Resolving Multiple Hyperonymy

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Abstract

WordNet contains a fair number of synsets with multiple hyperonyms. In parent–child relations, a child can have only one parent (ancestor). Consequently, multiple hyperonymy represents distinct semantic relations. In order to reclassify the multiple hyperonyms, we define a small set of new semantic relations (such as **function**, **origin** and **form**) that cover the various instances of multiple hyperonyms. The synsets with multiple hyperonyms that lead to the same root and belong to the same semantic class were grouped automatically, resulting in semantic patterns that serve as a point of departure for the classification. The proposed changes are based on semantic analysis and may involve the redefinition of one or several multiple hyperonymy relations to new ones, the removal of one or several multiple hyperonymy relations, and rarely the addition of a new hyperonymy relation. As a result, we incorporate the newly defined semantic relations that resolve the former multiple hyperonymy relations and propose an updated WordNet structure without multiple hyperonyms. The resulting WordNet structure without multiple hyperonyms may be used for a variety of purposes that require proper inheritance.

1 Introduction

WordNet (Miller et al., 1990; Fellbaum, 1998) is a lexical semantic network that encodes human knowledge about synonyms – words (or multi-word expressions) denoting the same concept – and the semantic relationships between the concepts. The nodes of the semantic network are synonym sets (synsets), which are connected by arcs representing semantic relations.

The **hyperonymy** relation (and its inverse relation, **hyponymy**) connects more general concepts to more specific ones and organizes noun synsets in hierarchies, with the most abstract concepts at the root of the trees and the most specific concepts at the leaves of the trees (Miller et al., 1990). Hyperonymy and hyponymy relations satisfy properties for asymmetry and transitivity (Lyons, 1977; Miller et al., 1990). For instance, if *bird* is a hyperonym of *parrot*, then *parrot* is not a hyperonym of *bird*; similarly, if *parrot* is a hyponym of *bird*, then *bird* is not a hyponym of *parrot*. Another example illustrates the transitivity: if *bird* is a hyperonym of *parrot* and *parrot* is a hyperonym of *cockatoo*, then *bird* is a hyperonym of *cockatoo*. And vice versa, if *cockatoo* is a hyponym of *parrot* and *parrot* is a hyponym of *bird*, then *cockatoo* is a hyponym of *bird*.

The structure of nouns in WordNet is a cycle-free directed connected graph whose root is an abstraction that refers to all concepts included in the hierarchy and is therefore a hyperonym of all other synsets. A unique path exists between two nodes in the tree. A hyperonym may have multiple hyponyms, and a hyponym should have exactly one hyperonym.

However, a common practice in wordnets is to use multiple hyperonyms. Multiple hyperonyms can be exclusive (*albino* is either an *animal* or a *human*), conjunctive (*spoon* is both *cutlery* and *container*) or nonexclusive (*knife* can be *cutlery*, a *weapon*, or both) (EAGLES, 1999).

Disjunctive (exclusive) hyperonymy is related to polysemy in that different meanings of the same word can have different hyperonyms; thus, disjunctive multiple hyperonyms should not be present in the WordNet. Actually, in WordNet, the hyperonym of *albino* with the meaning 'a person with congenital albinism: white hair and milky skin; eyes are usually pink' is one – *person*. This suggests that for an albino animal, there must be another concept in the WordNet structure that refers only to an animal with the relevant anomaly.

Conjunctive multiple hyperonyms have a common hyperonym (usually not the direct one). In fact, conjunctive hyperonymy exemplifies the cases in which different types of semantic relations can be defined to replace multiple hyponymy relations.

The so-called non-exclusive hyperonymy allows both disjunctive and conjunctive relations, and such cases should not occur in WordNet because different senses could not be encoded in one and the same synset. For example, *hatmaker* defined as 'someone who makes and sells hats' has two hyperonyms: *maker* – 'a person who makes things' and *merchant* – 'a businessperson engaged in retail trade'.

Our work aims to investigate and resolve multiple hyperonymy relations in WordNet, which can be accomplished in one of two ways: either by defining new relations in place of some hyperonymy relations (since multiple hyperonymy may encompass several semantic relations that can be further specified) or by deleting hyperonymy relations (if appropriate). In our study, we define a small set of new semantic relations (such as **function**, **origin** and **form)** that will cover the different instances of multiple hyperonymy relations, and we classify these relations according to the defined set.

