Compound Noun Polysemy and Sense Enumeration in WordNet

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***Abstract*—Sense enumeration in WordNet is one of the main reasons behind the problem of high polysemous nature of WordNet. The sense enumeration refers to misconstruction that results in wrong assigning of a synset to a term. In this paper, we propose a novel approach to discover and solve the problem of sense enumerations in compound noun polysemy in WordNet. The proposed solution reduces the number of sense enumerations in WordNet and thus its high polysemous nature without affecting its efficiency as a lexical resource for natural language processing.**

Keywords–Polysemy; wordNet; compound nouns; sense enumeration.

I. INTRODUCTION

WordNet or Princeton WordNet [1] is a machine readable online lexical database for the English language. Based on psycholinguistic principles, WordNet has been developed since 1985 by linguists and psycholinguists as a conceptual dictionary rather than an alphabetic one [2].

Compound nouns are multi-words or collocations that consist of modified nouns and noun modifiers. One such example is the noun `nerve center`, where the `center` is the modified noun and `nerve` is the noun modifier. Compound noun polysemy in WordNet refers to the cases where we use the modified noun to refer to several different compound nouns such as using the modified noun `center` to refer to `nerve center` and `shopping center` [3]. The meanings of a compound noun polysemous term may correspond to a specialization polysemy [4] [5], metonymy [6] [7], or they are just sense enumerations, i.e., a misconstruction that results in wrong assignment of a synset to a term. Assigning the term `center` to the following two synsets is an example of sense enumerations:

#3 `center, nerve center: a cluster of nerve cells governing a specific bodily process.`

#15 `plaza, mall, center, shopping mall, shopping center: mercantile establishment consisting of a carefully landscaped complex of shops...`

The problem of sense enumerations in compound nouns is that they are a source of noise rather than a source of knowledge when using WordNet as a source for natural language processing (NLP) and knowledge-based applications, especially Information Retrievel (IR) [8] and semantic search [9]. Although specific instances of the compound noun polysemy have been addressed when solving the problem of specialization polysemy [4] [5] [10] or metonymy [7] [11] [12] [13], no or little research has been made towards solving the problem of compound noun polysemy as a problem of sense enumeration in WordNet.

In this paper, we discuss the problem of sense enumerations in compound noun polysemy in general and propose a semi-automatic method which allows us to discover and resolve sense enumerations in compound noun polysemy. The proposed solution is a cleaning process that reduces the number of sense enumerations in WordNet and thus its high polysemous nature without affecting its efficiency as a lexical resource.

The paper is organized as follows. In Section II, we discuss the compound noun polysemy and the relation between this kind of polysemy and the high polysemous nature in WordNet. In Section III, we briefly discuss the state of the art. In Section IV, we introduce the formal definitions that we used in our approach. In Section V, we present a semi automatic method for solving the problem of sense enumerations in WordNet in the case of compound noun polysemy. In Section VI, we discuss the results of the proposed method. In Section VII, we conclude the paper.

II. SENSE ENUMERATIONS IN COMPOUND NOUN POLYSEMY

A term in wordNet can be a single word such as `center` or a collocation such as `nerve center`. In the case of nouns, collocations correspond to compound nouns. A compound noun contains two parts.

1) *noun adjunct/modifier*: a noun that modifies another noun in a compound noun.
2) *noun head/modified noun*: the modified noun in a compound noun.

For example, the noun `head` is the noun adjunct and `word` is the modified noun in the compound noun `head word`. WordNet contains 104290 nouns. These nouns belong to 74314 synsets. The number of compound nouns is 58946 and the number of the synsets that contain at least one compound noun is 40560. That means, more than 56% of the nouns in WordNet are compound nouns and more than 45.4% of the synsets contain compound nouns. *Compound noun polysemy* refers to the cases, where we use the modified noun to refer to several different compound nouns. The number of the compound

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polysemous nouns in WordNet is 3407. These nouns belong to 4918 polysemous synsets. Compound noun polysemy in WordNet belong to the following three groups:

1) *Metonymy*: Corresponds to the metonymy polysemy cases where the modified noun belongs to two synsets, one of these synsets is base meaning and the other is derived meaning. For example, the compound noun polysemy between the following two synsets is an instance of metonymy.
   - #2 `cherry, cherry tree: any of numerous trees and shrubs producing a small fleshy round fruit with a single hard stone.`
   - #3 `cherry: a red fruit with a single hard stone.`
2) *Specialization Polysemy*: Corresponds to the specialization polysemy cases where the modified noun belongs to two synsets, one of these synsets is a more general meaning of the other or both synsets are more specific meanings of a third synset. For example, the compound noun polysemy between the following two synsets is an instance of specialization polysemy.
   - #1 `red laver, laver: edible red seaweeds.`
   - #2 `sea lettuce, laver: seaweed with edible translucent crinkly ...`
3) *Sense enumeration*: Sense enumeration means a misconstruction that results in wrong assignment of a synset to a term, i.e., assignment the noun modifier or the modified noun as a synonym of the compound noun itself. For example, assigning the the term `head` as a synonym to the compound nouns in the following synsets is an instance of sense enumerations.
   - #8 `fountainhead, headspring, head: the source of water from which a stream arise.`
   - #9 `head, head word:` *grammar* `the word in a grammatical constituent that plays the same grammatical role as the whole constituent.`
   - #13 `principal, school principal, head teacher, head: the educator who has executive authority for a school.`
   - #16 `promontory, headland, head, foreland: a natural elevation (especially a rocky one that juts out into the sea).`
   - #21 `headway, head: forward movement.`
   - #27 `read/write head, head: a tiny electromagnetic coil and metal pole used to write and read magnetic patterns on a disk.`
   - #32 `drumhead, head: a membrane that is stretched taut over a drum.`

In general, using the modified noun to refer to the compound noun itself is usual in natural language. In such cases, we use the context to understand and disambiguate the modified noun. An important question here is the relation between the lexicon and the ability to understand and disambiguate the modified noun. The issue is whether compound nouns and their corresponding modified nouns should be stored as synonyms in the lexicon. In natural language processing, do we need a lexical database that assigns each modified noun as a synonym to its corresponding compound nouns to be able to disambiguate the cases in which we use modified nouns to refer to compound nouns?

If we need to explicitly store the synonymity between each modified noun and its corresponding compound nouns, then the polysemous nouns in WordNet should be at least 56% and the polysemous synsets at least 45% just to store this information. For example WordNet contains 135 non polysemous synsets in which the term `head` is a noun modifier or modified noun of a compound noun. That means, the number of the senses of the term `head` in WordNet should be 168 (`head` has 33 senses in WordNet). For example the term `head` should be synonymous to the terms `department head, head of household, head of state, head nurse, human head, nominal head, hammerhead, axe head, spearhead, magnetic head,....`

In this approach, we argue that using a noun adjunct/modified noun to refer to its corresponding compound noun is similar to the use of anaphoric pronouns [14] (`he, she , it`, ...). This means that the disambiguation of polysemous modified nouns depends on the context rather on the used lexicon. In this sense, we may call a noun adjunct/modified noun that refers to a compound noun an *anaphoric term*. Anaphoric pronouns and anaphoric terms are similar in the following aspects:

1) Anaphoric pronouns and anaphoric terms are usually used to avoid repetition of the same word.
2) Anaphoric pronouns and anaphoric terms are usually ambiguous.
3) Using and understanding of anaphoric pronouns and anaphoric terms depends on a term that precedes them.
4) Anaphoric pronouns and anaphoric terms usually need a disambiguation process which allows to bind them to their corresponding referred term in the discourse.

In point 3, the discourse dependency of anaphoric terms means that an anaphoric term is used to refer to another (explicit or implicit) term in the context that enables disambiguating the reference term. That means, without (the explicit or implicit) referred term, the anaphoric term has no meaning or its meaning can not be disambiguated. We think that the referred term is the nearest understood compound noun. Thus, using and understanding the reference term is dependent on a compound noun that can be understood from the discourse and does not depend on storing the polysemy relation between the referred term and the the reference term in the lexicon.

Similar to anaphoric pronouns in point 4, anaphoric terms need to be disambiguated. Anaphoric pronoun disambiguation is called *anaphoric resolution* which is a syntactic process that binds the pronouns to their corresponding referred terms.

Our hypothesis in this approach is that reference term disambiguation is similar to pronoun disambiguation. That means, removing the anaphoric terms from WordNet in all compound noun polysemy cases reduces the sense enumerations without affecting its efficiency as a lexical resource for NLP tools.

