Anaphora resolution and generation in a multilingual system. An Interlingua mechanism

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Abstract

In this paper, an Interlingua mechanism called *Interlingua Slot Structure* (*ISS*) due to the fact that it is based on *Slot Structure* (*SS*) presented in Ferrández *et al.* (1997a, 1997b), is proposed. *SS* stores the lexical, syntactic, morphologic and semantic information of every constituent of the grammar. The mechanism *ISS* allows to carry out translations of pronouns between different languages. In this paper, *ISS* has been proposed and evaluated for the translation between English and Spanish languages. Pronominal anaphora resolution both in English and Spanish languages has been compared to accomplish a study of the existing discrepancies between two languages.

Introduction

As presented in Peral *et al*. (1999b), the establishment of the antecedents of anaphora is of crucial importance for a correct translation. It is essential to solve the anaphoric relation when a language is translated into one that marks the pronoun gender. On the other hand, anaphora resolution is vital when translating discourse rather than isolated sentences since the anaphoric references to preceding discourse entities have to be identified. Unfortunately, the majority of Machine Translation (MT) systems do not deal with anaphora resolution and their successful operation usually does not go beyond the sentence level.

This Interlingua mechanism proposal considers that the pronouns are not autonomous in their meaning/function but dependent on other units in the text. After applying the anaphora resolution module, a structure that stores the pronominal anaphora and its antecedent in the source language is used. From this structure, a similar one in the target language is generated. Using this new structure, it is possible to generate the final surface structure of the original sentence.

Section 1 will show an evaluation of several MT systems. This evaluation justifies the main objective of this work, it means, the development of an anaphora resolution system in a multilingual scope. This is the main point that marks the difference between the Interlingua mechanism and the rest of the commercial and experimental MT systems. In section 2, the general purpose anaphora resolution system will be described. In section 3, the anaphora resolution module will be detailed, where the differences between English and Spanish systems on resolving anaphora will be studied and some evaluation results in both languages will be reported. In section 4, the Interlingua mechanism will be presented. This mechanism is based on the English-Spanish discrepancy analysis. This analysis will be explained in section 5. An analysis about the evaluation of anaphora generation and conclusions about this work will finish the paper.

1. Evaluation and discussion of MT systems

As it has been mentioned, MT systems usually do not solve anaphora. In this work, different MT systems with several sentences containing pronominal anaphoric expressions have been evaluated.

Systems used for this analysis[1] are shown below.

(a) Key Translator Pro Version 2.0.
(b) Power Translator Professional.
(c) DosAmigos version 4.0.
(d) SYSTRAN Translation Software *(http:// babelfish.altavista.com/cgi-bin/translate).*
(e) TRASCEND Translator *(http://www.translc. com/main.htm*).
(f) INTERTRAN Internet Translator *(http://www. tranexp.com:2000/InterTran).*

[1] All the systems with an URL address in their reference have been visited on February 1999.

(g) WINBABEL Translator *(http://www.winbabel. com).*
(h) SANCHO. Automatic translation of Spanish web pages into English. Only Spanish→English *(http://www.sancho.com).*
(i) MINDS. Three Languages Summarization-Translation[2]. Only Spanish→English *(http:// messene.nmsu.edu/~mcm/minds/Summarizer/SummarizerDemos/FourLanguages/Demo/SummTransDemoMain.html).*

These systems with several sentences containing different classes of pronominal anaphora have been tested. These kinds of anaphora try to test the behaviour of each system with possible translation problems.
Globally, the studied systems do not use information about previous translated sentences. Some of them make a word-to-word translation –e.g. (1) from MT system (g)– and some others make a sentence-to-sentence translation –e.g. (2) from MT system (b)–.

(1) ENG Women were in the duty-free shop. They were buying gifts for their husbands.
SPA Women[3] fueron en el tienda duty-gratis. Ellas fueron comprando dádivas para sus maridos.
(2) ENG Women were in the duty-free shop. They were buying gifts for their husbands.
SPA Las mujeres estaban en la tienda libre de impuestos. Ellos compraban los regalos para sus esposos.

