

Using relational adjectives for extracting hyponyms from medical texts

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Abstract. We expose a method for extracting hyponyms and hypernyms from analytical definitions, focusing on the relation observed between hypernyms and relational adjectives (e.g., *cardiovascular disease*). These adjectives introduce a set of specialized features according to a categorization proper to a particular knowledge domain. For detecting these sequences of hypernyms associated to relational adjectives, we perform a set of linguistic heuristics for recognizing such adjectives from others (e.g. *psychological/ugly disorder*). In our case, we applied linguistic heuristics for identifying such sequences from medical texts in Spanish. The use of these heuristics allows a trade-off between precision & recall, which is an important advance that complements other works.

Keywords: Hypernym/hyponym, lexical relation, analytical definition, categorization, prototype theory.

1 Introduction

One relevant line of research into NLP is the automatic recognition of lexical relations, particularly hyponymy/hyperonymy (Hearts 1992; Ryu and Choy 2005; Pantel and Pennacchiotti 2006; Ritter, Soderland, and Etzioni 2009). In Spanish Acosta, Aguilar and Sierra (2010); Ortega et al. (2011); and Acosta, Sierra and Aguilar (2011) have reported good results detecting hyponymy/hyperonymy relations in corpus of general language, as well as specialized corpus on medicine.

From a cognitive point of view, hyponymy/hyperonymy lexical relation is a process of *categorization*, which implies that these relations allow recognizing, differentiating and understanding entities according to a set of specific features. Following the works of Rosch (1978), Smith and Medin (1981), as well Evans and Green (2006), hypernyms are associated to *basic levels* of categorization. If we considered a taxonomy, the *basic level* is a level where categories carry the most information, as well they possess the highest cue validity, and are the most differentiated from one another (Rosch, 1978). In other words, as Murphy (2002) points out, *basic level* (e.g., *chair*) can represent a compromise between the accuracy of classification at a higher superordinate category (e.g., *furniture*) and the predictive power of a subordinate category (e.g., *rocking chair*). However, as Tanaka and Taylor's (1991) study showed, in spe-

cific domains experts primarily use subordinate levels because of they know more distinctive features of their entities than novices do. In this work, we propose a method for extracting these subordinate categories from hypernyms found in analytical definitions.

We develop here a method for extracting hyponymy-hyperonymy relations from analytical definitions in Spanish, having in mind this process of categorization. We perform this extraction using a set of syntactic patterns that introduce definitions on texts. Once we obtained a set of candidates to analytical definitions, we filter this set considering the most common hyperonyms (in this case, the Genus terms of such definitions), which are detected by establishing specific frequency thresholds. Finally, the most frequent hypernym subset is used for extracting subordinate categories. We prioritize here relational adjectives because they associate a set of specialized properties to a noun (that is, the hypernym).

2 Concept theories

Categorization is one of the most basic and important cognitive processes. Categorization involves recognizing a new entity as part of abstract something conceived with other real instances (Croft and Cruse, 2004). Concepts and categories are two elements that cannot be seen separated each other. As Smith and Medin (1981) point out, concepts have a categorization function used for classifying new entities and extracting inferences about them.

Several theories have been proposed in order to explain formation of concepts. The classical theory (Aristotelian) holds that all instances of a concept share common properties, and that these common properties are necessary and sufficient to define the concept. However, classical approach did not provide explanation about many concepts, This fact led to Rosch to propose the prototype theory (1978) which explains, unlike to the classical theory, the instances of a concept differ in the degree to which they share certain properties, and consequently show a variation respect to the degree of representation of such concept. Thus, prototype theory provides a new view in which a unitary description of concepts remains, but where the properties are true of most, and not all members. On the other hand, exemplar theory holds that there is no single representation of an entire class or concept; categories are represented by specific exemplars instead of abstracted prototypes (Minda and Smith, 2002).

Finally, as mentioned in section 1, prototype theory supports existence of a hierarchical category system where a basic level is the most used level. In this work we assumed this basic level is genus found in analytical definitions, so that we use it for extracting subordinate categories.