The paper is organised as follows. Section 2 explains the motivation behind our work. Section 3 places our work in the context of related studies. Section 4 presents our approach. In Subsection 4.1 we show how the synsets with multiple hyperonyms were grouped automatically, such as to form semantic patterns appropriate for the next semantic analysis. We propose an updated WordNet structure that eliminates multiple hyperonymy and incorporates the newly defined relations between the respective synsets (Subsection 4.2). Then, in Section 5, we propose a brief description of the new relations, followed by conclusions and future work (Section 6).

The resulting WordNet structure without multiple hyperonyms may be used for a variety of purposes that require proper inheritance.

2 Motivation

The hyperonymy relation is exploited in many implementations related with word sense disambiguation (Otegi et al., 2022), taxonomy extraction (Pontiki et al., 2015) or ontology learning (Lourdusamy and Abraham, 2020; Wątróbski, 2020), knowledge mining (Chen et al., 2020), etc. Thus, the unambiguous definition of hyperonymy is important for many language processing tasks.

Our motivation stems from the use of semantic classes for nouns and their inheritance from hyponyms when encoding the syntagmatic combinations of verbs and nouns. Nouns and verbs are grouped in WordNet into more specific semantic classes (Miller et al., 1990, p. 16), (Fellbaum, 1998, p. 41), describing their general meaning: noun.person, noun.animal, noun.cognition; verb.cognition, verb.change, etc. Nouns are classified into twenty-five semantic classes and verbs – into fifteen semantic classes. For example, the verbs *cook*; *fix*; *prepare* with a definition 'prepare for eating by applying heat' can be combined with nouns classified as noun.person: *the mother cooks dinner*. However, not all nouns from the class noun.person can collocate with these verbs as their subject and not every noun that is not classified as a noun.person can be their object (*the exspouse*, ?*the neoliberal*, **the infant cooks dinner*, ?*elephant*, **books*). In other words, the WordNet noun semantic classes could be further specified in order to correlate precisely with the verb-noun selectional preferences.

In a previous work we mapped 253 Corpus Pattern Analysis semantic types to the appropriate WordNet noun synsets (Koeva et al., 2018). For example, the semantic type [Permission] is mapped to the synset *permission* 'approval to do something', the semantic type [Dispute] is mapped to the synset *disagreement* 'the speech act of disagreeing or arguing or disputing', and so on. 55 semantic classes are employed so far in our work aiming at defining Conceptual frames (Koeva and Doychev, 2022), and 28 new specific semantic classes are added to encode verb-noun compatibility. The mapping of hyponym synsets to the semantic class of their hyperonym is done automatically. For this purpose, eliminating multiple hyperonyms is critical for inheriting the detailed semantic classes we employ.

3 Related work

WordNet is an **inheritance (is-a)** based semantic resource, although inheritance is only one of the semantic relations in the network. In WordNet, a hyponym inherits all the features of the more generic concept and adds at least one feature that distinguishes it from its superordinate and from any other hyponyms of that superordinate (Miller et al., 1990). In order to use the inheritance relation in WordNet, the paths along the hyperonymy – hyponymy trees should be unambiguous, or, in other words, multiple hyperonymy should be resolved where possible.

Inheritance is important in the way that all noun synsets that are hyponyms of a synset representing a particular semantic class should inherit the properties of this class. This is generally true, and if the inheritance relations of nouns are further specified by assigning more particular semantic classes, noun synset hierarchies can serve as sets of words eligible to fill in particular verb predicate slots.

D. Alan Cruse proposes a three-category hyponymy model that includes natural kinds, nominal kinds, and functional kinds (Cruse, 2002, p. 18–19). **Natural kinds** are classifications of objects such as chemical elements, biological species, and so on, for example: *a dog is an animal*, *a violin is a musical instrument*. Sets of features can express the relations between natural kinds and their hyperonyms. In contrast, the relations between **nominal kinds** and their hyperonyms can be expressed as a single distinguishing feature: *mare is a female horse*, *kitten is a small cat*, *blonde is a blond woman*, and so on. **Functional kinds** are groups of entities that are linked together by a common function, i.e., their activities and causal roles. Inherent functional kinds are typical kinds of their hyperonyms, such as *gun is a type of weapon*, *hammer is a type of tool*, *jacket is a type garment*, and so on (Cruse, 2002, p. 19).