When translating, systems have different problems. One of them is the gender and number agreement, that is, they cannot relate pronoun gender and number with antecedent gender –e.g. (3) from MT system (a)– and number –e.g. (4) and (5) from MT system (d)– .

(3) ENG ***Some actresses*** went on strike because ***they*** didn't agree with the company.
SPA ***Algunas actrices*** ido en huelga por que ***ellos*** no estuvieron de acuerdo con la compañía.

(4) ENG The police ***are*** coming and ***they are*** late.
SPA El policía ***está*** viniendo y ***él es*** atrasado.

(5) SPA La ***gente*** no es feliz y ***ésta*** siempre quiere más.
ENG People ***are*** not happy and this one always ***wants*** more.

Another problem is the lack of semantic information –e.g. (6) from MT system (f)–. This information is very important to deduce the pronoun to be used (for example, *he* for person and *it* for animals and things).

(6) SPA ***El león*** y la cebra bebían agua en el río y después ***él*** saltó detrás de los árboles.
ENG ***The lion*** and her zebra they drank water in the river and hereinafter ***he*** jumped behind the trees.

One important aspect of Spanish language is that the pronominal subject is usually omitted. The use of this pronoun is necessary only if it is used to emphasise or to choose one of several possible antecedents. However, pronominal subjects should not be omitted in English. This phenomenon is usually called zero-subject constructions and it has been tested in the analysis[4] –e.g. (7) from MT system (i)–.

(7) SPA La mujer tenía hambre y ∅ comió una manzana.
ENG the woman had hunger and ∅ ate a apple

In the proposed mechanism, these translation problems of MT systems are studied in discrepancy analysis and they are solved by Interlingua mechanism. This mechanism allows the correct generation of pronouns into the target language.

2. General purpose anaphora resolution system

The complete MT system presented in this paper is based on the scheme of *Figure 1*. It can be observed that there are two processes in parallel, corresponding to anaphora resolution in English and Spanish. These two processes are independent of each other and they are connected by means of the Interlingua mechanism.
The input of each process is a grammar defined by means of the grammatical formalism *SUG* (*Slot Unification Grammar*) Ferrández *et al.* (1997a). This formalism makes the resolution of several NLP problems easier, such as ellipsis or anaphora mentioned in Ferrández *et al.* (1997b). A translator that transforms *SUG* rules into Prolog clauses has been developed. This translator will provide a Prolog program that will parse each sentence.
One of the advantages of this system is that it can carry out a partial or full parsing of the text with the

[2] Although this system is defined as a summarization one, a direct translation using a summarization ratio of 99% has been obtained.

[3] Some MT systems do not translate all the words in the sentence. In this case, "Women" has not been translated into Spanish word "Mujeres".

[4] The symbol ∅ in the sentence marks the omitted pronominal subject in that position.

same parser and grammar. By means of partial parsing (*SUPP*) presented in Martínez-Barco *et al.* (1998) and Peral *et al.* (1999a) the system can work on unrestricted corpora that contain the words tagged with their obtained grammatical categories from the output of a "part-of-speech (POS) tagger". It can also treat restricted texts that contain words without tagging (grammatical categories of the words will be obtained by accessing their lexical entries in the dictionary). Therefore, this system is very flexible and it allows to work with different dictionaries and taggers with the same *SUG* grammar since only the appropriate interface between the 'labels' of the *SUG* grammar and the 'tags' of the tagger or the dictionary has to be defined. In this paper, a bilingual corpus has been used (*The Blue Book*, English and Spanish), CRATER (1994), for the evaluation of pronominal references resolution module.

The output of the parsing module will be the *Slot Structure* (henceforth *SS*) that stores the necessary information for linguistic phenomena resolution. This *SS* will be the input for the following module in which anaphora resolution as well as other linguistic phenomena (extraposition, ellipsis, etc.) will be treated.

After applying the linguistic phenomena resolution algorithm a new Slot Structure (*SS'*) is obtained. It will store the anaphora and their antecedents. This new structure in the source language will be the input for the Interlingua mechanism, which will provide the corresponding Slot Structure in the target language. Using this new structure, the final surface structure of the original sentence will be generated.

