Multilingual linguistic resources: from monolingual lexicons to bilingual interrelated lexicons

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Abstract

This paper describes a procedure to convert the PAROLE-SIMPLE monolingual lexicons into bilingual interrelated lexicons where each word sense of a given language is linked to the pertinent sense of the right words in one or more target lexicons. Nowadays, SIMPLE lexicons are monolingual although the ultimate goal of these harmonised monolingual lexicons is to build multilingual lexical resources. For achieving this goal it is necessary to automatise the linking among the different senses of the different monolingual lexicons, as the production of such multilingual relations by hand will be, as all tasks related with the development of linguistic resources, unaffordable in terms of human resources and time spent. The system we describe in this paper takes advantage of the SIMPLE model and the SIMPLE based lexicons so that, in the best case, it can find fully automatically the relevant sense-to-sense correspondences for determining the translational equivalence of two words in two different languages and, in the worst case, it will be able to narrow the set of admissible links between words and relevant senses. This paper also explores to what extent semantic encoding in already existing computational lexicons such as SIMPLE can help in overcoming the problems arisen when using monolingual meaning descriptions for bilingual links and aims to set the basis for defining a model for adding a bilingual layer to the SIMPLE model. This bilingual layer based on a bilingual relation model will be the basis indeed for defining the multilingual language resource we want PAROLE-SIMPLE lexicons to become.

1. Introduction

Re-utilization of existing lexical resources and automatic production of more information to enrich them so that these become the basis for a broad range of HLT applications is the main objective of the work presented in this paper. Thus, the objective was to study the feasibility of reusing SIMPLE monolingual semantic lexicons to build a multilingual lexical resource.

SIMPLE is a follow up of the PAROLE project (see www.ub.es/gilcub/SIMPLE/simple.html) that has added a semantic layer to the already existing morphological and syntactic layers developed by PAROLE, being these layers an harmonized common model for computational lexicons encoding relevant information. The semantic lexicons produced (about 10,000 semantic units for each of the 12 PAROLE languages) follow an harmonized common model that encodes structured semantic types and frames, linked to syntactic and morphological information.

The ultimate aim of the work we are reporting is to define a new layer of information that supplies a model for encoding word to word links paired via sense-to-sense correspondences between two, or more, monolingual computational lexicons. This model has to provide the means to create bilingual, in a first step, and multilingual, at the end, links among the words contained in the different lexicons. This paper is however mainly concerned with the procedures that will allow automatic creation of links among words based on their translational equivalence.

The starting point has been to profit of traditional bilingual dictionaries as they are the obvious and most extensive repository of bilingual knowledge. Being, though, for human consultation, the only information we should rely on are the word to word correspondences, as traditional bilingual dictionaries bear little systematic information about constraints on the input and target senses for these words to be related. Thus an entry for the Spanish word manzana in a Spanish-Catalan bilingual dictionary may look like:

(1) manzana: 1. (Fruit) poma (‘apple’), 2. (of houses) illa (‘block’)

Once having extracted the words which can be considered translational equivalents in at least one case, the key point is then to determine under what sense is this correspondence based, so as to consider the combination of ‘word+sense’ as an element of a fully translational equivalent pair for both languages.

The most obvious argument supporting the need for this sense identification is to ensure bi-directionality between bilingual dictionary entries. For example, while in (1) above we know that the correspondence manzana-poma is true bi-directionally, in the correspondence manzana-illa bi-directionality does not hold, as the Catalan entry illa can also refer to an island. This case of partial equivalents is the most frequent case in bilingual dictionaries, due to the polysemy of most words.

1 Sometimes there is no information at all, or it is non-systematically expressed in terms of (i) a semantic descriptor or hyperonym; (ii) an example; (iii) a reference to a domain; etc.
The objective of our experiment is, hence, to evaluate to what extent the sense encoding done in SIMPLE, allows pairing the relevant sense, for example, of the Spanish word *manzana* with the relevant senses of one, or more than one, Catalan words (those that appear in the traditional bilingual dictionary) so that bi-directionality of the word-to-word correspondences is guaranteed when pointing to that sense.