The proposed distinction is used to create wordnets for languages other than English, emphasizing the distinction between natural kinds and functional kinds as taxonomic relations on the one hand, and nominal kinds as a non-taxonomic relation on the other (Pederson and Sørensen, 2006).

The inheritance properties are part of the inclusion relations, which connect a more general entity to a more specific entity. Class inclusion is described as follows: X's are a type of Y, X's are Y's, X is a type of Y, and X is a Y, for example: *Cars are a type of vehicle*; *Roses are a type of flower*; *Theft is a type of crime*; and *Employee is a person* (Winston et al., 1987). V. Storey (Storey, 1993) describes several types of inclusion: classification, which relates an entity occurrence to an entity type; generalisation, in which an entity type is the union of non-overlapping subtypes; specialisation, which is defined as the inverse of generalisation; and subset hierarchy, in which potentially overlapping subtypes exist. The inheritance principle of **is-a relations** states that anything that is true about the generic entity type A, must also be true of the specific entity type B. Therefore, any attributes of A are also attributable to B (but not necessarily vice versa). Similarly, in any relations in which A can participate, B can also participate (Storey, 1993).

Other authors divide inclusion into two categories: those that relate generic to generic concepts (subset and superset, generalization and specialization, a kind of, conceptual containment, role value restrictions, sets and their characteristic types) and those that relate generic to individual concepts (set membership, predication, conceptual containment, abstraction) (Brachman, 1983). According to this analysis, the inclusion hierarchy of noun synsets may be divided into different hierarchies depending on the type of inclusion. Our goal is not to achieve this; instead, we will concentrate on cases of multiple hyperonymy and propose changing one or more hyperonymy relations based on the semantics of the relations between the synsets.

The hyponymy relation has been approached from a qualia-based perspective, yielding two types of hyponymy (Mendes and Chaves, 2001). Briefly, the level of representation at which the semantic content of a lexical item is encoded through the properties and events that define it is referred to as the Qualia structure. Four fundamental qualia roles determining the lexical-semantic structure of words have been defined (Pustejovsky, 1995):

- Constitutive: conveying the relations between an object and its components;
- Formal: expressing the characteristics that set an entity apart within a bigger domain;
- Telic: expressing an object's purpose and function;
- Agentive: showing the factors involved in the origin or emergence of an object.

It was noticed that two distinct sets of hyponyms can be distinguished: those that share the same constitutive role and those that show more specific information about this role. Based on this assumption, a distinction between true taxonomic hyponymy and functional hyponymy has been proposed (Mendes and Chaves, 2001).

Hyperonymy and hyponymy in WordNet refer to the Formal quale, meronymy relations – to the Constitutive quale, cause relations – to the Agentive quale (Pederson and Sørensen, 2006). To systematically capture all qualia roles, the EuroWordNet relations were extended with two relations (Vossen, 1998): **results (originates) from** and **has as function (goal)** (Amaro et al., 2010).

The fact that the multiple hyperonymy (or multiple inheritance) relations (in many cases) encode other relations or are used to indicate something other than the conjunction of two properties has already been pointed out (Kaplan and Schubert, 2001; Gangemi et al., 2001). So far, the investigations into multiple inheritance in WordNet have been directed mainly at validating the WordNet structure. For example, multiple inheritance test patterns were created to check and validate the semantic hierarchies of the Estonian WordNet (Lohk, 2015).

There is general agreement that hyponymy is a complicated concept and that the relation can be separated into several relations based on the hyponym's intrinsic features and the conveyed semantic relation with the hyperonym. The presence of multiple hyperonyms indicates that the WordNet hyperonymy (and its properties) exhibits a wide range of cases.

The goal of presented study is to resolve multiple hyperonymy, and we achieve it by: a) removing superfluous hyperonyms; b) replacing some inappropriate hyperonymy relations with holonymy ones; c) adding missing hyperonymy relations; and d) formulating new semantic relations to replace the multiple hyperonymy.

4 Description of the approach

We assume that multiple conjunctive hyperonyms do not represent the same relations. In addition to hyperonymy in this case, other semantic relations are also expressed. Because of the various relations, the conjunction of several hyperonyms is feasible, i.e., two or more general concepts might refer to the more specific one at the same time. We use the term **true hyperonymy**, or simply – **hyperonymy**, by which we mean a hyperonymy that expresses only the **is a** relation between more general and more specific concepts. In conjunctive multiple hyperonymy, one of the hyperonyms expresses the true hyperonymy relation, and the second hyperonym (and subsequent ones) express another semantic relation.