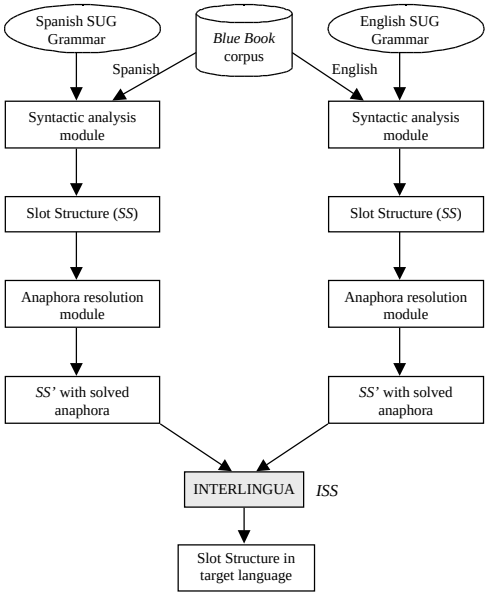

Figure 1.

3. The anaphora resolution module

In this section the anaphora resolution module of the system will be described. This section consists of two subsections. In the first one, the algorithm for anaphora resolution will be detailed, and in the second one, the evaluation of the system will be shown.

3.1. The algorithm

As it can be observed in *Figure 1*, the algorithm for anaphora resolution will be applied after the parsing of a sentence. This algorithm deals with discourse anaphora in unrestricted texts using partial or full parsing. It can deal with pronominal references, surface-count anaphora and one-anaphora as it has been shown in Ferrández (1998a,1998b).

The input of the algorithm is the sentence's *SS* obtained after the parsing module. A set of constraints (morphosyntactic agreement and c-command constraints) will be applied to the list of possible antecedents (noun phrases) of each anaphor in this *SS*, in order to discount candidates. If there is only one candidate, this one will be the antecedent of the anaphor. Otherwise, if there is still more than one candidate left, a set of preferences (syntactic parallelism, lexical information, reiteration of an antecedent in the text,...) will be applied. These preferences will sort the list of remaining antecedents, and the first one will be the selected antecedent. These constraints and preferences are described in detail in Ferrández (1998a,1998b).

The proposed algorithm detects the anaphora and possible antecedents by means of the information stored in each *SS*, i.e. its functor and arity. For example, the antecedents (noun phrases) have a *SS* with *np* as their functor, whereas the pronouns have *pron*. The previous two sentences have been considered to search for antecedents of a pronoun due to there is no semantic information. Good results with several corpora (including *The Blue Book*) have been obtained with this strategy.

The output of this algorithm will be a new Slot Structure (*SS'*). This structure will store the anaphoric expression and its correct antecedent (chosen from the possible candidates). *Figure 2* shows the way of storing the information about the antecedent into *SS'*.

This *SS* stores for each constituent the following information: constituent name, semantic and morphologic information (structure with functor *conc*), discourse marker (identifier of the entity or discourse object: *X*, *Y*, *Z* and *V* in *Figure 2*) and the *SS* of its subconstituents. Antecedent information is stored into pronoun's *SS* in the position of its discourse marker.

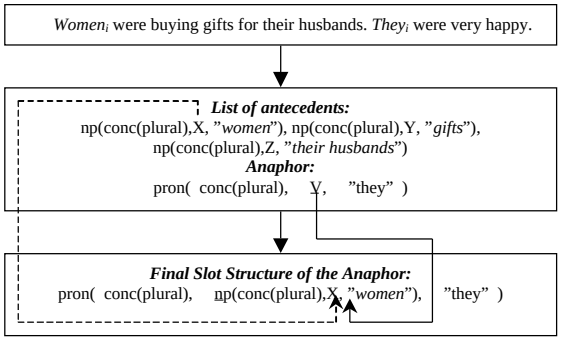

Figure 2.

