Modeling Adjectives in Computational Relational Lexica

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Abstract

In this paper we propose a small set of lexical conceptual relations which allow to encode adjectives in computational relational lexica in a principled and integrated way. Our main motivation comes from the fact that adjectives and certain classes of verbs, related in a way or another with adjectives, do not have a satisfactory representation in this kind of lexica. This is due to a great extent to the heterogeneity of their semantic and syntactic properties. We sustain that such properties are mostly derived from the relations holding between adjectives and other POS. Accordingly, our proposal is mainly concerned with the specification of appropriate cross-POS relations to encode adjectives in lexica of the type considered here.

1 Introduction

As well known, the experiment conducted by George Miller on the mental lexicon properties in the early 80s pointed out that lexical meaning is derived from a set of lexical and conceptual relations among concepts. Subsequently, a computational lexicon conceived as a semantic network has been built (the Princeton WordNet (Miller, 1990; Fellbaum, 1998)). Given its psychological plausibility and its crucial role for applications like machine translation, information retrieval and language learning systems, among many others, this relational lexicon model is being extensively adopted for machine lexical knowledge representations, playing a leading role in this field.

One of the most salient undertaking in this domain is EuroWordNet (Vossen, 1998), a multilingual database which stores wordnets for several European languages that follow the same main lines as the Princeton WordNet (Miller, 1990; Fellbaum, 1998) and are inter-related amongst them.

EuroWordNet wordnets follow the Princeton WordNet model, but they are richer concerning both the number and the nature of conceptual relations.

The work depicted here programmatically adopts the EuroWordNet framework.

In general terms, it deals with the specifications for an accurate modeling of lexical knowledge in a EuroWordNet wordnet-like database for Portuguese (WordNet.PT, henceforth), specifically focusing on the lexical semantics of adjectives.

Although WordNet.PT (Marrafa, 2001; Marrafa, 2002) is being developed in the general EuroWordNet framework, basic research has been carried out on Portuguese in order to guarantee the WordNet.PT accuracy. This work has already led to some changes and new directions (cf. Marrafa et al., (2006) and Amaro et al., (2006), for instance).

In this paper we propose a small set of new relations which allow a strongly empirical motivated encoding of the major POS in WordNet.PT, despite the fact that we particularly focus on adjectives. The empirical issues at stake are described in section 2. In section 3 we discuss the strategies adopted in previous work carried out both in WordNet and EuroWordNet frameworks, in order to make their shortcomings apparent. In section 4 we present our proposal

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and argue for its relevance and soundness. Section 5 presents some results concerning the encoding of adjectives in WordNet.PT. We conclude the paper with some final remarks.

2 Empirical Issues

Adjective semantic analysis and representation is far from being a trivial issue, as adjectives show a very particular linguistic behavior, namely in what concerns sense change depending on linguistic context. Being so, there are several different typologies and classifications of adjectives in the literature: semantic based classifications, syntactic based classifications, classifications regarding the relation holding between the adjective and the modified noun, and so on.

As our work on this issue progresses, it has become clear that only a combination of syntactic and semantic criteria can offer interesting insights concerning adjective linguistic behavior and the identification of relevant common features, which may set the basis for an accurate modeling of this POS in computational relational lexica. In this section we will briefly look at some of the main adjective classifications.

Regarding the way adjectives relate to the noun they modify, we consider two classes: property ascribing adjectives (in (1)), which add a new restriction to the properties introduced by the modified noun; and reference modifying adjectives (in (2)), which behave like a semantic operator, taking the reference of the modified noun as its argument[1].

(1) o livro azul
'the blue book'
(2) o diamante falso
'the fake diamond'

Adjectives like *falso* (fake), for instance, deal with concepts instead of real or referential objects, showing how a concept applies to a particular object. These adjectives constitute a closed class with very particular properties, which makes them somewhat close to semantic operators. In this work we will therefore focus on property ascribing adjectives.