Following the general division of hyponyms (Cruse, 2002), the properties of the Qualia structure (Pustejovsky, 1995), and their application so far in the WordNet (Vossen, 1998), we have identified the following three groups of relations that replace multiple hyperonyms:

- **Property** (here we have distinguished three relations depending on the intrinsic properties of the hyponym):
  - **characteristic** – what feature distinguishes a given entity;
  - **origin** – what is the source of a given entity: natural object, living organism (human, animal), etc.;
  - **form** – what is the form of existence of a given entity: gas, liquid, solid body, material body, etc.
- **Application** (here we have also distinguished three relations depending on the intrinsic properties of the hyponym):
  - **function** – what is the function of a given entity: tool, container, building, etc.;
  - **purpose** – what is the purpose of a given entity;
  - **use** – what is an entity used for.
- **Composition** – what is the composition of a given entity (composition is included since many of the multiple hyperonyms express meronymy relations):
  - **member** – a member to a set;
  - **part** – a part of a whole;
  - **portion** – a portion of a whole.

The following is a description of the data preparation steps that are taken before performing the multiple hyperonymy resolving procedure.

4.1 Data preparation

For the purposes of our study, we used an XML-encoded version of the Princeton WordNet 3.0. This version of WordNet contains 82,114 noun synsets, each assigned with a WordNet semantic class. Out of these, 7,725 synsets are linked only with instance hyperonymy relations (Table 1), while 1,421 synsets have multiple hyperonyms, with the latter defining the scope of our work. Additionally, out of the 13,767 verb synsets, 31 have multiple hyperonyms.

Group	Count
With hyperonyms	74,388
With instance hyperonyms	7,725
With no hyperonyms	1
Total	82,114

Table 1: Noun synset groups based on hyperonymy type

Our interest is focused on the hyperonymy relations of the noun synsets with multiple hyperonyms, taking into consideration all their ancestors (indirect hyperonyms) up to the top level synset {*entity*:1}, which has no hyperonyms (Table 2).

Group	Count
With 2 hyperonyms	1,387
With 3 hyperonyms	30
With 4 hyperonyms	3
With 5 hyperonyms	1
Total	1,421

Table 2: Counts of synsets with multiple hyperonyms

In order to easily analyse the cases of multiple hyperonymy and identify classes of its occurrence, the synsets with multiple hyperonyms were divided non-exclusively into groups based on common hyperonyms. Two types of grouping were performed – defining groups using one common hyperonym (further called single groups) and two common hyperonyms (further called double groups). As synsets with multiple hyperonyms have at least two and up to five hyperonyms, we then expect each synset to be present in as many single groups as the number of its hyperonyms and in as many double groups as the number of its hyperonyms' pairs.

These grouping resulted in 1,814 single groups, of which 512 have 2 or more members and 66 have 5 or more members, and 1,305 double groups, of which 121 have 2 or more members and 40 have 3 or more members. We take particular interest in single groups of 5 or more synsets and double groups of 3 or more synsets, as these suggest larger classes suitable for our analysis. Tables 3 and 4 show the sizes of the 10 largest single and double groups, respectively (in number of hyponyms).

Thematic groups were distinguished within the two large groups (single and double) based on the general thematic class of the hyponym: for example, musical instruments, chemical elements, diseases, and so on. Our hypothesis is that the resolution of multiple hyperonymy will (in many cases) be identical within thematic groups.

Common hyperonym	Size
{*transparent gem*:1}	20
{*gas*:7}	20
{*chemical element*:1; *element*:6}	18
{*woman*:3; *adult female*:1}	17
{*mineral*:3}	12
{*heresy*:1; *unorthodoxy*:2}	11
{*autoimmune disease*:1; *autoimmune disorder*:1}	10
{*monogenic disorder*:1; *monogenic disease*:1}	10
{*theological doctrine*:1}	10
{*food fish*:1}	10