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III. Related Work

In general, the polysemy approaches address the Compound noun polysemy as a sub case of metonymy and specialization polysemy. These approaches did not address solving the sub cases of compound noun polysemy that correspond to sense enumerations. In the following, we summarize the most prominent polysemy approaches for solving metonymy and specialization polysemy.

CORELEX [11] is a database of systematic polysemy classes (based on the generative lexicon theory [15]). These classes are combinations of 39 basic types that reside at the top level of WordNet hierarchy such as {animal, plant, food, attribute, state, artifact, ...}. The idea is that metonymy cases can be underspecified to one of these classes. Systematic polysemous meanings are systematic and predictable. The polysemy type of the term banana in the following example is systematic since the meaning food can be predicted from the plant meaning and so these two meanings of banana belong to the systematic class plant#food.

#1 banana, banana tree: any of several tropical and subtropical treelike herbs of the genus Musa having a terminal crown of large entire....

#2 elongated crescent-shaped yellow fruit with soft sweet flesh.

The semantic relations extraction approaches are regular polysemy [16] approaches that attempt to extract implicit semantic relations between the polysemous senses via regular structural patterns. The basic idea in these approaches is that the implicit relatedness between the polysemous terms corresponds to variety of semantic relations. Extracting these relations and making them explicitly should improve wordNet [12]. These approaches refine and extend CORELEX patterns to extract the semantic relations. Beside the structural regularity, these approaches exploit also the synset gloss [4] and the cousin relationship [7] [12] in WordNet. For example, the approach described in [4] exploits synset glosses to extract auto-referent candidates. The approach described in [7] uses several rules, such as ontological bridging [7] to detect relations between the sense pairs.

In general, the extracted relations in the semantic relations extraction approaches are similar. For example, we find the relations similar to or color of in the results of the approach in [4]. The results in [7] contains relations such as contained in, obtain from. Similarly, the result in [12] contain relations such as fruit of, tree of.

Specialization polysemy approaches such as [3] [4] are regular polysemy approaches that attempt to transform the implicit hierarchical relation between the synsets from lexical level to the semantic level. The approach described in [10] [5] considers representing the hierarchical relation at lexical level as a kind of sense enumeration that leads to high polysemy and information lost. An example for transforming the hierarchical relation from lexical level to the semantic level is shown in Figure 1.

IV. Approach Definitions

In this section, we present the definitions that we use in our approach. We start with the basic definitions. We define terms as follows.

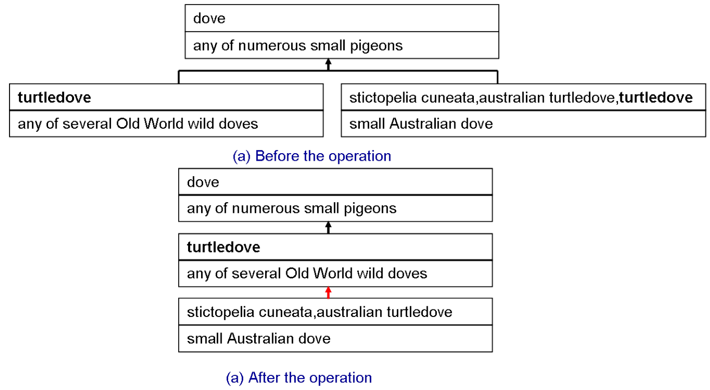

Figure 1. Example of transforming the hierarchical relation from the lexical level to the semantic level

Definition 1: (Term) A term T is a triple ⟨Lemma, Cat, T-Rank⟩, where

a) Lemma is the term lemma, i.e., the orthographic string representation of the term;
b) Cat ∈ {noun, verb, adjective, adverb} is the grammatical category of the term;
c) T-Rank is the term rank, i.e., a natural number >0.

T-Rank is used to reflect which is the preferred term of a synset. For example, man and adult male in the following synset correspond to the following term instances: ⟨Lemma: "man", Cat: noun, T-Rank: 1⟩ and ⟨Lemma: "adult male", Cat: noun, T-Rank: 2⟩.

#1 man, adult male: an adult person who is male (as opposed to a woman).

In the following, we define wordNet synsets.