2.1 Principles of categorization

Rosch (1978) proposes two principles in order to build a system of categories. The first refers to the function of this system, which must provide a maximum of information with the least cognitive effort. The second emphasizes that perceived world (not-metaphysical) has structure. Maximum information with least cognitive effort is

achieved if categories reflect the structure of the perceived world as better as possible. Both the cognitive economy principle and the structure of perceived world have important implications in the construction of a system of categories.

Rosch conceives two dimensions in this system: vertical and horizontal. Vertical dimension refers to the category's level of inclusiveness, that is, the subsumption relation between different categories. In this sense, each subcategory C' must be a proper subset from its immediately preceding category C , that is:

$$C' \subset C, \text{ where } |C'| < |C| \quad (1)$$

The implications of both principles in the vertical dimension are that not all the levels of categorization C are equally useful. There are basic and inclusive levels C_i^b where categories can reflect the structure of attributes perceived in the world. This inclusiveness level is the mid-part between the most and least inclusive levels, that is:

$$C_i^b \subset C_j^{\text{sup}} \text{ and } C_k^{\text{sub}} \subset C_i^b, \text{ for } i, j, k > 0 \quad (2)$$

In the figure 1, basic levels C_i^b are associated with categories such as *car*, *dog* and *chair*. Categories situated on the top of the vertical axis—which provide less detail—are called superordinate categories C_j^{sup} (*vehicle*, *mammal*, and *furniture*). In contrast, those located in the lower vertical axis, which provide more detail, are called subordinate categories C_k^{sub} (*saloon*, *collie*, and *rocking chair*).

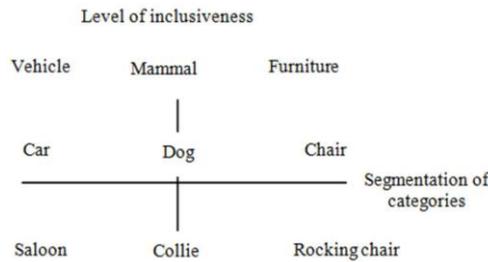


Fig. 1. The human categorization system (extracted from Evans and Green 2006)

On the other hand, horizontal dimension focuses on segmentation of categories in the same level of inclusiveness, that is:

$$\bigcup_{i=1}^n C_i = C, \text{ where } C_i \cap C_k = \emptyset, i \neq k \quad (3)$$

Where n represents number of subcategories C_i within category C . Ideally, these subcategories must be a relevant partition from C . The implications of these principles of categorization in the horizontal dimension are that—when there is an increase in the level of differentiation and flexibility of the categories C_i — they tend to be defined in

terms of prototypes. These prototypes have the most representative attributes of instances within a category, and fewer representative attributes of elements of others. This horizontal dimension is related to the principle of structure of the perceived world.

2.2 Levels of categorization

Studies on cognitive psychology reveal the prevalence of basic levels in natural language. Firstly, basic level terms tend to be monolexemic (*dog, car, chair*); in contrast, subordinate terms have at least two lexemes (e.g.: *rocking chair*), and often include basic level terms (Murphy 2002; Minda and Smith 2002, Croft and Cruse 2004; Evans and Green 2006). Secondly, the basic level is the most inclusive and the least specific for delineating a mental image. Thus, if we considered a superordinate level, it is difficult to create an image of the category, e.g.: *furniture*, without thinking in a specific item like a *chair* or a *table*. Despite preponderance of the basic level, superordinate and subordinate levels also have very relevant functions. According to Croft and Cruse (2004), superordinate level emphasizes functional attributes of the category, and also performing a collecting function. Meanwhile, subordinate categories achieve a function of specificity. Given the function of specificity of subordinate categories in specialized domains, we consider them are important for building lexicons and taxonomies.