Demonte (1999) classifies property ascribing adjectives based on their intrinsic meaning, a classification combining syntactic and semantic criteria to determine which adjectives belong to which class. Two main subclasses are considered: descriptive adjectives and relational adjectives. Each of these classes displays specific semantic and syntactic properties.

In languages like Portuguese, descriptive adjectives can occur both in attributive and predicative contexts, while relational adjectives occur almost exclusively in attributive contexts[2]. Both prenominal and postnominal positions are possible for descriptive adjectives in attributive contexts. Relational adjectives, on the contrary, can only occur in postnominal position. Finally, descriptive adjectives are gradable, i.e. they can co-occur with degree adverbs, which is not the case for relational adjectives. However, these criteria are not always sufficient to make a clear-cut distinction between relational and descriptive adjectives. Demonte (1999) proposes some additional criteria in order to make a more accurate distinction between these adjectives: their occurrence in comparative structures, and the formation of polarity systems.

(3) a. O sabor desta laranja é mais doce do que o daquela.
'this orange taste is sweeter than that one's'
b. o rapaz alto / o rapaz baixo
'the tall boy / the short boy'
(4) a. *Este sabor é mais mineral do que aquele.
'this taste is more mineral than that one'
b. o sabor mineral / *o sabor amineral
'the mineral taste / the amineral taste'

But most of all, and besides all the syntactical contrasts we have mentioned above, there is a clear contrast in the way these two adjective classes relate to the noun they modify. Descriptive adjectives ascribe a single property, setting a value for an attribute, whereas relational adjectives introduce a set of properties.

(5) o prédio alto
'the high building'

1 This distinction between *property ascribing adjectives* and *reference modifying adjectives* is basically equivalent to the one used in the SIMPLE project (Lenci et al., 2000) (*extensional* vs. *intensional adjectives*, following Chierchia and McConnel-Ginet (1990)) to address the semantics of adjectives. This distinction is also included in the EAGLES recommendations for a semantic typology of adjectives.

2 Predicative contexts with relational adjectives are generally ruled out in Portuguese. Nonetheless, some specific contexts, like contrastive contexts, for instance, seem to license predicative uses of relational adjectives:

(I) As próximas eleições são autárquicas, não são presidenciais.
'next election will be autarchic, not presidential'

(6) a indústria alimentar
'the alimentary industry'

Looking at (5) and (6), we see that, while *alto* (high) sets the value of the **height** attribute of *prédio* (building) to **high**, *alimentar* (alimentary) does not ascribe a single property, but a set of properties to *indústria* (industry). Moreover, this set of properties corresponds to the main features describing another noun – *alimento* (food) in the example above. In fact, the way properties are ascribed to the modified nouns in (5) and in (6) are quite different. Ascribing a singular property usually corresponds to an incidence relation of this property in the nominal referent, while ascribing sets of properties usually entails more complex and diversified semantic relations.

However, despite the relevance of the descriptive/relational dichotomy, it cannot account for the following contrasts:

(7) a. *Ele viu a Maria alta.
'He saw Mary tall'
b. Ele viu a Maria triste.
'He saw Mary sad'.

Both *alta* and *triste* are descriptive adjectives, but they do not behave in the same way regarding secondary predication.

We can refine the classification, considering, for instance, the opposition between accidental properties and permanent or inherent properties (this distinction goes back to Milsark (1974; 1977) and Carlson (1977)). According to this distinction, the property denoted by *alta* (tall) belongs to the latter class and the property denoted by *triste* (sad) to the former one. However, as pointed out by Marrafa (2004) and previous work, the characterization of adjectives on the basis of this dichotomy is not straightforward, since certain adjectives are ambiguous with regard to those properties, as it is the case of *triste* (sad). In the example above *triste* (sad) denotes an accidental property, but in an expression like um *livro triste* (a sad book) it denotes a permanent property.

Intuitively, we can say that *triste* (sad) expresses a state of *tristeza* (sadness), but we let the discussion of the status of this relation out of the scope of this paper.