3.2. Evaluation of the anaphora resolution module

As presented in Ferrández *et al.* (1998b), the system has been evaluated on part of the Spanish version of *The Blue Book* corpus. In this evaluation, semantic information was not used since the tagger did not provide this information. In spite of this lack of information the following figures were obtained: it detected 100% of the pronominal anaphors, medium length of sentences with anaphors was 48 words and for pronominal references 83% accuracy[5] was obtained.

Taking as base the Spanish version of the system, two main changes have been carried out in order to adapt it to the English language. The first one is the new English grammar in which the grammatical rules of the constituents to parse (*np* and *pp*) have been written. Obviously, this new grammar is formed by different sets of terminal and nonterminal symbols. The second change has been the interface between the grammar and the tagger, due to the English Xerox tagger has also different tags.

The set of constraints and preferences has not suffered any change from one system to the another one since the same kinds of knowledge have been used. Only the different relevance of these constraints and preferences between both languages has been bore in mind in the English system.

As presented in Peral *et al.* (1999b), the following figures have been obtained for *The Blue Book* in English: 79 pronouns (*it*[6]*:41, they:29, themselves:9*) with an accuracy of 87.3% (*it:80.5%, they:93.1%, themselves:100%*); on average, 22 words per sentence. These percentages are better than the obtained results by Kennedy and Boguraev (1996), 75%, although it is difficult to compare both measures since have been obtained from different texts.

The reason why some of the references failed is mainly due to the lack of semantic information and due to some weakness of the English grammar used in the evaluation.

The differences between English and Spanish pronoun resolution have been reported in Peral *et al.* (1999b). With reference to the number of antecedents, a greater number of possible antecedents for Spanish pronouns (26) than for English (11) has been observed. This fact could be due to the larger size of Spanish sentences. Another difference is that constraints (c-command and morphologic agreement) have played a more important role for Spanish texts in the detection of the antecedent. The total number of possible antecedents is reduced from 733 to 222 (a reduction of 70%), whereas for English texts it has only a reduction of 37.7%. This fact is mainly due to the fact that Spanish language has more morphologic information than English one. With regard to the relevance of each kind of knowledge for each language, if the same set of preferences in Spanish and English is applied, 76% accuracy in English is obtained. However, a better accuracy (87.3%) is obtained if more relevance to syntactic parallelism (same syntactic role in the sentence) and less relevance to statistical information is given. This statistical information includes two indexes: on one hand, the number of occurrences of a *np* in the text, and on the other hand, the number of occurrences of a *np* before and after the verbs at the same clause.

4. Interlingua mechanism: *Interlingua Slot Structure* (*ISS*)

In this section, the translation process for a pronoun's *SS* from the source language into the target language will be detailed.

Once the anaphora resolution module has ended, the pronoun's *SS* is obtained. This *SS* contains the antecedent's *SS*. The mechanism *ISS* translates pronoun and antecedent to obtain the new *SS* in the target language.

Next, the process of pronominal anaphora English-Spanish translation when the antecedent is a noun phrase (*np*), where the head is a noun, will be explained. The complete process is shown in *Figure 3.*

The process begins with the translation of the English grammar terminal symbols into the Spanish ones. Gender and number information of the pronoun and the antecedent is extracted from the *np* head chosen as the anaphora solution.

[5] Pronouns rightly solved divided by total number of pronouns.

[6] Pleonastic pronouns *it* (i.e. non-anaphoric *it*) have not been included in these results.

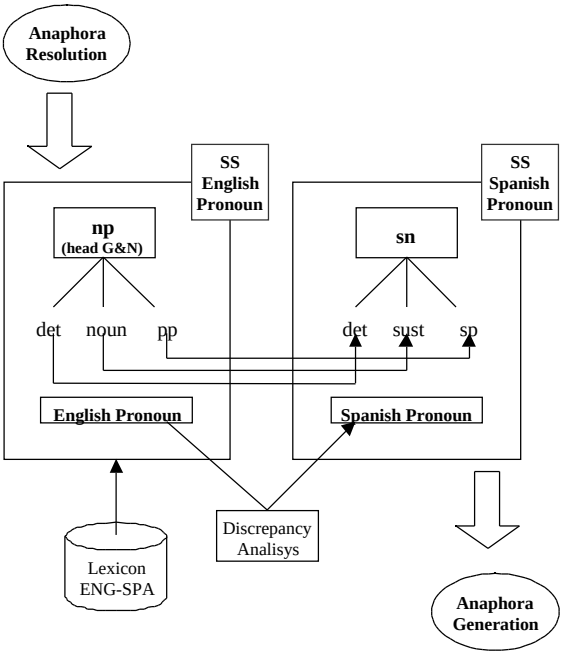

Figure 3.