Definition 2: (WordNet synset) A synset S is defined as ⟨Cat, Terms, Label, Gloss⟩, where

a) Cat ∈ {noun, verb, adjective, adverb } is the grammatical category of the synset ;
b) Terms is an ordered list of synonymous terms that have the same grammatical category as the synset grammatical category;
c) Label ∈ Terms is the preferred term of the synset, i.e., the term whose T-Rank = 1;
d) Gloss is a natural language text that describes the synset.

A term is polysemous if it is found in the terms of more than one synset. We define polysemous term as follows.

Definition 3: (polysemous term) A term t = ⟨Lemma, Cat, T-Rank⟩ is polysemous if there is a term $t^{'}$ and two synsets s and $s^{'}$, $s \neq s^{'}$ such that

a) t ∈ s.Terms and $t^{'} \in s^{'}$.Terms
b) t.Lemma = $t^{'}$.Lemma
c) t.Cat = $t^{'}$.Cat.

A synset is polysemous if it contains at least one polysemous term. We define polysemous synsets as follows.

Definition 4: (polysemous synset) A synset s is polysemous if one of its terms is a polysemous term.

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It is possible for two polysemous synsets to share more than one term. Two polysemous synsets and their shared terms constitute a polysemy instance. In the following, we define polysemy instances.

Definition 5: (polysemy instance) A polysemy instance is a triple $[\{T\}, s_1, s_2]$, where s_1, s_2 are two polysemous synsets that have the terms {T} in common.

The second step is to formalize the case where we have a polysemy instance of a compound noun.

Definition 6: (compound noun polysemous term) A term t is compound noun polysemous term of a term t' if t is the noun adjunct or the modified noun of t'.

For example, the term `center` is a compound noun polysemous term of the term `nerve center`. In the following, we define a compound noun polysemous synset.

Definition 7: (compound noun polysemous synset) A synset s is compound noun polysemous if it contains a compound noun polysemous term.

For example, the following synset is a compound noun polysemous synset.

#7 `center, centre, nerve center, nerve centre: a cluster of nerve cells governing a specific bodily process`

In the following, we define compound noun polysemy instance.

Definition 8: (compound noun polysemy instance) A polysemy instance $I = [\{T\}, s_1, s_2]$ is compound noun polysemy instance if s_1 or s_2 is a compound noun polysemous synset.

For example, $[\{center, centre\}, \#7, \#8]$ is a compound noun polysemy instance because #7 is a compound noun polysemous synset.

#7 `center, centre, nerve center, nerve centre: a cluster of nerve cells governing a specific bodily process`

#8 `center: the middle of a military or naval formation`

The third step is to define the structural patterns which allow us to identify specialization polysemy instances in compound nouns.

Definition 9: (structural pattern) A structural pattern of a polysemy instance I = [$\{T\}, s_1, s_2$] is a triple $P = \langle r, p_1, p_2\rangle$, where

a) r is the least common subsumer of s_1 and s_2;
b) p_1 and p_2 are children of r.
c) p_1 subsumes s_1 and $p2$ subsumes s_2

For example, $\langle mercantile \quad establishment, marketplace, shop\rangle$ is the structural pattern of the polysemy instance [$\{bazaar; bazar\}, s_1, s_2$] as shown in Figure 2.

The following definition allows us to define the specialization polysemy instances in compound nouns.

Definition 10: (Specialization Polysemy instance) A compound noun polysemy instance I = [$\{T\}, s_1, s_2$] is a specialization polysemy instance if its structural pattern p=$\langle r, p_1, p_2\rangle$ has one of the following forms $\langle r, s_1, s_2\rangle$, $\langle r, s_1, p_2\rangle$ or $\langle r, p_1, s_2\rangle$ as illustrated in Figure 3.

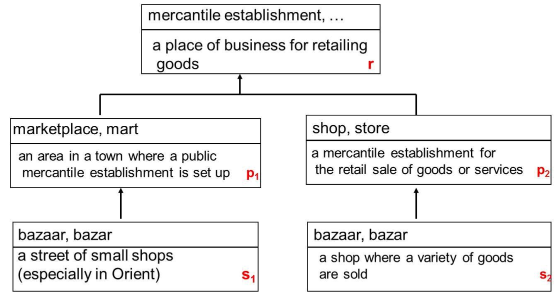

Figure 2. Example of a structural pattern

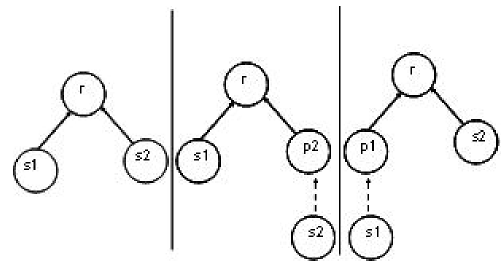

Figure 3. Specialization polysemy pattern

In the following, we define compound noun polysemy instances that belongs to metonymy by using CORELEX structural patterns.