(2) manzana → poma  \(\text{poma} \rightarrow \text{manzana}\)  
    manzana → illa  \(\text{illa} \rightarrow \text{manzana}\)  

Besides, closure of the different senses found for the involved lexical units must also be guaranteed. That is, we want to ensure that the Catalan word *illa* is also put in correspondence with the corresponding Spanish word *isla* under the pertinent sense (i.e. the corresponding 'island'):

(3) manzana → poma  \(\text{poma} \rightarrow \text{manzana}\)  
    manzana → illa  \(\text{illa} \rightarrow \text{manzana}\)  
    isla → illa  \(\text{illa} \rightarrow \text{isla}\)  

Last but not least, when moving from monolingual descriptions to bilingual descriptions we have also had to deal with the well known differences between monolingual sense division and bilingual meaning discrimination. Thus, for instance, in a Catalan monolingual dictionary the ‘food’ meaning of *peix* (‘fish’) is considered a sub-sense inside the prime sense ‘animal’ as represented in (4), whereas in a bilingual Catalan-Spanish dictionary, the ‘food’ sense is promoted to be a sense, as represented in (5), and in a Catalan-English dictionary there is no reference at all to any ‘food’ meaning component, as represented in (6):

(4) Peix: 1 .... 2 1 ‘name given to animals which exclusively live in water’. 2 ‘the meet and certain products of fishes’. 3 ...
(5) peix: *(ichthyology)* pez || *(gastronomy)* pescado  
(6) peix: fish || *pl. (zodiac)* Piscis

Summing up, the system we describe takes advantage of the SIMPLE\(^2\) model (Lenci et al., 2000) and SIMPLE lexicons. The SIMPLE model is based on the recommendations of the EAGLES\(^3\) Lexicon/Semantic Working Group and on extensions of the Generative Lexicon theory. SIMPLE aims at capturing the various dimensions of word meaning and relies on an extension of ‘qualia structure’ (Pustejowsky 1995) for structuring the semantic/conceptual types as a representational aspect of word meaning. The semantic types in SIMPLE are defined as clusters of structured information and form a general ontology which is organized following the principles of orthogonal organization of types, as formalized in the Generative Lexicon. The SIMPLE model makes a crucial use of the Template notion which is introduced to satisfy two different needs: (i) making the encoding task more easy; and, (ii) enhancing the general consistency of the lexicons by providing structured sets of information. Templates are defined so as to mirror semantic types.

2. Description of the experiment

The input to the procedure are word-to-word correspondences extracted out of bilingual dictionaries, and the procedure output is modeled sense-to-sense correspondences among two monolingual computational lexicons. The sample data for this preliminary exercise only includes nouns and the words has been taken out of the 500 most frequent ones in Catalan (and their translations into Spanish and Italian). For this experiment we have dealt only with Catalan, Spanish and Italian word to word correspondences that have been extracted out of traditional bilingual dictionaries.

The system includes four modules: monolingual computational lexicons, word-to-word correspondences, set of candidate senses, and resolution algorithm as described below.

2.1. Monolingual computational lexicons

The system we describe takes advantage of the SIMPLE\(^2\) model (Lenci et al., 2000) and SIMPLE lexicons. The SIMPLE model is based on the recommendations of the EAGLES\(^3\) Lexicon/Semantic Working Group and on extensions of the Generative Lexicon theory. SIMPLE aims at capturing the various dimensions of word meaning and relies on an extension of ‘qualia structure’ (Pustejowsky 1995) for structuring the semantic/conceptual types as a representational aspect of word meaning. The semantic types in SIMPLE are defined as clusters of structured information and form a general ontology which is organized following the principles of orthogonal organization of types, as formalized in the Generative Lexicon. The SIMPLE model makes a crucial use of the Template notion which is introduced to satisfy two different needs: (i) making the encoding task more easy; and, (ii) enhancing the general consistency of the lexicons by providing structured sets of information. Templates are defined so as to mirror semantic types.