Nevertheless, this kind of adjectives is of great importance to model telic verbs. The semantics of telic verbs involves a change of state of their theme argument, i.e. the subevent that closes the whole event is an atomic event, (a state) that affects the theme and is different from its initial state. As argued in Marrafa (2005) and previous work, by default, verbs like *lavar* (to wash) are associated to the following Lexical-Conceptual Structure (LCS' in Pustejovsky (1991)):

(8) $[_T [_P$ act(x,y)and ~ Q(y)], $[_e$Q(y)]]
T:transition, P:process, e: event, Q: atomic event

When syntactically realized, the telic subevent generally corresponds to an adjectival constituent, like in the example below:

(9) Ele lavou a camisa bem lavada.
'He washed the shirt well washed'

In (9) the absence of the telic expression *bem lavada* (well washed) does not induce ungrammaticality. However, in the case of verbs like *tornar* (to make*)*, it seems impossible to assign a value to *Q* independently of the telic expression.

(10) a. Ele tornou a Maria triste.
'He made Mary sad'
b. *Ele tornou a Maria.
'He made Mary'

Along the lines of Marrafa (1993) and further work, verbs like *tornar* (to make*)* are assumed here to be LCS deficitary, the telic expression filling the gap of the LCS of the verb.

As shown below, the troponyms of these verbs incorporate the telic state:

(12) a. Ele entristeceu a Maria.
'He saddened Mary'
b. *Ele entristeceu a Maria triste.
'He saddened Mary sad'

The grammaticality contrast above is due to the fact that *entristecer* (to sadden) incorporates the telic state. This justifies that this verb can be paraphrased by *tornar triste* (to make sad).

In this section we have mainly focused on property ascribing adjectives. We have considered two main subclasses, descriptive and relational adjectives, briefly presenting their syntactic and semantic behavior with regard to gradability, formation of polarity systems and their occurrence in predicative and attributive (both pronominally and postnominally) contexts and comparative structures. We have also addressed the issue of adjective relation with the noun they modify. Different adjective behavior regarding secondary predication is also discussed and analyzed in terms of the opposition between acci-

dental and permanent properties. The properties discussed in this section should be encoded in computational relational lexica such as wordnets.

3 Adjectives in WordNet and in EuroWordNet

Hyponymy is the main structuring relation both in WordNet and in EuroWordNet. However, the semantic organization of adjectives is entirely different from that of other POS: nothing like the hierarchies of hyponymic (in the semantic organization of nouns) and troponymic relations (in the semantic organization of verbs) is available for adjectives. Even if it is possible to find some small local hierarchies, hyperonymy/hyponymy is far from being the crucial semantic relation in the organization of adjectives in relational lexical databases such as wordnets.

However, some authors working within the EuroWordNet framework have reconsidered the possibility of encoding hyponymy for adjectives. Hamp and Feldweg (1998), in the development of GermaNet, abandon the cluster organization of WordNet in favor of a hierarchical structuring of adjectives, arguing for a uniform treatment of all POS. Even though taxonomic chains of adjectives yield rather flat in comparison to those of nouns and verbs, these authors claim to derive more structural information from these small taxonomies than from clusters, as they seek to eliminate what they consider to be the 'rather fuzzy concept of indirect antonyms'. Even though the concept of indirect antonymy is not completely clear, it is not obvious to us why this fact should entail that adjectives must show a hierarchical organization instead.

In ItalWordNet, Alonge et al. (2000) also organize adjectives into classes sharing a superordinate. These classes correspond to adjectives sharing some semantic features, and are generally rather flat. These authors argue for the possibility of inferring semantic preferences and syntactic characteristics of adjectives found in the same taxonomy. The SIMPLE project addresses the semantics of adjectives in a similar way, identifying a set of common features relevant for classifying and describing adjective behavior. However, as noted by Peters and Peters (2000), even though similarities exist "adjectives belonging to the same semantic class may differ from each other in numerous ways", i.e. the classes established in this way are not homogeneous.

In WordNet, descriptive and relational adjectives are distinguished, first, by being encoded in separate files, and second, by the relations holding between synsets.