3 Subordinate categories of interest

Let H be set of all single-word hyperonyms implicit in a corpus, and F the set of the most frequent hyperonyms in a set of candidate analytical definitions by establishing a specific frequency threshold m :

$$F = \{x \mid x \in H, \text{freq}(x) \geq m\} \quad (4)$$

On the other hand, NP is the set of noun phrases representing candidate categories:

$$NP = \{np \mid \text{head}(np) \in F, \text{modifier}(np) \in \text{adjective}\} \quad (5)$$

Subordinate categories C of a basic level b are those holding:

$$C^b = \{np \mid \text{head}(np) \in F, \text{modifier}(np) \in \text{relational-adjective}\} \quad (6)$$

Where modifier (np) represents an adjective inserted on a noun phrase np with head b . We hope these subcategories reveal important division perspectives of a basic level. In this work we only focused on relational adjectives, although prepositional phrases can generate relevant subordinate categories (e.g., *disease of Lyme* or *Lyme disease*).

4 Types of adjectives

According to Demonte (1999), adjectives are a grammatical category whose function is to modify nouns. There are two kinds of adjectives which assign properties to nouns: attributive and relational adjectives. On the one hand, descriptive adjectives refer to constitutive features of the modified noun. These features are exhibited or characterized by means of a single physical property: color, form, character, predisposition, sound, etc.: *el libro azul* (the blue book), *la señora delgada* (the slim lady). On the other hand, relational adjectives assign a set of properties, e.g., all of the characteristics jointly defining names as: *puerto marítimo* (maritime port), *paseo campestre* (country walk). In terminological extraction, relational adjectives represent an important element for building specialized terms, e.g.: *inguinal hernia*, *venereal disease*, *psychological disorder* and others are considered terms in medicine. In contrast, *rare hernia*, *serious disease* and *critical disorder* seem more descriptive judgments.

5 Methodology

We expose here our methodology for extracting first conceptual information, and then recognizing our candidates of hyponyms.

5.1 Automatic extraction of analytical definitions

We assume that the best sources for finding hyponymy-hyperonymy relations are the definitions expressed in specialized texts, following to Sager and Ndi-Kimbi (1995), Pearson (1998), Meyer (2001), as well Klavans and Muresan (2001). In order to achieve this goal, we take into account the approach proposed by Acosta et al. (2011). Figure 2 shows an overview of the general methodology, where input is a non-structured text source. This text source is tokenized in sentences, annotated with POS tags and normalized. Then, syntactical and semantic filters provide the first candidate set of analytical definitions. Syntactical filter consists on a chunk grammar considering verb characteristics of analytical definitions, and its contextual patterns (Sierra *et al.*, 2008), as well as syntactical structure of the most common constituents such as term, synonyms, and hyperonyms. On the other hand, semantic phase filters candidates by means of a list of noun heads indicating relations part-whole and causal as well as empty heads semantically not related with term defined. An additional step extracts terms and hyperonyms from candidate set.

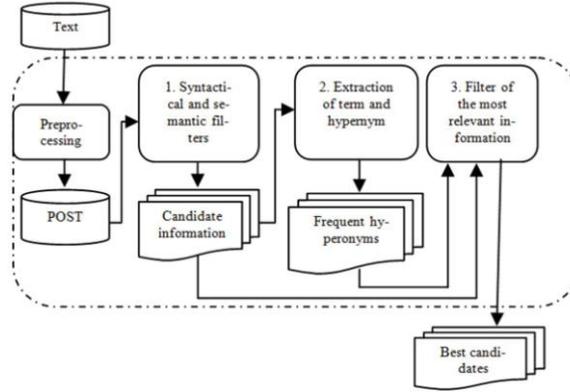


Fig. 2. Methodology for extracting analytical definitions

5.2 Extraction of subordinate categories

As in the case of terms, we consider relational adjectives and prepositional phrases are used for building subordinate categories in specialized domains, but in this work we only focused on relational adjectives. Thus, we use the most frequent hyperonyms for extracting these relevant subordinate categories. In first place, we obtain a set of noun phrases with structure: noun + adjective from corpus, as well as its frequency. Then, noun phrases with hyperonyms as head are selected, and we calculate the pointwise mutual information (PMI) for each combination. Given its use in collocation extraction, we select a PMI measure, where PMI thresholds are established in order to filter non-relevant (NR) information. We considered the normalized PMI measure proposed by Bouma (2009):

$$i_x(x, y) = \left(\ln \frac{p(x, y)}{p(x)p(y)} \right) / -\ln p(x, y) \quad (7)$$

This normalized variant is due to two fundamental issues: to use association measures whose values have a fixed interpretation, and to reduce sensibility to low frequencies of data occurrence.