Table 3: 10 largest single groups

Common hyperonyms	Size
{*dynasty*:1} {*royalty*:1; *royal family*:1; *royal line*:1; *royal house*:1}	9
{*heresy*:1; *unorthodoxy*:2} {*theological doctrine*:1}	9
{*clergyman*:1; *reverend*:2; *man of the cloth*:1} {*Holy Order*:1; *Order*:1}	7
{*chemical element*:1; *element*:6} {*gas*:7}	6
{*chemical element*:1; *element*:6} {*noble gas*:1; *inert gas*:1; *argonon*:1}	6
{*athlete*:1; *jock*:2} {*player*:3; *participant*:2}	6
{*chemical element*:1; *element*:6} {*halogen*:1}	5
{*school*:7} {*artistic movement*:1; *art movement*:1}	5
{*edible fruit*:1} {*drupe*:1; *stone fruit*:1}	5
{*musical composition*:1; *opus*:1; *composition*:8; *piece*:13; *piece of music*:1} {*passage*:9; *musical passage*:1}	5

Table 4: 10 largest double groups

In order to aid the manual resolution of multiple hyperonymy, we generated visualisations of the hyperonymy graphs of all synsets with multiple hyperonyms, displaying all direct and indirect hyperonyms up to {*entity*:1}. These display the synset ID in WordNet 3.0 and literals for each synset in the graph. The visualisations were generated using graphviz (Gansner and North, 2000).

Figure 1 shows an example of one such graph visualisation for the synset {*person*:1; *individual*:1; *someone*:1; *somebody*:1; *mortal*:1; *soul*:1}, which has two hyperonyms – {*organism*:1; *being*:1} and {*causal agent*:1; *cause*:1; *causal agency*:1}. The figure displays all direct and indirect hyperonyms of {*person*:1; *individual*:1; *someone*:1; *somebody*:1; *mortal*:1; *soul*:1} up to {*entity*:1} and the hyperonymy relations between them.

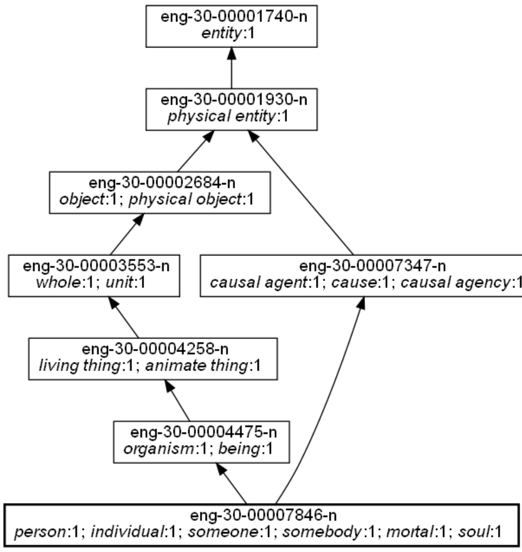

Figure 1: Graph for synset {*person*:1}

4.2 Resolving multiple hyperonymy

Initially, we focused on the 40 double groups of synsets with multiple hyperonyms with 3 or more members, as well as on some large single groups. We then expanded the scope to all 1,421 synsets with multiple hyperonyms. Our proposed changes include:

- Changing a multiple hyperonymy relation to one of 9 other relation types, 6 of which are newly defined;
- Removing a hyperonymy relation in rare cases where it is not properly connected;
- Adding a new hyperonymy relation where none of the currently linked hyperonyms is deemed suitable.

As a result of our efforts, we proposed resolving multiple hyperonymy for 1,421 synsets, with 1,638 changes to relations[1]. Table 5 presents the proposed actions and their count within the scope of the effort. As of the submission of this paper, validation of the proposed changes is ongoing, so the numbers presented are indicative.

Action	**Count**
Remove relation	66
Change relation to **characteristic**	388
Change relation to **origin**	19
Change relation to **form**	122
Change relation to **function**	431
Change relation to **purpose**	117
Change relation to **use**	123
Change relation to **member**	13
Change relation to **part**	76
Change relation to **portion**	23
Add new hyperonymy relation	76
Remove relation of a hyperonym	11
Change relation type of a hyperonym	1
Add relation of a hyperonym	14

Table 5: Proposed action types

The changes affecting the hyperonyms and their relations to next-level hyperonyms are shown in the last three rows of Table 5. They are a result of the change in the WordNet structure that removes multiple hyperonyms, and they represent the removal of an incorrect link or the addition of a missing link.

As an illustrative example, we will present the proposed changes for synsets with a common multiple hyperonym {*chemical element*:1; *element*:6}. For this hyperonym synset there are three large double groups and one single group.