2.2. Word to Word Correspondences

Word-to-word correspondences (from now on WWC) are binary relations between the input word and the target word given by bilingual dictionaries as translational equivalents. These words are checked against PAROLE SIMPLE lexicons in order to extract all relevant information: (i) all morphological units whose ‘Lemma’\(^4\) matches with the words extracted, plus (ii) the syntactic and semantic units linked to these morphological units. This means that the resulting modeled sense-to-sense correspondences (from now on, SSC) will eventually be independent of the criteria applied when establishing

\(^2\) Semantic Information for Multifunctional Plurilingual Lexicons is a project sponsored by the EC DGXIII in the framework of the Language Engineering programme.

\(^3\) http://www.lilc.pi.cnr.it/EAGLES/rep2.

\(^4\) Due to the different criteria used in traditional lexicons and in a multipurpose computational lexicon such as SIMPLE, we prefer to use ‘word’ as to refer to lexical units, and ‘lemma’ to what in SIMPLE is actually ‘Spelling’.

\[ (\text{peix}: \{\text{ichthyology}\}) \text{pez} || (\text{gastronomy}) \text{pescado} \]
lexical units in both paper bilingual dictionaries and PAROLE/SIMPLE lexicons. This is the case of the Catalan word cort (meaning 'pigsty' and 'royal court') which, due to etymological matters, has two different entries in paper dictionary but only one morphological unit in the PAROLE lexicon. As we will see, the system will establish the correct sense to sense correspondences despite the criteria applied.

For the sake of the exercise, WWCs only include the first translational equivalent supplied by the bilingual dictionary. Thus, for instance, despite of the fact that in the bilingual Catalan-Spanish dictionary the word paraula is assigned the Spanish words palabra, vocablo, termino and voz as almost synonymous, the set of WWC derived for the experiment only includes the first candidate palabra, which generally corresponds to the 'preferred' equivalent.

Two different WWCs sets are generated for each pair of involved languages, according to the ordering of being in one case source language, and in the other case target language. This is explained in terms of closure so as to cover all possible bi-directional correspondences, specifically in the case of disambiguating a one to many correspondences. That is, WWCs are to be bi-directional, thus if a Catalan word X is linked to the Spanish word Y, we know that the Spanish word Y will be also linked to the Catalan word X. We can see this by comparing the two examples below:

(7) CAT to SP WWCs: SP to CAT WWCs:
(ala,ala) (ala,ala)

(8) CAT to SP WWCs: SP to CAT WWCs:
(poma,manzana) (manzana,poma)
(illa,manzana) (manzana,illa)

In (7), the set of WWCs reflect the fact that the Catalan word ala ('win') is related to the Spanish word ala, and that this relation is fully bi-directional (for every sense involved). In (8), the Catalan word poma is related to the Spanish word manzana, but such word-to-word relation is not fully bi-directional as the Spanish word manzana is also related with the Catalan word illa. In this case, the set of WWCs needs to include all (illa,X) WWCs in order to guarantee the closure of the system.

Note, however, that not all bi-directional WWCs are included in a first instance. This is the case of the example below:

(9) CAT to SP WWCs: SP to CAT WWCs:
(paraula,palabra) (palabra,paraula)
(mot,palabra) ...

In this case, the Spanish to Catalan WWC (palabra,mot) is not included, as such correspondence is not the 'preferred' one (the first candidate in the bilingual dictionary). As we will see, this does not mean that we obviate such correspondence but rather helps in typing correspondences in terms of [+- preferred].

2.3. Set of involved senses

For each set of binary WWCs, we get the related senses for both all source and target words in PAROLE/SIMPLE lexicons. So, in the trivial examples in (7) and (8) above, the Sets of Involved Senses5 include (10) and (11) respectively.