6 Results

In these sections we expose the results of our experiments.

6.1 Text source

Our source is a set of medical documents, basically human body diseases and related topics (surgery, treatments, and so on). These documents were collected from *MedLinePlus* in Spanish. *MedLinePlus* is a site whose goal is to provide information about diseases and conditions in an accessible way of reading. The size of the corpus is 1.3 million of words. We chose a medical domain for reasons of availability of textual resources in digital format. Further, we assume that the choice of this domain does not suppose a very strong constraint for generalization of results to other domains.

6.2 Programming language and tools

Programming language used for automatizing all of the tasks was Python and NLTK module (Bird, Klein and Loper 2009). Our proposal is based on lexical-syntactical patterns, so that we assumed as input a corpus with POS tags. POS tagged was done with TreeTagger (Schmid 1994).

6.3 Some problems for analyzing

In these sections we delineate some important problems detected in our experiment: the recognition to a relation of semantic compositionality between hyperonyms.

6.3.1 Semantic compositionality between hyperonyms and relational adjectives

We understand semantic compositionality as a regulation principle that assigns a specific meaning to each of lexical units in a phrase structure, depending on the syntactical configuration assuming such structure (Partee, 1995). Specific combinations of lexical units determine the global meaning of a phrase or sentence generating not only isolated lexical units, but blocks which refer to specific concepts (Jackendoff, 2002). Given this principle, a term as *gastrointestinal inflammation* operates as a hyponym or subordinate category with more wealth of specific information, than the hypernym *inflammation*.

6.3.2 Hypernym and its lexical fields

Hypernyms, as generic classes of a domain, are expected to be related to a great deal of modifiers such as adjectives, nouns and prepositional phrases reflecting more specific categories (e.g., *cardiovascular disease*) than hyperonyms, or simply sensitive descriptions to a specific context (e.g., *rare disease*). As an illustrative example and only for the case of adjective modifiers, table 1 shows the disease hypernym and the first most related subset of 50 adjectives, taking into account its PMI values. In this example extracted of a real corpus, only 30 out of 50 (60%) are relevant relations. In total, disease is related to 132 adjectives, of which, 76 (58%) can be considered relevant.

Table 1. The first 50 adjectives with most high PMI value

| C(enfermedad, w_i) |
|---|
| Transmisible, prevenible, diarreica, diverticular, indicadora, autoinmunitaria, aterosclerótica, meningocócica, cardiovascular, pulmonar, afecto, febril, agravante, hepática, seudogripal, periodontal, sujeto, bacteriano, emergente, benigno, parasitaria, postrombótica, bacteriémica, coexistente, catastrófica, exclusiva, vectorial, supurativa, infecciosa, debilitante, digestiva, invasora, rara, inflamatoria, esporádica, antimembrana, predisponente, ulcerosa, contagiosa, cardíaca, sistémica, activa, grave, preexistente, miocárdica, somática, fulminante, atribuible, linfoproliferativa |

On the other hand, if we consider a relational adjective, for example, cardiovascular, we find that it modifies to a set of nouns, as shown in table 2. The case of a descriptive adjective as rare is similar; it also modifies a set of nouns. Thus, we have both relational and descriptive adjectives can be linked with other elements, this situation mirrors how the compositionality principle operates, decreasing precision to the association measures for detecting relevant relations.