Descriptive adjectives are organized in clusters of synsets, each cluster being associated by semantic similarity to a focal adjective which is linked to a contrasting cluster through an antonymy relation. Therefore, antonymy is the basic semantic relation used in WordNet to encode descriptive adjectives. As argued for in Miller (1998), this cluster organization of adjectives seems to mirror psychological principles. In fact, this organization is clearly motivated if we recognize that these adjectives main function regards the expression of attributes, and that an important number of attributes are bipolar.

Relational adjectives, on the other hand, do not have antonyms. Therefore, they cannot be organized in opposite clusters. As pointed out by Levi (1978), the intrinsic meaning of these adjectives is something along the following lines: 'of, relating/pertaining to, associated with' some noun. The way these adjectives are encoded in WordNet mirrors this as it links relational adjectives to the nouns they relate to.

In GermaNet a distinct treatment of relational and descriptive adjectives is abandoned, as the distinction between these two classes is considered to be 'not at all clear'. Nonetheless, the WordNet strategy for distinguishing between different adjective classes is maintained: listing lexical items in different files[3].

As pointed out in the previous section, even if the distinction between these two classes is not always clear-cut, testing adjectives against the set of syntactic and semantic criteria presented in section 2 allows us to distinguish descriptive from relational adjectives. We consider that this distinction can be mirrored in the database via the semantic relations expressed in the network, adjective listing in different files not being therefore necessary. In order to do this we propose several cross-POS relations, since in the EuroWordNet model, unlike what happens in WordNet where each POS forms a separate system, it is possible to relate lexical items belonging to different POS. Such an approach has the

[3] GermaNet classifies the adjectives into 15 semantic classes, following the classes proposed by Hundsnurscher and Splett (1982), with some minor changes: perceptional, spatial, temporality-related, motion-related, material-related, weather-related, body-related, mood-related, spirit-related, behaviour-related, social-related, quantity-related, relational and general adjectives. One special class is added for pertainyms.

advantage of coping with adjective representation in lexical semantic databases without using strategies external to the lexical model, such as *a priori* semantic classes or separate files corresponding to different classes.

4 Relating adjectives, nouns and verbs

It is undeniable that important structural information can be extracted from the hierarchical organization of lexical items, namely of nouns and verbs. However, extending wordnets to all the main POS involves a revision of certain commonly used relations and the specification of several cross-POS relations.

We previously mentioned that adjectives show a very particular semantic organization. Thus, encoding adjectives in wordnets calls for the specification of a number of cross-POS semantic relations. Here we use these cross-POS semantic relations to mirror adjectives main features in wordnet-like databases, which allows us to make adjective classes emerge from the relations expressed in the network.

According to the strategies discussed in Mendes (2006), we present here the relations we argue are appropriate to encode adjectives and show how they conform to some complex phenomena.

4.1 Relating Adjectives and Nouns

To put it somewhat simplistically, descriptive adjectives ascribe a value of an attribute to a noun. We link each descriptive adjective to the attribute it modifies via the semantic relation *characterizes with regard to/can be characterized by*[4]. Thus, instead of linking adjectives amongst themselves by a similarity relation, following what is done in WordNet, all adjectives modifying the same attribute are linked to the noun that lexicalizes this attribute. This way, and in combination with the *antonymy* relation, we obtain the cluster effect argued to be the basis of the organization of adjectives (Miller, 1998; Fellbaum et al, 1993), without having to encode it directly in the database.

As shown by word association tests, *antonymy* is also a basic relation in the organization of descriptive adjectives. Nonetheless, this relation does not correspond to conceptual opposition, which is one of the semantic relations used for the definition of adjective clusters. We argue that conceptual opposition does not have to be explicitly encoded in wordnets, since it is possible to infer it from the combination of *synonymy* and *antonymy* relations (see Mendes (2006) for more details).

Concerning relational adjectives, even though they are also property ascribing adjectives, they entail more complex and diversified relations between the set of properties they introduce and the modified noun, often pointing to the denotation of another noun (cf. section 2). We use the *is related to* relation to encode this.