Double group 1 has 6 members, which share the following multiple hyperonyms:

- {*chemical element*:1; *element*:6}
- {*noble gas*:1; *inert gas*:1; *argonon*:1}

The group includes synsets for noble gas elements such as {*helium*:1; *He*:2; *atomic number 2*:1} and {*neon*:1; *Ne*:2; *atomic number 10*:1}. The proposed change is:

- Remove the hyperonym {*chemical element*:1; *element*:6}, as it is already a hyperonym of {*noble gas*:1; *inert gas*:1; *argonon*:1}.

[1]The results are available online at https://github.com/DCL-IBL/SemNet

Double group 2 has 5 members with the following multiple hyperonyms:

- {*chemical element*:1; *element*:6}
- {*halogen*:1}

The group includes synsets for halogen elements, such as {*chlorine*:1; *Cl*:2; *atomic number 17*:1}, {*bromine*:1; *Br*:1; *atomic number 35*:1} and {*fluorine*:1; *F*:6; *atomic number 9*:1}, halogens that are usually gasses, covered also in the group 3 of this topic. The proposed changes for group 2 are:

- Change the hyperonym of {*halogen*:1} from {*group*:1; *grouping*:1} to {*chemical element*:1; *element*:6};
- Remove the hyperonym {*chemical element*:1; *element*:6} as it is already a hyperonym of {*halogen*:1};
- Change the hyperonym relations from {*chlorine*:1; *Cl*:2; *atomic number 17*:1} and {*fluorine*:1; *F*:6; *atomic number 9*:1} to {*gas*:7} to **form**;
- Add a relation **form** from {*bromine*:1; *Br*:1; *atomic number 35*:1} to {*gas*:7}.

Double group 3 has 6 members with the following common hyperonyms:

- {*chemical element*:1; *element*:6}
- {*gas*:7}

The group includes synsets for elements that usually take the form of a gas, such as {*oxygen*:1; *O*:4; *atomic number 8*:1} and {*nitrogen*:1; *N*:8; *atomic number 7*:1}. The proposed change is:

- Change the hyperonymy relation to {*gas:7*} to the relation **form**.

There are 3 more synsets in the single group with common hyperonym {*chemical element*:1; *element*:6}, not covered as members of the above double groups. These are:

- {*germanium*:1; *Ge*:3; *atomic number 32*:1} with hyperonyms:
  - {*chemical element*:1; *element*:6};
  - {*semiconductor*:2; *semiconducting material*:1} (This hyperonymy relation's proposed change is to **function**.)
- {*silicon*:1; *Si*:2; *atomic number 14*:1} with hyperonyms:
  - {*chemical element*:1; *element*:6};
  - {*semiconductor*:2; *semiconducting material*:1} (This hyperonymy relation's proposed change is to **function**.)
- {*selenium*:1; *Se*:1; *atomic number 34*:1} with hyperonyms:
  - {*chemical element*:1; *element*:6};
  - {*antioxidant*:1} (This hyperonymy relation's proposed change is to **function**.)

As a result of the proposed changes, for these synsets the following is observed:

- Each synset has only one hyperonymy relation, which is to {*chemical element*:1; *element*:6};
- A synset may have a relation **function** to a synset which was previously marked as a hyperonym;
- A relation **form** to {*gas*:7} may be inserted to keep uniformity with the rest of the chemical elements existing in gas form.

In some cases, such as with the synset {*halogen*:1}, an appropriate restructuring of the hyperonymy tree (immediately above the considered synset with multiple hyperonymy) may be required to properly resolve multiple hyperonymy. Figures 2 and 3 visualise the state of the WordNet structure immediately above the synset {*chlorine*:1; *Cl*:2; *atomic number 17*:1} before and after the proposed changes to relations.

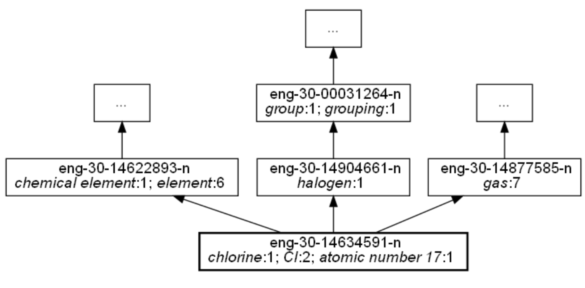

Figure 2: Local graph for synset {*chlorine*:1; *Cl*:2; *atomic number 17*:1} without the proposed changes

The synset {*chlorine*:1; *Cl*:2; *atomic number 17*:1} was originally related with three hyperonyms, two of which have a common hyperonym {*abstraction*:1; *abstract entity*:1}, and all three are finally related to the hyperonym {*entity*:1}.