Table 2. Nouns modified by relational adjective cardiovascular and descriptive adjective rare

| C(w_i , cardiovascular) | C(w_i , raro) |
|---|---|
| efecto, problema, congreso, función, evento, relación, examen, inestabilidad, trastorno, enfermedad, bypass, causa, beneficio, sistema, reparador, descompensación, cirugía, operación, mortalidad, aparato, educación, síntoma, eficiencia, episodio, riesgo, investigación, manifestación, afección, medicamento, director, muerte, salud | televisión, enfermedad, complicación, infancia, niño, color, obesidad, mhc, nucleótido, sustancia, mutación, trastorno, grupo, meconio, epistaxis, derecha, síndrome, cáncer, alelo, forma, caso, párpado |

6.3.3 Linguistic heuristics for filtering non-relevant adjectives

In order to face the phenomenon of compositionality between hyperonyms and relational adjectives that affect the performance of traditional measures, we automatically extract a stop-list of descriptive adjectives from the same source of input information, implementing three criteria proposed in Demonte (1999) for distinguishing between descriptive and relational adjectives. These criteria are:

- Adjective used predicatively: *The method is important.*
- Adjective used in comparisons, so that its meaning is modified by adverbs of degree: *relatively fast.*
- Precedence of adjective respect to the noun: *A serious disease.*

6.4 Automatic extraction of conceptual information

We consider two approaches based on patterns, and a baseline derived from only most common verbs used in analytical definitions. Both of the methods outperformed baseline's precision, but recall was significantly decreased. On the one hand, the method proposed by Sierra *et al.* (2008) achieved a good recall (63%), but the precision was very low (24%). On the other hand, with the method proposed by Acosta *et al.* (2011) we achieved a high precision (68%), and a trade-off between precision and recall (56%). Given that this latter method achieved the better results, we decided to implement it in order to obtain our set of hyperonyms necessary for the next phase of extraction of subordinate categories.

Table 3. Extraction of analytical definitions

| | Precision | Recall | F-Measure |
|-----------------------------|-----------|--------|-----------|
| Baseline | 8% | 100% | 15% |
| Sierra <i>et al.</i> (2008) | 24% | 63% | 35% |
| Acosta <i>et al.</i> (2011) | 68% | 56% | 61% |

6.5 Extraction to subordinate categories

We extract a set of descriptive adjectives by implementing linguistic heuristics. Our results show a high precision (68%) with a recall acceptable (45%). This subset of descriptive adjectives is removed from the set of noun phrases with structure: noun + adjective before final results. Table 4 shows the initial precision, that is, precision obtained without some filtering process.

Table 4. Initial precision

| Hyperonym | Initial precision | Hyperonym | Initial precision |
|---------------|-------------------|-------------|-------------------|
| Enfermedad | 61 | Tratamiento | 36 |
| Desorden | 80 | Cirugía | 67 |
| Examinación | 52 | Método | 37 |
| Condición | 61 | Problema | 62 |
| Procedimiento | 40 | Proceso | 47 |
| Infección | 56 | Inflamación | 58 |
| Proteína | 67 | Glándula | 95 |
| Cáncer | 55 | Órgano | 43 |
| Tumor | 63 | Medicamento | 60 |

This precision is compared with precision by setting several PMI thresholds (0, 0.10, 0.15, and 0.25) as shown in table 5. Results show a significant improvement in precision from PMI 0.25, but recall is negatively affected as this threshold is increased. On the other hand, if we consider linguistic heuristics we obtain a trade-off between precision and recall, as shown in table 6.

7 Final considerations

In this paper we present a comparison between two approaches for automatically extracting subordinate categories arising from a hypernym within a domain of medical knowledge.

The main point in this discussion is the possibility to generate a lot of relevant hyponyms having as head a hypernym. Unfortunately, given the generic nature of the single-word hypernyms, these can be directly linked with a large amount of modifiers such as nouns, adjectives and prepositional phrase, so that to extract the most relevant subordinate categories with traditional measures become a very complex task.

In this paper we only consider relational adjectives, because we consider they are best candidates for codifying subordinate categories. It is remarkable the high degree of compositionality present in the relation between hyperonyms and relational adjectives, which is detrimental to the accuracy of measures of association to select relevant relations. It is just in these scenarios where the regularity of language, according to Manning and Schütze (1999) acquires great importance for assisting methods such as parsing, lexical/semantic disambiguation and, in our particular case, extracting relevant hyponyms.