Definition 11: (CORELEX structural pattern) CORELEX structural pattern is a sequence of synset labels separated by # where each synset label corresponds to a synset in WordNet.

For example, a CORELEX structural pattern is `plant#fruit` In the following, we define CORELEX polysemy classes.

Definition 12: (CORELEX polysemy class) Let `p=p1# p2` be a CORELEX pattern. The polysemy class of `p` is defined as the set of all polysemy instances $\{I = [\{T\}, s_1, s_2] \mid s_1$ is subsumed by p_1 and s_2 is subsumed by $p_2\}$

For example, the polysemy instance $\{I = [\{peach\}, \#1, \#3]$ belongs to the polysemy class of CORELEX structural pattern `plant#fruit` because the synset #1 is subsumed by `plant` and #3 is subsumed by `fruit`.

#1 `peach, peach tree, Prunus persica: cultivated in temperate regions.`

#3 `peach: downy juicy fruit with sweet yellowish or whitish flesh.`

In the following, we define the notion of metonymy instance.

Definition 13: (Metonymy instance) A polysemy instance I is a metonymy instance if it belongs to some CORELEX polysemy class.

Finally, we define sense enumeration in compound noun polysemy.

Definition 14: (Sense enumeration in compound noun polysemy) A compound noun polysemous term in a compound noun polysemous synset s_1 is considered to be a sense enumeration if the following hold:

a) s_1 is a compound noun polysemous synset;

b) There is no polysemy instance $I = [\{T\}, s_1, s_2]$ such that I is a metonymy or a specialization polysemy instance.

V. DISCOVERY AND ELIMINATION OF SENSE ENUMERATIONS IN COMPOUND NOUNS

In this section, we describe the discovery and elimination of sense enumerations in compound nouns. This is performed by a semi-automatic process that includes the following steps.

P1 **Discovery of sense enumerations in Compound Nouns**: Sense enumerations discovery in compound nouns is performed semi-automatically as follows.

1) **Sense enumeration candidates discovery**: This step is automatic and performed by deploying an algorithm that returns sense enumeration candidates in compound noun polysemous nouns.
2) **Excluding of false positives**: This step is manual where we exclude the false positives from the output of the algorithm in the previous step. For example, we exclude term abbreviations.

P2 **Elimination of sense enumerations**: This step is automatic and performed by deploying an algorithm which allows us to eliminate sense enumerations in the identified cases by removing the polysemous noun modifier and keeping the compound noun.

A. Discovery of sense Enumerations in Compound Nouns

In the following, we discuss the algorithm that we deployed in the discovery of sense enumerations in compound nouns. The algorithm returns a hash map of compound noun polysemous terms and senses enumeration candidates according to definition 14 and it works as follows:

1 It retrieves all compound noun polysemous terms in WordNet.

2 It iterates over all retrieved compound nouns to identify sense enumeration candidates as follows. For each retrieved compound noun term:

2.a It computes a list of the term sysnets.

2.b It computes a list of the polysemy instances of each of the retrieved synsets.

2.c It checks if any of the polysemy instances of the synset is a specialization polysemy instance according to definition 10 or a metonymy instance according to definition 13.

2.d if none of the polysemy instances of the synset is specialization polysemy or metonymy, the synset is considered as a sense enumeration according to definition 14 and added to the sense enumeration list of the term.

2.e The compound noun polysemous term and its corresponding sense enumerations are stored in a hash map.

3 The algorithm returns the hash map that correponds to the compound noun polysemous terms and their corresponding sense enumerations.

B. Excluding of False Positives

The input of this phase is the output of the algorithm `senseEnumerationsDiscovery`. The task of this phase is to exclude false positives. Experimentally, it turns out that the false positives can be classified into the following two groups:

1) **Missing adjunct noun/modified noun synset**: In some cases, a synset of the adjunct noun or the modified noun is missing. Such cases are excluded. For example, none of the 6 synsets of the term `party` can be considered as a general meaning of the term `political party` in the following synset.

