Hypernymy in WordNet, Its Role in WSD and Its Limitations

Udaya Raj Dhungana[1] and Subarna Shakya[2]

[1,2] *Department of Electronics and Computer Engineering*
Pulchowk Campus, Institute of Engineering, Tribhuvan University
Lalitpur, Nepal
[1]*Department of Computer Science*
Hochschule Darmstadt University of Applied Sciences
Darmstadt, Germany
[1] udayas.epost@gmail.com
[2] drss@ioe.edu.np

***Abstract* - This paper closely analysed and depicted the role of the hypernymy that is used in the lexical database called the WordNet to relate the words semantically with a relation ”... is a kind of ...”. The relation has very important role for disambiguating the senses of a polysemy word in any natural language and is, therefore, massively used in knowledge-based Word Sense Disambiguation (WSD) approaches. However, the limitation of this relation is not so cared about. In many cases, the use of the hypernymy does not only mean nothing for disambiguation but also it increases only the computational effort for the system. The improper use of hypernymy is very costly. In some cases, which are described later, the use of this relation even decreases the accuracy of the WSD approaches.**

Keywords - Hypernymy; WordNet; Polysemy Words; Word Sense Disambiguation; knowledge-based approach.

I. INTRODUCTION

Natural languages are used and understood within a group of people, a society, a region, a country or within a continent. According to the Ethnologue’s most recent record [1], the living languages all over the World are 7,106 in number. BBC has reported in [2] that the ninety percent of these languages are used and spoken by less than one hundred thousand people and 150 to 200 languages are used by more than a million people for conversation. To automate the systems which require natural language understanding capability, the natural languages must undergo for their processing. The processing may be within the same language like in Information Retrieval (IR), Information Extraction (IE), Summarization of text information, Speech Recognition etc. or within the two different languages like in Machine Translation (MT). In each case, ambiguity is the main problem in natural language processing tasks. The ambiguity arises in speech recognition system when the two different words have the same pronunciation while it arises in written text if the same word has multiple meanings in different contexts. A large number of Word Sense Disambiguation (WSD) approaches has been proposed till now to disambiguate the meaning of polysemy words.

The problem of Word Sense Disambiguation was taken as an AI-complete problem [3] since the beginning of the Machine Translation. The WSD approaches fall into two main categories:- (a) the knowledge-based and (b) corpus-based approaches [3]. In this research, we focused our research in the knowledge-based approaches. The WSD problem was taken as a separate task for research since the beginning of the Machine Translation in the late 1940s [4]. In 1949, Weaver had described the nature of ambiguity in his famous memorandum on Machine Translation [4]. According to him, if a single word which is polysemous is taken at a time, it is impossible to determine the meaning of the word even for the human . However, if the words from either side of the target word are considered, then the meaning can be determined unambiguously.

The dictionary-based WSD had been started when the

Michel Lesk used the overlap of the word sense definition in the Oxford Advanced Learner’s Dictionary of Current English (OALD) to disambiguate the word senses [5]. However, the information in the dictionary were found to be insufficient to represent the context of a target word and to resolve the ambiguity since the dictionary only contains the short definitions of the words[4]. With the development of the lexical database called the WordNet resolved the problem of lack of information for WSD approaches [6]. The WordNet provided the more information about the words using various semantic relations such as synonym sets, hypernymy/hyponymy, meronymy/holonymy relations etc. and therefore became a popular resource for the knowledge-based WSD approaches [7].

A. Motivation to WordNet: - The Popular Resource for WSD

The lexical information in the dictionaries are put together using alphabetical order in which the words that spell alike come together in the list [7]. Keeping the words which spell alike together results in scattering of the words that have same or at least similar meanings in many contexts [7]. The word ”put”, for example, in the dictionary is scattered with its synonym words ”arrange” or ”place” etc. while the words ”pustule” and ”put” which have different meanings are found together in the dictionary. To search the words with same or similar meaning in dictionary is, therefore, tedious and time consuming. To overcome the problems found in lexicographic information, in 1985, a group of psychologist and linguistics was formed in Princeton University to develop a lexical database with the aim to search dictionary conceptually rather than alphabetically. The resulted product of this research was the WordNet. The development of the WordNet is, therefore, greatly influenced with human lexical memory [7].