In *The Blue Book* Spanish corpus, the tagset contains gender and number information of the basic constituents in the grammar, so this information can be extracted from the *np* head. Most of the nouns in *The Blue Book* English corpus do not contain gender information in their tag and in many cases neither number information. In these cases, this information can be obtained from the translation of the *np* head into Spanish. This translation is obtained from a bilingual lexicon.

The equivalence of English and Spanish terminal symbols is shown in *next table*.

ENGLISH GRAMMAR		*SPANISH GRAMMAR*
Enoun (N, EngWord)	⇒	**Snoun (HN, HG, SpaWord)**
Edet (EngWord)		Sdet(HN, HG, SpaWord)
Eadj (EngWord)		Sadj(HN, HG, SpaWord)
Everb (T, EngWord)		Sverb(HN,HG,T, SpaWord)
Eadv (EngWord)		Sadv(SpaWord)
Eprep (EngWord)		Sprep(SpaWord)
Econj (EngWord)		Sconj(SpaWord)
Epron(N, P, EngWord)		Spron(HN, HG, P, SpaWord)

In this table, *N* is the number, *HN* and *HG* are head number and head gender extracted from the bilingual lexicon, *T* is tense, *P* is person and *EngWord* and *SpaWord* are the English and Spanish words respectively. In addition, the identifier of the language is the first letter in the name of each terminal symbol. *Figure 4* shows an example of terminal symbol translation.

Figure 4.

When the translation of the terminal symbols has been made, the translation of the non-terminal symbols begins. Translation of prepositional and noun phrases is shown in next table.

ENGLISH GRAMMAR	*SPANISH GRAMMAR*
pp (Eprep, np)	sp (Sprep, sn)
np (Edet, Eadj$_1$, Eadj$_2$, ..., Eadj$_n$, Enoun)	sn (Sdet, Snoun, Sadj$_n$, Sadj$_{n-1}$,..., Sadj$_1$)
np (Edet, Eadj, Enoun$_1$, Enoun$_2$, ..., Enoun$_n$)	sn (Sdet, Snoun$_n$, sp$_{n-1}$, sp$_{n-2}$, ..., sp$_1$, Sadj)
np (Edet, Eadj$_1$, Enoun, Eadj$_2$)	sn (Sdet, Snoun, Sadj$_1$, Sadj$_2$)
np (Edet, Enoun, pp)	sn (Sdet, Snoun, sp)
np (Edet, Enoun, relClause)	sn (Sdet, Snoun, oracionRel)
np (np$_1$, Econj, np$_2$)	sn (sn$_1$, Sconj, sn$_2$)

An example of the translation of the *np*'s *SS* extracted from the corpus can be observed in *Figure 5*. Gender and number information of the Spanish *np* is extracted from the *np*'s head (noun). In this case, the head is masculine and singular (information obtained from the translation of the English word *protocol* into the Spanish word *protocolo*). Furthermore, the modifiers of the *np*'s head agree in gender and number with the head. Therefore, the English determiner *the* is translated into the Spanish determiner *el* (masculine singular) and the English adjective *relevant* is translated into the Spanish adjective *relevante* (masculine singular). After carrying out the translation of the terminal symbols, the process of translating non-terminal symbols begins. Consulting the previous table, the English *np* formed by a determiner, an adjective and a noun is translated into the Spanish *np* formed by a determiner, a noun and an adjective. Then, the English *np «the relevant protocol»* is translated into the Spanish *np «el protocolo relevante»*.