Therefore, the *characterizes with regard to*/*can be characterized by* and the *antonymy* relations, for descriptive adjectives, and the *is related to* relation for relational adjectives, allows us to encode the basic features of these adjectives in computational relational lexica such as wordnets, while making it possible to derive membership to these classes from the relations expressed in the network.

Another issue regarding adjectives is that they have a rather sparse net of relations. We introduce a new relation to encode salient characteristics of nouns: *is characteristic of*/*has as a characteristic to be*. These characteristics are often expressed by adjectival expressions. Although in terms of lexical knowledge we can discuss the status of this relation, it regards crucial information for many wordnet-based applications, namely those using inference systems, allowing for richer and clearer synsets.

Also, it may allow for deducing semantic domains from the database, as it makes it possible to identify the typical semantic domains of application of adjectives. Research on the classes and semantic domains emerging from the relations expressed in the database is still ongoing.

Thus, the combination of these relations allows us to encode a less sparse net of adjectives. Besides the importance of having a more dense net from the point of view of wordnet-based applications, as mentioned above, this is also crucial with regard to relational lexica such as wordnets themselves, as the meaning of each unit is determined by the set of relations it holds with other units. Thus, a denser network of relations allows for richer and clearer synsets. Fig. 1 illustrates this idea, presenting an example of the way adjectives are being encoded in WordNet.PT.

4 This semantic relation is very close to the *is a value of*/*attributes* relation used in WordNet. We have changed its label in order to make it more straightforward to the common user.

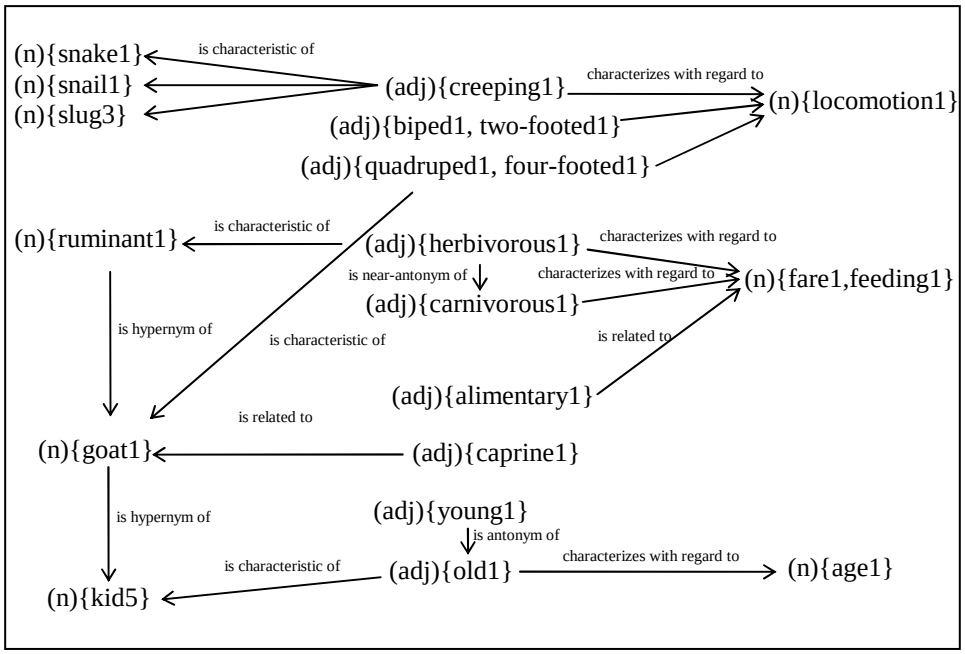

Figure 1. Fragment showing relations between adjectives and nouns[5]

4.2 Relating Adjectives and Verbs

We also introduce new semantic relations to encode telic verbs in the database (on this issue see also Marrafa, 2005; Amaro et al., 2006).

As shown in section 2, the facts render evident that the representation of LCS deficitary telic verbs has to include information regarding the telic expression. Obviously, it would not be adequate to overtly include in the synset all the expressions that can integrate the predicate, among other reasons, because they seem to constitute an open set. Rather, we claim that we can capture the telicity of these verbs by including a new relation in the set of internal relations of wordnets: the *telic sub-event* relation, as exemplified below.