(10) Catalan Senses: Spanish Senses:
ala_BodyPart
ala_Artifact
ala_Part

(11) Catalan Senses: Spanish Senses:
poma_Fruit
illa_Area
illa_ArtifactualArea

The objective is to discriminate and to model the correct correspondences between the input senses in bold (i.e. all the senses of the source word in the bilingual dictionary) and the target senses (i.e. all the senses of all target words in the bilingual dictionary). As we will see, in order to resolve the case of manzana and poma/illa in (3) above, in order to disambiguate which one of the two target senses (Fruit and Artifactual Area) correspond to the input sense, the system has to check all the material derived from closure. This aspect will be further explained in 2.4.

2.4. Resolution algorithm

Once we have all involved senses, the system has to establish the correct SSCs between the input senses and the target senses. Ideally the system should find a candidate for all input senses.

The system acts according to three different admissible scenarios:

Trivial Case (TC): involving one source sense and one target sense. In these cases, the system checks the correctness of the only candidate sense and the [+- preferred] status of the correspondence. These trivial cases merely serve to determine the harmony between lexicons.

Non Trivial Case1 (NTC1): for cases involving one input sense and >1 target senses (for instance, the Catalan to Spanish WWC(poma,manzana) in (8) above). The objective consists on identifying the best candidate among the target senses and checking the [+- preferred] status of the correspondence.

Non Trivial Case2 (NTC2): for cases involving >1 input senses and >1 target senses (for instance the Catalan to Spanish WWC(ala,ala) in (7) above). The objective in this case is to identify the relevant candidates for all source senses.

5 For the sake of clarity, we represent 'senses' as 'word_Template'
The system includes two main procedures: Check best Candidate and Check Closure, defined as follows:

**Check best Candidate** is expressed in terms of ponderation according to the following terms:

1. Identity of Template Labels for source and target senses, as in the case of (12a, b, c) where the template labels are identified.

2. Subsumption relations between input and target Templates according to the SIMPLE ontological hierarchy they are structured. This will be the case for the Spanish caballo_Animal ('horse') being related to the Italian cavallo_EarthAnimal.

3. Identity of Semantic Type between input and target senses. This allows us to overcome differences in encoding between input and target lexicons as illustrated in the following example for the WWCs corresponding to the Spanish cocina and the Italian culinária and cucina (the senses refer to a: 'cooking', b: 'kitchen', c: 'cooker' and d: 'furniture of the kitchen')

   (12) Spanish Senses          Italian Senses
   a. cocina1_Domain →        culinária1_Domain
   b. cocina2_Building →      cucina1_Building
   c. cocina3_Instrument →    cucina2_Instrument
   d. cocina4_Group →         cucina3_Furniture
     &[Sem_Type: Furniture] &[Sem_Type: Furniture]

   In (12d), despite the Template assigned to the Spanish sense, cocina4 does not match with the Template assigned to the Italian cucina3, but the correspondence can be correctly established by means of the Semantic Type6.

4. Subsumption relations between input and target Semantic Type. The hierarchy that structures Semantic Types also allows to determine that the Spanish cuchillo_tool ('knife') is to be related to the Catalan ganivet_Instrument.

5. Matching between features and Template information. As mentioned in 2.1, SIMPLE model includes a set of Template types organized as an orthogonal hierarchy. Templates are defined in terms of clusters of information describing the various dimensions of meaning participating in a given word sense. Sometimes, dimensions in word meaning compete and may derive into conflicting results. The system, therefore, predicts on these conflicting results by checking the different dimensions involved. Thus, for instance, we can predict that input and target senses defined as [+edible] are related despite the Template assigned in each case.