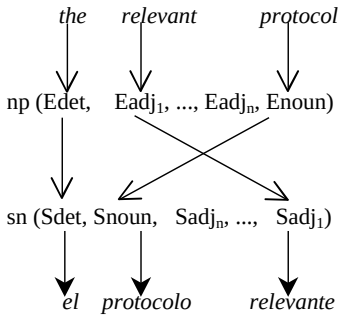

Figure 5.

Another example of this translation extracted from the corpus is shown in *Figure 6*.

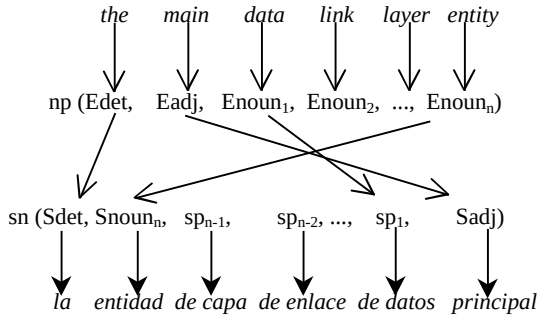

Figure 6.

In pronoun translation, the gender and number information of the antecedent and the discrepancy analysis (explained in detail in the following section) are counted on. These characteristics allow to translate the English pronoun into the correct Spanish pronoun.

5. Discrepancy analysis

Discrepancy denotes the difference between two languages when translating an expression. This section is divided into several subsections that treat different discrepancies between English and Spanish in the generation of pronominal anaphora with subject role. In Peral *et al.* (1999b) an exhaustive discrepancy analysis was presented.

5.1. Number discrepancy resolution

One of the problems in translation is the discrepancy between words of different languages that express the same concept. These words can be referred to a singular pronoun in the source language and to a plural pronoun in the target language.

A table with the words that refer to a singular pronoun in the source language and to a plural pronoun in the target language is constructed in order to be able to solve these discrepancies correctly. Firstly, this table in the anaphora translation is consulted. If the pronoun and its antecedent appear in this figure, the indicated transformation will be carried out. In *Figure 7*, some examples of these pronouns are shown.

Anteced	***Span. Anaphor***	***Eng. Anaphor***	***Anteced***
Juventud	Ésta	They	Youth
Ganado	Éste	They	Cattle
Gente	Ésta	They	People
...			

Figure 7.

In *Figure 8* the English-Spanish translation of a sentence with number discrepancies is described. In this figure, the translation of English *SS* into Spanish *SS* is shown. Henceforth, the simplified *SS* where it solely appears the relevant information for each example will be written.

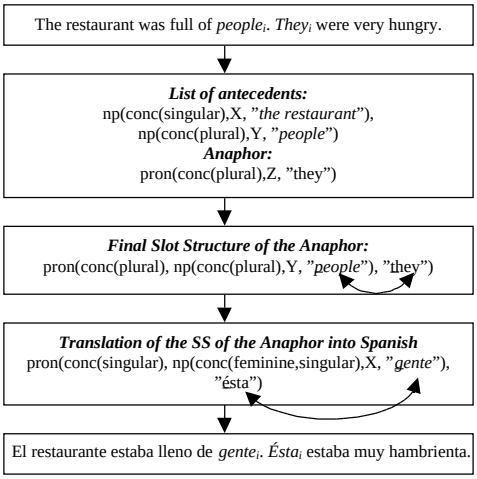

Figure 8.

5.2. Gender discrepancy resolution

In order to solve personal pronoun gender discrepancies, a table that translates Spanish personal pronouns into the English ones and vice versa is constructed.

In the Spanish-English translation, the main problem is the pronoun *it*. The Spanish pronoun *él/éste* (masculine singular third person) can be translated into *he* or *it*. If the antecedent of the pronoun *él/éste* refers to a person, it will be translated *he*. If the antecedent of the pronoun is an animal or a thing it will be translated into *it*. These characteristics of the antecedent can be obtained from the semantic information that it is stored in its *SS*.