Table 5. Precision (P), recall (R) and F-Measure (F) by PMI threshold

| Hyperonym | PMI >= 0 | | | PMI >= 0.10 | | | PMI >= 0.15 | | | PMI >= 0.25 | | |
|---------------|----------|-----|----|-------------|-----|----|-------------|-----|----|-------------|----|----|
| | P | R | F | P | R | F | P | R | F | P | R | F |
| Enfermedad | 66 | 89 | 76 | 69 | 74 | 71 | 68 | 61 | 64 | 74 | 30 | 43 |
| Desorden | 82 | 92 | 87 | 85 | 79 | 82 | 85 | 74 | 79 | 87 | 58 | 70 |
| Examinación | 55 | 96 | 70 | 62 | 85 | 72 | 67 | 78 | 72 | 76 | 69 | 72 |
| Condición | 62 | 97 | 76 | 62 | 86 | 72 | 66 | 78 | 72 | 69 | 55 | 61 |
| Procedimiento | 40 | 100 | 57 | 43 | 100 | 60 | 40 | 84 | 54 | 57 | 68 | 62 |
| Infección | 58 | 92 | 71 | 64 | 81 | 72 | 67 | 67 | 67 | 73 | 47 | 57 |
| Proteína | 67 | 100 | 80 | 71 | 100 | 83 | 74 | 100 | 85 | 83 | 89 | 86 |
| Cáncer | 59 | 97 | 73 | 56 | 81 | 66 | 57 | 72 | 64 | 61 | 61 | 61 |
| Tumor | 63 | 100 | 77 | 64 | 88 | 74 | 66 | 83 | 74 | 69 | 64 | 66 |
| Tratamiento | 36 | 90 | 51 | 39 | 78 | 52 | 45 | 73 | 56 | 52 | 47 | 49 |
| Cirugía | 68 | 100 | 81 | 73 | 91 | 81 | 74 | 84 | 79 | 72 | 52 | 60 |
| Método | 37 | 100 | 54 | 39 | 100 | 56 | 39 | 93 | 55 | 38 | 64 | 48 |
| Problema | 64 | 93 | 76 | 63 | 75 | 68 | 65 | 54 | 59 | 67 | 29 | 40 |
| Proceso | 47 | 100 | 64 | 50 | 95 | 66 | 50 | 86 | 63 | 53 | 65 | 58 |
| Inflamación | 57 | 94 | 71 | 55 | 89 | 68 | 57 | 89 | 69 | 52 | 61 | 56 |
| Glándula | 95 | 100 | 97 | 95 | 100 | 97 | 95 | 100 | 97 | 95 | 95 | 95 |
| Órgano | 44 | 100 | 61 | 40 | 82 | 54 | 39 | 71 | 50 | 43 | 71 | 54 |
| Medicamento | 60 | 98 | 74 | 69 | 94 | 80 | 67 | 92 | 78 | 77 | 81 | 79 |

Table 6. Precision, recall and F-measure by linguistic heuristics

| Hyperonym | Linguistic Heuristics | | |
|---------------|-----------------------|-----|-----|
| | P | R | F |
| Enfermedad | 79 | 74 | 76 |
| Desorden | 95 | 69 | 80 |
| Examinación | 74 | 85 | 79 |
| Condición | 88 | 75 | 81 |
| Procedimiento | 85 | 89 | 87 |
| Infección | 84 | 76 | 82 |
| Proteína | 88 | 76 | 82 |
| Cáncer | 69 | 94 | 80 |
| Tumor | 82 | 86 | 84 |
| Tratamiento | 68 | 70 | 69 |
| Cirugía | 90 | 82 | 86 |
| Método | 72 | 82 | 77 |
| Problema | 83 | 67 | 74 |
| Proceso | 73 | 73 | 73 |
| Inflamación | 82 | 78 | 80 |
| Glándula | 100 | 100 | 100 |
| Órgano | 71 | 71 | 71 |
| Medicamento | 76 | 72 | 74 |

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