6. Checking co-occurrence of other additional features such as Domain, Connotation, etc. for disambiguation purposes. The system can also disambiguate correspondences by means of relevant features. Thus, in the following example the Italian sense acqua2 ('amniotic liquid') is rejected as it bears the Domain feature Obstetrics:

   (13) Spanish Senses: Italian Senses:
     agua1_Substance         acqua1_NatSubstance
     acqua2_NatSubstance     &[Domain: Obstetrics]

7. Syntactic Information. As the semantic units in SIMPLE are linked to the corresponding syntactic unit, the system can also have access to further information that can help in disambiguation, if required. This will be the case for (14). The Spanish campo ('field' or 'country') and the target Italian campo, where the system can add to the subsumption information, information regarding their countable nature to determine the SSC.

   (14) Spanish Senses: Italian Senses:
     campo_ArtifArea         campo_Area
     &[COUNTABLE]            &[COUNTABLE]
     campo_Location          &[UNCOUNTABLE]

**Check Closure** of WWCs serves a double purpose: first, it allows to discriminate between 'preferred' correspondences and 'non-preferred' correspondences as described above and, second, it is required for disambiguation when a one to many relations or many to many relations are possible.

A combination of all these checking is what allows the resolution of the the Spanish to Italian WWC (campesino,contadino) ('peasant') as in (15). In this example, if closure of WWC were obviated, we would have one input sense and two target senses and, according to the Template Identity in 1 above, the Spanish campesino1_Human sense would be wrongly related to the Italian contadino2_Human ('yokel') sense:

   (15) SP to IT WWCs: IT to SP WWCs:
     (campesino,contadino)   (cont.,campesino)
     (cont.,pueblerino)

   Spanish Senses: Italian Senses:
     campesino1_Human       contadino1_Profesion
     contadino2_Human

Note, however, that if senses derived from closure are included, we obtain the following Set of Involved Senses:

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6 Additional information will be represented here by brackets.
Here the occurrence of Connotation features for pueblerino and contadino2 and the metaphoric status of contadino2 allows the system to establish the correct correspondences.

3. Quantitative results

The results are given in groups according to Cases in 2.4 above. For each case we supply: the number of WWCs; the input and target words involved; the input and target senses involved; the number of resolved WWCs for the source language and, for them, the number of resolved SSCs.

Resolved WWCs are those WWCs with at least one resolved SSC correspondence between input/target senses involved. Resolved input senses are those input senses that are correctly assigned a SSC with a target sense.

| WWC  | 95  |
|------|-----|
| Input words | 95 |
| Target words | 95 |
| Input Senses | 95 |
| Target Senses | 95 |
| Resolved WWC | 93 | 97.89% |
| Resolved SSC | 93 | 97.89% |

Table 1: Results for Catalan to Spanish TC

All correspondences but one are bi-directional, therefore SSCs are suggested as ‘preferred’.

| WWC  | 35  |
|------|-----|
| Input words | 35 |
| Target words | 35 |

Table 4: Results for Spanish to Italian TC
### 4. Conclusions

The main point of this exercise was to assess whether the lexicons and the model used to encode them were useful to identify the sense on which the correspondence relative to fully translation equivalents is made. In this sense, the results of the exercise are highly satisfactory.

Besides, the examples clearly show that sense-to-sense correspondences cannot be based on ontological terms only. Not only languages differ as far as lexicalisation of concepts is concerned, but also, and probably more critically if we want to provide automatic means for linking monolingual lexicons, we have to be able to cope with the fact that the criteria used for encoding using ontological labels might differ from one lexicon to another. This is the point where SIMPLE model proves crucial. SIMPLE Template Type system is not a mere collection of ontological labels. SIMPLE Templates are a generalisation on clusters of atomic elements of information. The procedure we have described analyses the clusters of information supplied by the input sense and looks for the target senses that better suit each of the input one.

Besides the relevance of the figures above, the results of the experiment lead us to suggest a classification of the relations that hold for the different correspondences in the following terms:

1. **[+/- EQUIVALENT]**, for one-to-one correspondences vs. one-to-many correspondences.
2. **[+/- PREFERRED]**, whenever the input-target correspondence is bi-directional we also suggest a ponderation which reflects the preferred WWC. We expect the model to also allow for adding specific-to-general, slang-to-standard information to the correspondences.

