 21st Southeast-Asia-New-Zealand-Australia (SANZA) Central Bank Organization Presidents' Symposium, the vice president of the People's Bank of China, Yin Jie Yan, expressed his opinion on the issue of the macro-economic policy coordination under the condition that capital inflow in large amounts.*

We present below extracts from the f-structure, where compounds were left at the same level of ambiguity, followed by their respective TMRs.

```
COMPOUND1 (东新澳中央银行组织行长研讨会)
... (MODS ((ROOT 东新澳) (CAT PROP)
           (GLOSS Southeast-Asia-New-Zealand-Australia (SANZA))
           (SEM LARGE-GEOPOLITICAL-ENTITY))
      (MODS ((ROOT 中央银行组织) (CAT PROP) (GLOSS Central Bank Organization)
           (SEM FOR-PROFIT-CORPORATION)))
      (MODS ((ROOT 行长) (CAT N) (GLOSS business-leader) (SEM PRESIDENT-CORPORATION))
      (ROOT 研讨会) (CAT N) (GLOSS symposium) (SEM ACADEMIC-CONFERENCE))
```

```

COMPOUND2 (宏观经济政策)
(MODS (MODS ((ROOT 宏观) (CAT ADJ) (GLOSS macroscopic) (SEM MACROSCOPIC-ATTRIBUTE)))
(MODS ((ROOT 经济) (CAT N) (GLOSS economic) (SEM ECONOMY)))
(ROOT 政策) (CAT N) (GLOSS policy) (SEM LAW)))
(MODS ((ROOT 的) (CAT MKADJ) (GLOSS of, that) (SEM RELATION)))
(ROOT 协调) (CAT N) (GLOSS coordination) (SEM COORDINATE)))
(ROOT 问题) (CAT N) (GLOSS issue) (SEM PROBLEM))) ...

```

FRAMES IN COMPOUND1:

```

large-geopolitical-entity-644
    object-name: Southeast-Asia-New-Zealand-Australia (SANZA)
    RELATION-OF: academic-conference-663
president-corporation-651
    RELATION-OF: academic-conference-663
for-profit-corporation-658
    object-name: central-bank-organization
    RELATION-OF: academic-conference-663
academic-conference-663

```

FRAMES IN COMPOUND2:

```

macroscopic-attribute-647 domain: law-648
law-648
    mental-object-attribute: macroscopic-attribute-647
    theme-of: coordinate-665
    RELATION: economy-654
problem-649
economy-654
coordinate-665 RELATION-OF: problem-649
    theme: law-648

```

Note all the RELATION(-OF) introduced by the semantic processor, enabling the generator to later identify semantic heads to produce English compounds or phrases.

The generator produced the following compounds: “At the 21st *presidents' symposium of the Southeast-Asia-New-Zealand-Australia Central Bank Organization*, the vice president **of the People's Bank of China**. Yin Jie Yan, expressed his opinion on the problem coordinating *the macroscopic economic law* under the situation that capital largely inflow.”

We marked above in *italics* the compounds generated, and in **bold face** the links, absent in Chinese that were added by the generator. Note that our semantic approach will enable the generator to produce the verb *coordinating* instead of the noun *coordinating*. This is due to what we call a *transcategorical* approach, where a semantic frame is not linked to a specific part of speech, providing for more room for paraphrasing at the generation level. For instance, *explode* and *explosion* will both have the exact same semantics (e.g. Viegas, 1999). RELATIONS have been so far grammaticalized as *N of N* or as an English compound for nouns *NN*, and results for our texts are very reasonable. However, there are cases where one needs to explicitly lexicalized the relation in a compound, as we discuss in section 4. This implies to have a high confidence on the senses selected during WSD. We present the table for the complex sentence

98000 above. We measure complexity in terms of number of words in a compound and numbers of markers present in the sentence. For instance, in 98000, 7 words (out of 28) were 2-ways ambiguous and 1 was 4-ways ambiguous among open-class words. The table below is for open-class words only.

|                              |                       |
|------------------------------|-----------------------|
| Sentence Number:             | 98000                 |
| Number of senses in lexicon: | 1 2 3 4 5 6           |
| correct:                     | -----<br>12 5 0 0 0 0 |
| incorrect:                   | 0 1 0 1 0 0           |
| total:                       | 12 6 0 1 0 0          |

In next section we turn to the discovery of the relation holding between words.