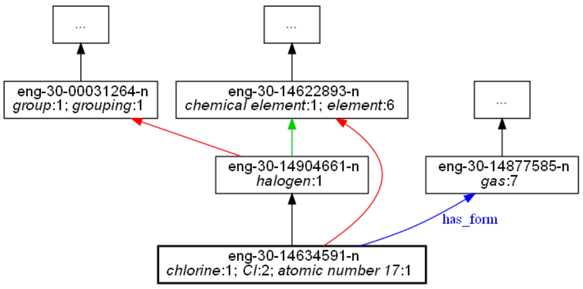

Figure 3: Local graph for synset {*chlorine*:1; *Cl*:2; *atomic number 17*:1} with the proposed changes – blue lines are changed relations, green line is added relation, red lines are removed relations

5 A brief description of the new relations

Conjunctive multiple hyperonyms are assumed not to indicate the same relation. Other semantic relations are formulated in addition to true hyperonymy, allowing a conjunction between several "hyperonyms", or when two or more more general concepts relate to a more specific one at the same time. Conjunctive multiple hyperonymy represents the newly proposed semantic relations and the true hyperonym, which reflects the genuine hyperonymy relation.

The new relations are antisymmetric and intransitive and the direction of the relations is important for expressing their semantics. Inverse relations with analogous properties are defined: has characteristic, is characteristic of, has origin, is origin for, has form, is form for, has function, is function for, uses, is used for, has member, is member of, has part, is part of, has portion, is portion of.

Following existing approaches (Alonge et al., 1998) we formulated diagnostic tests for the new relations. Let we consider the synset {*hydrogen*:1; *H*:7; *atomic number 1*:1}, currently linked with two hyperonyms: {*chemical element*:1; *element*:6} and {*gas*:7}. The relation to {*gas*:7} is redefined as **form**: hydrogen has form of gas.

We can apply the following tests to detect the relation **form** between nouns:

X has the form of Y.

If it is X, then it must have the form of Y.

Examples:

Hydrogen has the form of a gas.

? A gas has the form of hydrogen.

It is hydrogen, therefore it has the form of a gas.

? It is a gas, therefore it has the form of hydrogen.

If it is hydrogen, then it must have the form of a gas.

? If it is a gas, then it must have the form of hydrogen.

An application of the hyperonymy test shows that the relation **form** also expresses the semantics of the hyperonymy:

It is hydrogen, therefore it is also a gas.

? It is a gas, therefore it is also hydrogen.

If it is hydrogen, then it must be a gas.

? If it is a gas, then it must be hydrogen.

The hyperonymy test is applicable to true hyperonyms, but the **form** test is not:

It is hydrogen, therefore it is also a chemical element.

? It is a chemical element, therefore it is also hydrogen.

? Hydrogen has the form of a chemical element.

? A chemical element has the form of hydrogen.

? It is hydrogen, therefore it has the form of a chemical element.

? It is a chemical element, therefore it has the form of hydrogen.

The newly introduced semantic relations obey the formal tests of true hyperonymy, while the reverse is not true.

6 Conclusion and future work

Based on the hypothesis that one synset cannot be related to more than one hyperonym, other semantic relations are defined in the scope of multiple hyperonymy. Tests for the identification of new relations can be formulated following the pattern of the tests for other relations. The overall conclusion is that multiple hyperonymy embraces several semantic relations which, in turn, are only partially shown within the WordNet structure. Relations such as **origin**, **form**, **function**, etc. bear additional semantics and where they exist, they can be defined regardless of resolving multiple hyperonymy occurrences. Such specification would better outline the subsets of nouns that saturate semantic preferences of a verb predicate within the semantic classes of nouns, which are propagated through the inheritance (hyperonymy) relation.

We intend to use the **is-a** inheritance relation to subclassify the semantic classes of noun synsets to more specific groups depending on verb-noun combinability in sentences. We will demonstrate how the mapping of detailed semantic classes of nouns can benefit from a proper taxonomic tree structure.

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