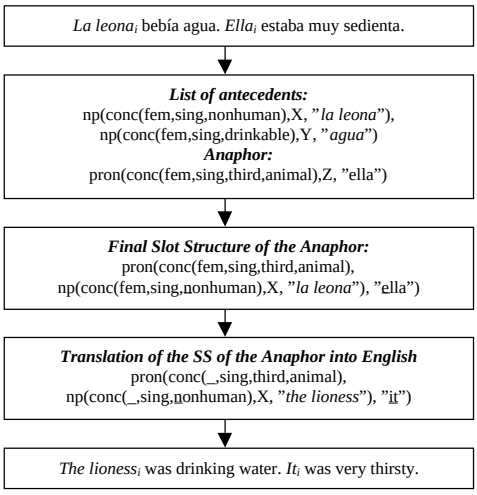

Figure 9.

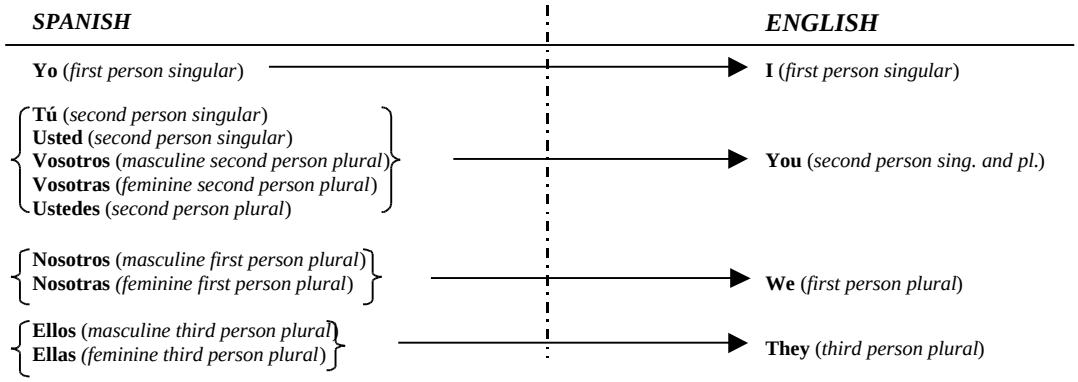

Figure 10

The semantic information can be incorporated to the system using IRSAS method in Moreno *et al.* (1992) or another linguistic resource, like WordNet presented in Miller *et al.* (1990). A similar trouble occurs with the Spanish pronoun *ella/ésta*, which is solved in the same way.

In the example of *Figure 9*, the third argument of the *conc* structures of these *SS* is the semantic type, according to the IRSAS ontology. As it can be observed, the *np "the lioness"* has the semantic type nonhuman (animal), and for this reason, the pronoun *ella* is translated into *it*.

The table of *Figure 10* is used for the remaining pronouns and a direct conversion into English is made.

Spanish has more morphologic information than English. This is extremely relevant in the English-Spanish translation. In order to solve this problem and to choose the right Spanish pronoun, it is necessary to obtain the gender and number information from the antecedent of the anaphora and carry out the translation. The pronoun *it* involves a series of problems since it can be translated into four different Spanish pronouns (*él*, *ella*, *éste*, *ésta*). These Spanish pronouns refer to both animals and things, but normally *él/ella* refers to animals and *éste/ésta* refers to things. Therefore, in the automatic Interlingua mechanism, when the antecedent of the pronoun is an animal it is directly translated into *él/ella* and when it is a thing it is translated into *éste/ésta*, since it is the most common use in Spanish.

5.3. Syntactic discrepancy resolution

This discrepancy is due to the more flexibility of the Spanish surface structures than the English ones since the constituents of the Spanish sentences can appear in any position of the sentence. In order to carry out a correct translation into English, it is important to reorganise the Spanish sentence as a first step. Nevertheless, in the English-Spanish translation, in general, this reorganisation is not necessary and a direct translation can be carried out.

For example, in the Spanish sentence *"A Pedro lo vi ayer"* (*I saw Peter yesterday*), the object appears before the verb (in the position of the theoretically subject) and the subject is omitted. Moreover, there is a pronoun, *lo* (*him*) that functions as complement of the verb *vi* (*saw*). This Spanish pronoun refers to the object of the verb, *Pedro* (*Peter*), when it is moved from its theoretical place after the verb (as it occurs in this sentence). In this sentence, the pronominal subject has been omitted. The subject can be found out since the verb is in first person and singular (information stored into its *conc* structure), so the subject would be the pronoun *yo* (*I*). Therefore, the solution would be a new *SS* in which the order of the constituents is the usual in English: *subject, verb, complements of the verb*.