## 4 Using Overt Semantics for the Translation of Chinese Compounds

Compounding in Chinese is a common phenomenon (Li and Thompson 1981; Palmer and Wu, 1995; Huang 1997; Starosta *et al.*, 1997). It is mainly used to combine 1) characters whose semantics is different and non compositional (Jin, 1994), and 2) sequences of words.

In this paper we are concerned with 2) only, with a focus on nouns. The head of the compound can be identified as the last noun in a sequence of Ns. Therefore in the task of translating Chinese compounds into English compounds, where English also makes use of compounds as opposed to say French, one could adopt a transfer-based approach, where each Chinese noun is translated into English in the same sequence, as in *应用软件(application software)* or *资料管理系统(data management system)*. But it gets a bit more complex when there is a large sequence of nouns in English, whereas it is still acceptable and normal in Chinese. In our corpus we found compounds containing up to 6 nouns with no markers to identify subheads: *军事理论考核题库管理系统 (the management system of the database for testing military theory)*. In these cases, it seems difficult to comprehend the compound in English and some “linking information” is needed to break the compound and make it understandable in English. One needs to first understand the underlying relationships between the nouns, and identify the semantic “sub-heads” inside the Chinese compounds, which will become the heads of smaller English compounds linked via relations. For instance, in *军事理论考核题库管理系统 (the management system of the database for testing military theory)* one might want to “break” the Chinese compound into smaller English compounds “management system,” “database” and “military theory” with a relation (e.g., “used for”) between the last compounds (the management system of the database used for testing military theories). In the following, we show how an overt semantics (i.e. where the meanings of the words are expressed via concepts which are defined in a rich and well-structured ontology) can help identify semantic sub-heads inside a Chinese compound (the head of the Chinese compound is the last noun (Huang 1997)).

To illustrate how to identify semantic sub-heads in a compound, we will first restrict the explanation to two Ns, assuming they are part of a larger compound. The same

approach applies to more than 2 nouns, as will be further illustrated, and also to other parts of speech.

Lexemes can be mapped to Objects (O) (“Car” car), Events (E) (“Explode” *to explode, explosion*), Relations (R) (“Utilizes” *to use, the use of...*) or Attributes (A) (“ColorAttribute” *color*). In the case of NNs, we have 14 combinations allowed (RR and AA do not seem to co-occur), where E, O and R can be heads, with the following hierarchy of headhood:

$$E > R > O$$

When the semantics of the NN is expressed with a combination of identical types (e.g. EE or OO), the semantic processor scores the constraints between the two nouns to find the head, and eventually finds the semantic relation linking the two nouns in the ontological entry of the nouns, as in the example OO below.

(OO) Object - Object

```
[[mods 计算机 (n, ji4suan4ji1, computer)] computer
 [n     技术   (n, ji4shu4, technology)]] technology
```

Here, both nouns are typed as O, and therefore we need a mechanism to assign the head. The generator must identify the underlying relation between the Os. This is done by searching for a relation R in the ontology shared by the 2 Os, such as UTILIZES with a DOMAIN and RANGE which are in ISA relationship with “technology” and “computer,” respectively. In this case, we could successfully generate *technology about computer* and *computer technology*, with a preference on the latter.

(OR) Object - Relation

```
[[mods 行 (n, hang2, business)] for-profit-service-corporation
 [n     长 (n, zhang3, leader)]] head-of
```

“Head-of” is a relation and therefore the head, as the other noun is an O. The generator can lexicalize this as *leader of business* or *business leader* via a rule; the latter is assigned a preference in absence of modifiers such that we can still generate *the leader of a big business* instead of *?big business leader*. We found this in a larger compound where the generator was able to generate *the major office of the business leader* and not say *?leader of the major office business*, as the MODS indicated.

(EA) Event - Attribute

```
[[mods 出口 (n.chukou3, export)] export
 [n     配额 (n, pei4e2, quota)]] quota
```

Here E is the head and this semantics is lexicalized as *quota of exporting* or *export quota*, with again a preference on the latter.



(OR) illustrates a transcategorial approach, where, for instance, an Adjective becomes a Noun, or a Noun a Verb, via a lexical rule.

```
[[mods 经济 (n,jing1ji4,economy)]      economy
 [n    效益 (n,xiao4yi4,benefit)]]    benefit-from
```

Here is a case where a transcategorial approach to lexicon representation helps in generating an AdjN construction *economic benefit* for an NN Chinese compound; this is due to the fact that both *economy* (Noun) and *economic* (Adj) share the same semantics, and thus the generator will present both possibilities. Moreover, they co-occur in English whereas *economy* and *benefit* do not. The head is easily identified in R “benefit-from” and as such the compound could also be generated as *benefit to economy*.