#### 4.1. Equivalent or Partial correspondences

Partial correspondences occur whenever in a given language a word is split up into several senses while in the other language the senses are considered as an indivisible meaning. The results of the experiment distinguish between three different situations:

**A. Union Case:** An 'under-specified' entry in one language subsumes two 'super-specified' entries in another language. This happens whenever a given feature is taken as 'sense discriminating' in only one language and the correspondence can be expressed in terms of set union:

\[
\text{SP:agua}_\text{Substance} \land [\text{Telic:} [+\text{Edible}] \land \text{Constitutive:} [+\text{Liquid}]] \\
\downarrow \\
\text{CAT:aigua}_\text{Substance} \land [\text{Constitutive:} [+\text{Liquid}]] \\
\cup \\
\text{CAT:aigua}_\text{Drink} \land [\text{Telic:} [+\text{Edible}]]
\]

**B. Constrained Case:** An 'under-specified' entry in one language is related to two entries in the other language but the relation can not be explained in terms of 'set union'. This happens whenever the occurrence of certain information derives into sense discrimination. This is the case of the doctor/doctora example mentioned above:

(i) **the semantic encoding** reflecting the differences between monolingual sense division and bilingual meaning discrimination—the target language contains two more fine grained descriptions for one under-specified input description (see WWC(agua,aigua) example below).

(ii) **the morphological encoding:** the way entries are split at the morphological layer might derive into a one-to-many correspondence—this is the case of the Spanish to Catalan doctor vs. doctor/doctora ('doctor-masculine', 'doctor-feminine') correspondence where the Spanish entry is under-specified for sex but the Catalan entries distinguish between masculine and feminine inheriting the distinction already made at the morphological level.

\[\text{[+/- PREFERRED]}\] whenever the input-target correspondence is bi-directional we also suggest a ponderation which reflects the preferred WWC. We expect the model to also allow for adding specific-to-general, slang-to-standard information to the correspondences.
the system we are reflecting, we resolve 552 Catalan input senses out of 665 (83%) and 289 Spanish senses out of 375 (77.06%).

An important issue to notice here is that the system we are considering to be the basis for the construction of a multilingual lexical resource. To model the relations that hold between different lexical units in different languages by ensuring that they are [+preferred] and [+equivalent] sense-to-sense correspondences will allow to draw paths of fully translational equivalents for more than two languages. Thus, when having identified WWCs for different languages we can derive the SSCs for more than two languages which ensure the sense for true translational equivalence for all the languages involved. Such a modelisation must foresee the properties of the relations that link two lexical units in two different languages (for instance full equivalent will be a transitive relation).

5. Future Perspectives of the work

The work reported gives some hints about what we have considered to be the basis for the construction of a multilingual lexical resource. To model the relations that hold between different lexical units in different languages by ensuring that they are [+preferred] and [+equivalent] sense-to-sense correspondences will allow to draw paths of fully translational equivalents for more than two languages. Thus, when having identified WWCs for different languages we can derive the SSCs for more than two languages which ensure the sense for true translational equivalence for all the languages involved. Such a modelisation must foresee the properties of the relations that link two lexical units in two different languages (for instance full equivalent will be a transitive relation).

We expect that partial correspondences will also be used to express complex relations based on restrictions. Using other information encoded, such as metaphoric use or synonymy, will be useful for identifying candidates that can be offered to the lexicographer for him to take the last decision in bilingual linking if possible.

However, we have to extend the scope of the experiment so as to include all translational equivalences given by bilingual dictionaries and synonym information.
in SIMPLE lexicons in order to extend correspondence assignments within a set of related senses. We predict that this exercise will provide better results and give new clues for further defining and modeling the set of possible correspondences for a multilingual resource.

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