The WordNet organizes the words in the lexical database based on their meanings instead of their forms as in dictionaries. In addition, the WordNet provides the more information than by the dictionaries. It groups the nouns, verbs, adjectives and adverbs together into synonym sets, each expressing a distinct concept [8]. The words in a synonym set can be interchangeably used in many contexts. The main relationship among the words in WordNet is the synonym [9].

After the development of WordNet, the knowledge-based WSD approaches began to use the more information from synset, gloss, hypernyms, meronyms etc. that are available in the WordNet [3] for the sense disambiguation purpose. Due to the popularity of English WordNet, many other WordNets on various languages such as GermaNet, Spanish WordNet, Italian WordNet, Hindi WordNet etc have been built.

B. The Hyponymy/Hypernymy Relation

A hyponymy/hypernymy is a semantic relation between word meanings. The hyponymy/hypernymy shows the subordinate/super-ordinate, subset/superset or ”is-a” relation. If a concept that represents a synset $\{x_1, x_2, ...\}$ is said to be hyponym of another concept that represents the synset $\{y_1, y_2, ...\}$ if x_1 is a kind of y_1. For example: {apple} is hyponym of {fruit} and {car} is a hyponym of {vehicle}.

The hyponym inherits all the features of the more generic concept and adds at least one feature that distinguishes it from its super-ordinate and from other hyponyms of that super-ordinate. For example, apple inherits the features from its super-ordinate fruit. Hyponymy is transitive and asymmetrical relation, since there is normally a single super-ordinate and multiple subordinates.

	Context Bag	**Sense Bags**	**No. of Overlaps**
Case-I: When no hypernyms are used in both context and sense bags	[**writing**, poem]	**Sense 1**: [***writing*** implement point which ink flows]	**1**
		Sense 2: [enclosure, confining, livestock]	**0**
		...	
Case-II: When one level hypernymy in the sense bag is used	[**writing**, poem]	**Sense 1**: [***writing*** implement point which **ink**, liquid, *used*, printing, ***writing***, drawing, liquid, substance, flows …]	**2**
		Sense 2: [enclosure, confining, **livestock**, farm, animal, kept, *use*, profit, placental, placental, mammal …]	**0**
		...	

Figure 1: Increased relatedness between the context bag and the sense bag of the correct sense of a polysemy word Pen with the use of hypernymy relation from the WordNet.

This hypernymy relation in the WordNet can be used to increase the relatedness of a context with the correct sense of a polysemy word. Suppose a given context C which contains $Cw_1, Cw_2, ..., Cw_m$ words. Now, suppose the polysemy word has n different senses $S_1, S_2, ..., S_n$. Suppose, in the first case, the sense bag for each sense is formed by taking only the gloss from the definition of corresponding sense (say $SB_d = SBd_1, SBd_2, ..., SBd_n$). In second case, suppose the sense bags are formed by including both gloss and the first level hypernymy of the corresponding sense (say $SB_h = SBh_1, SBh_2, ..., SBh_n$). Comparing to the first case, there is a higher chance to appear the more overlaps of words $Cw_1, Cw_2, ..., Cw_m$ with the words in the sense bag of the correct sense of the polysemy word in the second case. Mathematically, $\text{OVERLAPS}(C\textit{with}\text{CORRECT}(SB_h)) > \text{OVERLAPS}(C\textit{with}\text{CORRECT}(SB_d))$.

Let a context ”*He is writing a poem with my pen.*”. Suppose, we need to determine the correct sense of the polysemy word Pen. The word Pen is called a target word. Here, the context bag contains the words {writing, poem}. The glosses and sense bags of the different senses of Pen are shown in Fig. 2a and Fig. 2b respectively.