5.4. Elliptical zero-subject construction resolution

As described in this paper, the omission of pronominal subject is usual in Spanish. In these cases, the gender and person information is extracted from the verb to obtain the corresponding English pronoun.

The omission of the pronominal subject of a sentence can be checked by means of the *SS* of the sentence as it is shown in *Figure 11*. In this figure, the subject of the sentence has been omitted due to the Prolog variable that has been found. When it is omitted in the sentence, the *SS* would have a Prolog variable in the slot corresponding to this noun phrase. The information corresponding to the subject can be obtained from the verb of the sentence. In this figure, it would be third person, singular and masculine or feminine. With these omitted pronominal anaphors, the preference for the subject of the previous sentence (if it agrees in person and number, and if it is semantically consistent) will be applied. This information is used to find its antecedent. In this case

Juan (*John*) with masculine gender, so the final translation would choose a masculine pronoun (*he*).

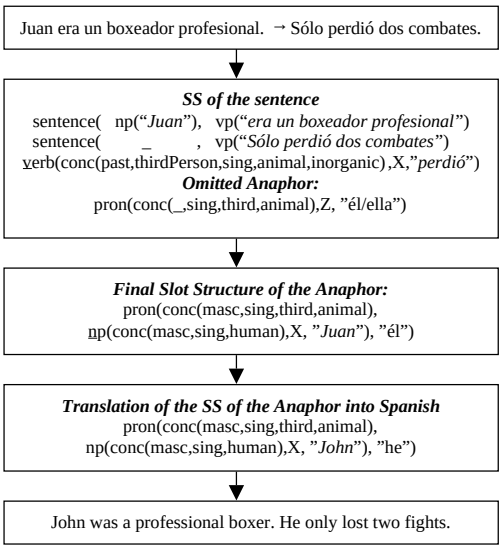

Figure 11.

6. Evaluation of anaphora generation

Interligua mechanism has been evaluated on a fragment from *The Blue Book* corpus in English. The main objective of the evaluation has been to obtain the success rate in pronominal anaphora generation into Spanish (pronouns with subject role have been treated).

With reference to pronominal anaphora, this fragment contains 60 pronouns correctly resolved (*it*:33, *they*:27). The system has rightly generated 56 pronouns and has failed in 4 pronouns, i.e. the mechanism achieves a success rate of 93.3%. Obviously, this good result depends directly on the output of the anaphora resolution phase.

The main cause of fault in generating pronouns has its origin in parsing errors. These errors lead the mechanism to an incorrect choice of the antecedent. Therefore, the generated pronoun does not match with the correct antecedent.

In the sentence

In normal conditions layer 3 ensures the delivery of information in ***the sequence it*** *is submitted by the user.*

the parser identifies *the delivery of information in the sequence* as the antecedent of *it* pronoun. Unfortunately, this pronoun refers to the noun *sequence* and *it* is a member of a relative clause where *that* is omitted. This parsing causes an incorrect generation.

Conclusion

After evaluating commercial MT systems, we consider that most of them do not deal with anaphora resolution. For this reason, we propose an Interlingua mechanism *ISS* that works on pronominal anaphoric expressions and relates the pronouns of different languages (English-Spanish) using information obtained from the anaphora resolution. This mechanism allows a correct translation between both languages.

ISS could be added to a Machine Translation system such as an additional module to solve the anaphora generation problem.

We have observed that if the anaphora resolution is correct, its translation is also correct in a 93.3% of the cases. Nevertheless, we have obtained an accuracy of 83% and 87.3% in pronominal anaphora resolution for Spanish and English languages respectively.

Acknowledgements

This paper has been supported by the Comisión Interministerial de Ciencia y Tecnología with project number TIC97 - 0671-C02 - 02.

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