(13) {*make*} has_telic_sub-event {*state*}
{*state*} is_telic_sub-event_of{*make*}
(defeasible)[6]

Relating *make* to *state* by means of this relation, we capture the telic properties of the verb and let the specific nature of the final state underspecified. This way, we also account for the weakness of the verb selection restrictions. As expected, we can also use this relation to encode telicity in the case of the troponyms of the class of verbs discussed in section 2.

In these cases, we use the *telic sub-event* relation to relate the verb to the expression corresponding to the incorporated telic information:

(14) {*sadden*} has_telic_sub-event {*sad*}
{*sad*} is_telic_sub-event of {*sadden*}
(defeasable)

The global solution is schematically presented below:

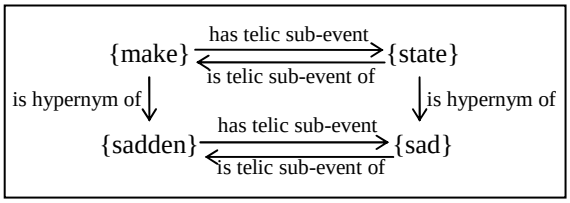

Figure 2. Relations between adjectives and verbs

As shown, the *telic sub-event* relation straightforwardly allows the encoding of lexical telicity in wordnets, in accordance with the empirical evidence.

It should be noticed that the existing *sub-event* relation in the EuroWordNet framework is different from the relation proposed here. It only stands for lexical entailment involving temporal proper inclusion. Therefore, it does not account for the geometry of the event. On the contrary, the *telic sub-event* relation regards the atomic sub-event that is the ending point of the global event.

[5] Word senses presented here correspond to Princeton WordNet synsets (2.1 version).

[6] The relation is not obligatory in this direction.

5 Encoding adjectives in WordNet.PT

As previously mentioned, the proposal presented in this paper is mainly concerned with the specification of appropriate cross-POS relations to encode adjectives in computational relational lexica.

In order to test whether the set of relations presented here is appropriate and allows the encoding of adjectives in wordnet-like lexica, we have introduced a selection of Portuguese adjectives in WordNet.PT.

In the first phase of the WordNet.PT project mostly nouns were encoded in the database. Thus, we have mainly focused on the encoding of relations between adjectives and nouns[7]. Table 1 presents the number of entries and relations specified at the present stage.

total number of adjectives	1462
synonymy relation	252
antonymy relation	134
near-antonymy relation	40
is related to relation	331
is characteristic of relation	1293
characterizes with regard to relation	261
total number of relations	2311

Table1. Statistics concerning the encoding of adjectives in WordNet.PT

Besides the discussion presented above, the implemented data, being already a representative sample, show that the cross-POS relations proposed here effectively allow for a fine-grained encoding of adjectives in relational lexica (specifically in wordnet-like lexica) through the specification of a denser network of relations.

6 Conclusion

In this paper we argue that the semantics of adjectives can be appropriately captured in wordnet-like lexica by means of the implementation of a small set of new relations, which have a strong linguistic motivation and preserve the coherence of the model.

We focus on property ascribing adjectives and we distinguish between descriptive and relational adjectives. Besides the relevance of this dichotomy, we also address the opposition between accidental and permanent properties, as adjective association to certain kind of properties determines their syntactic and semantic behavior, namely with regard to secondary predication. Here, we model these distinctions in WordNet.PT via cross-POS relations: *characterizes with regard to/can be characterized by* to model descriptive adjectives introducing permanent properties; *has_telic_subevent/is_telic_subevent* to model descriptive adjectives associated to accidental properties; and the *is related to* to model relational adjectives.

Moreover, we make apparent that increasing the expressive power of the system has an important impact in precision concerning the specifications of all POS, mainly induced by the cross-POS relations.

This way, we provide a simple and integrated solution for a complex and heterogeneous problem.

[7] Nevertheless, relations between adjectives and verbs are already being implemented at the current stage.

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