(OEE) illustrates a phrase

```
[[mods 科技 (propn,ke1ji4,science&technology)] science technology
 [mods 攻关 (n,gong1guan1,tackle key problem)] solve - problem[+saliency]
 [n    计划 (n,ji4hua4,plan)]]           planning-event
```

This NNN compound presents a case of mismatch (e.g. Dorr 1993) between Chinese and English, it can be paraphrased as: *plan to solve key problems in science and technology*. Here, a transfer-based approach would fail to translate adequately, as 攻关 (tackle key problem) must be expressed as an expression equivalent to *solving important problems*, and as such the following English compound *science technology solving key problem plans* must be broken into smaller compounds with explicit relations between them.

These examples illustrate why a semantic approach is preferable, and sometimes necessary, to translate Chinese compounds into English. However, this approach can be knowledge intensive. So, because English compounding seems to follow the same Chinese word order regularly enough, we also consider using a transfer approach as a back-up to generation.

We can do this because English allows compounding (whereas for French and Spanish, a transfer approach would be more problematic as compounding is not as productive and relations must be identified). However, as we noticed previously, it can become difficult in English to get the meaning of a large compound, it is therefore better to “break” the compound into 2 or 3 smaller compounds. We saw that in a semantic approach the headhood hierarchy provides a good heuristics to break a, compound.

One drawback of our “overt semantics” approach, with all mods left at the same level, is that it requires our lexicons 1) to be mapped to an ontology which allows for inferencing, and, 2) to encode refined lexico-semantic information in our lexicons, of the co-occurrence or collocational type, as can be seen in this example below for *computer database for test of military theory*:

|           |                             |                   |
|-----------|-----------------------------|-------------------|
| [mods 计算机 | (n, ji4suan4ji1, computer)] | computer          |
| [mods 军事  | (n, jun1shi4, military)]    | military-activity |
| [mods 理论  | (n, li3lun4, theory)]       | theory            |
| [mods 考核  | (n, kao3he2, test)]         | examination       |
| [n 题库     | (n, ti2ku4, database)]      | database          |

Here, if we wanted to generate “computer” and “database” together as a compound, then we need to encode the expression as a co-occurrence in the lexicon (see Viegas *et al.* (1998) for details).

## 5 Conclusions - Perspectives

In this paper, we showed the advantage of adopting an overt semantics for MT when the language does not offer morpho-syntactic clues.

The work reported here is being conducted on a small scale (about 100 sentences) using a Chinese lexicon of about 2500 word sense entries and an English lexicon of about 12,000 word sense entries. Results on WSD are promising (above 90% of open-class words correctly disambiguated in complex sentences). The Chinese effort has involved the tagging of all the words in our training corpus of 10 texts to identify the “right” sense with respect to our static knowledge sources. Note that there are yet no absolute measures to identify the “real” performance of a system in terms of sense assignment, as discussed recently in WSD meetings (e.g. SENSEVAL). We read the numbers for WSD as qualitative measures showing our progress (program debugging and development modification/tuning of lexical resources.)

Concerning compounds, we have shown that, we cannot avoid a semantic approach if we want a high-quality translation because of the number of words which can enter into a Chinese compound, making it difficult, to get the meaning of the compound in English. We focused in this paper on noun compounding, but our approach can be applied to other compounds as well, because it is semantic-driven. In other words, it is the semantics of words which help determine the privileged relations which are allowed by the semantic typing system. The only syntactic clues used are markers and final noun positions, which help identify the head of a compound. Note that for verb compounding, our syntactic clue will have to be changed to deal with right headed finals. We showed the advantage of exploiting semantics upfront (“overt semantics”), in order to resolve compounding ambiguities by recovering the relation between words in compounds. However, the decision of recovering or not the RELATION is left to the generator and not the analyzer. The decision is driven by the compounding properties of the target language. For instance, for Spanish and French, it is necessary to recover the RELATION whereas for English our threshold is above three RELATIONS.

Future work involves a large-scale experiment, and the translation of other types of compounds. From this larger experiment we expect to refine our threshold for English, and also add preferences to the generator, based on corpora co-occurrences for the English compounds. However, we believe it is very important to have a symbolic approach as our goal is to better understand the functioning of compounds to help us to better predict when to generate them or not.

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