   # `party, political party: an organization to gain political power.`

2) **Term abbreviations**: Since the algorithm in the previous step uses the string function to test compound noun polysemy, the algorithm returns polysemy instances that include term abbreviations as compound noun polysemy instances. For example, the term `mil` is abbreviation of the terms `milliliter` and `millilitre` in the following synset.

   # `milliliter, mil, ml, cubic centimeter, cc: a metric unit of volume equal....`

C. Elimination of Sense Enumerations in Compound Nouns

In this step, we eliminate the sense enumerations by removing the polysemous modified nouns. For example, the result of applying the function on `head` and the synset #32 is the synset #32':

#32 `drumhead, head: a membrane that is stretched taut over a drum.`

#32' `drumhead: a membrane that is stretched taut over a drum.`

VI. RESULTS AND EVALUATION

In the following, we present the results of our approach. Table I shows the results of the compound noun polysemy discovery algorithm that returned 2270 possible compound noun polysemous terms. These terms belong to 2952 synsets. The total number of compound noun polysemous instances is 11650 instance. Table II shows the results of the manual validation process, where the synsets of 1905 terms are classified to be sense enumerations. These terms belong to 2547 synsets. These synsets belong to 11088 compound noun polysemy instances. In Table III, we give an overview about number of nouns, noun senses and noun synsets in resulting

TABLE I. RESULTS OF THE DISCOVERY ALGORITHM

#Compound noun polysemous terms	2270
#Compound noun polysemous synsets	2952
#Compound noun polysemous instances	11650

TABLE II. MANUAL VALIDATION RESULTS

#Compound noun polysemous terms	1905
#Compound noun polysemous synsets	2547
#Compound noun polysemous instances	11088

WordNet after applying the disambiguation algorithm on the nouns in the WordNet 2.1. The table shows the reduction of

TABLE III. DISAMBIGUATION ALGORITHM RESULTS

	#Nouns	#Synsets	#Senses
Before Applying the Algorithm	104290	74314	130207
After Applying the Algorithm	104290	74314	127660

WordNet senses from 130207 to 127660. The average sense per noun before applying our algorithm is 1.25. Applying our algorithm reduces sense number per noun to 1.22.

A. Evaluation

To evaluate our approach, 200 synsets have been evaluated by two evaluators. In Table IV, we report the statistics of the evaluation, where we show the following:

a *Total agreement*: Measures the number of polysemy instances where both evaluators agrees with our approach (corresponds to second row in the table).

b *Partial agreement* Measures the number of polysemy instances where the at least one of the evaluators agrees with our approach (corresponds to third and fourth rows in the table).

c *Disagreement* Measures disagreement between the approach and the evaluators (corresponds to last row in the table).

In Table IV, a refers to our approach, e_1, e_2 refer to evaluator1 and evaluator 2 respectively.

TABLE IV. EVALUATION RESULTS

Evaluators Agreement	Result
$a = e_1 \wedge a = e_2$	161 (80.5%)
$a = e_1$	172 (86%)
$a = e_2$	177 (88.5%)
$a \neq e_1 \wedge a \neq e_2$	12 (6%)

VII. CONCLUSION AND FUTURE WORK

In this paper, we have introduced a new approach for solving the problem of sense enumerations in compound noun polysemy, where we have removed the sense enumerations in compound nouns in WordNet and thus reduced the high polysemy in compound nouns. The proposed solution is a necessary step that should be included in any approach for solving the polysemy problem in WordNet because the sense enumerations in compound nouns is a source of noise rather than a source of knowledge that affects the quality of WordNet as a source for NLP and knowledge-based applications.

Although the manual treatment in the approach guarantees the quality of the approach, we plan to run an indirect evaluation to test the effects of our approach in terms of precision and recall as a future work. As future work, we plan also to examine the relation between sense enumeration and missing terms in WordNet especially when a synset contains a modified noun and the compound noun itself is missing in the synset. For example, solving the sense enumeration problem in the following two meanings of the term `head`, we add the missing terms `bony pelvis` and `head of muscle` in the following two synsets respectively.

#25 `head:the rounded end of a bone that bits into a rounded cavity in another bone to form a joint.`

#26 `head: that part of a skeletal muscle that is away from the bone that it moves.`

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