The Fig. 1 shows when the hypernym of the words in the sense bags are included, the overlaps between the context and the correct sense of the polysemy word Pen are increased by double while the overlap with the incorrect sense is remained the same.

This simple example illustrates briefly how the use of hypernymy relation from the WordNet is used to increase the semantic relation of a context with the correct sense of a polysemy word. This is the reason why, the hypernymy relations are massively used in the WSD approaches. However, this is not always the case that hypernymy relation increases the relatedness of a context with a correct sense of a polysemy word but it also decreases this relatedness due to the entry of the noise information from the hypernymy relation. This is discussed in detail in section III.

pen : (a writing implement with a point from which ink flows)	**pen :** (a writing implement with a point from which ink flows)
pen : (an enclosure for confining livestock)	**pen :** (an enclosure for confining livestock)
pen : (a portable enclosure in which babies may be left to play)	**pen :** (a portable enclosure in which babies may be left to play)
pen : (a correctional institution for those convicted of major crimes)	**pen :** (a correctional institution for those convicted of major crimes)
pen : (female swan)	**pen :** (female swan)

Figure 2: (a) Five senses of English word Pen when it is used as a noun and (b) Sense bags for different senses of the Pen.

II. USE OF HYPERNYMS IN WSD APPROACHES

In 1986, Lesk Michael used the definitions of the words that need to be disambiguated from the Oxford Advanced Learners Dictionary of Current English (OALD) [10]. From his work, the dictionary based WSD had begun. After this, Guthrie et al. in 1991 and Yarowsky in 1992 also used the concept of dictionary based approach in their methods [4]. The dictionary based approaches were promising. However, due to the lack of sufficient information in the dictionary, they were not giving better accuracies. This problem of lack of information was solved in some extent after the development of the WordNet.

Banerjee and Pedersen in [6] adapted the original Lesk algorithm using the lexical database WordNet. They used the information from the relations hypernymy, hyponymy/torponymy, holonymy/meronymy links for both nouns and verbs. They used Senseval-2 word sense disambiguation exercise to evaluate their system and found an overall accuracy of 32% which was the double of the original Lesk algorithm. Patwardhan in 2003 had generalised the Adapted Lesk Algorithm of Banerjee and Pedersen based on semantic relatedness [11]. They used mainly the ”is-a” relationship in the WordNet for their measure of semantic relatedness. The average length of a gloss in the WordNet is seven words [12]. Therefore, Banerjee and Pedersen again in 2003 used the extended gloss overlap measure method to expand the glosses of words being compared by looking for the overlaps not only between the glosses of the synsets but also between the glosses of the hypernyms, hyponym, meronym, holonym and troponym, synsets [12].

Fragos et al. in [13] formed their context and sense bags by using the gloss definition and the definition of all the hypernyms associated with the nouns and verbs. They also tested their system including the hyponymy relation but their experiment showed that there was no improvement in accuracy using the hyponymy. For the nouns and verbs, they also climbed up the hierarchy in every level to assign hypernymy synsets. Liu et al. in [14] had also used the information from the synonyms, hyponyms, hypernyms for disambiguation. Similarly, in other WSD approaches such as Shirai et al. in [15] , Kolte et al. in [16] , Roy in [17], Seo et al. in [18], Montoyo in [19], Dhungana and Shakya in [20], and Dhungana et al. in [21] had used the information from synonyms, hyponyms, hypernyms relationship in their algorithms.

There are so many WSD approaches which used the information from hypernyms for word sense disambiguation. However, the most important question is that why these approaches are not achieving the satisfactory accuracy. Therefore, this research analyzed the hypernymy relation in detail and pointed out the lacking factors in the use of the hypernymy relation.

III. ILLUSTRATION OF USE OF HYPERNYMS IN WSD APPROACHES

In WordNet 2.1, the word Pen as a noun has five different senses which are shown in Fig. 2a [7]. Let us again take the same context ”He is writing a poem with my pen.” where the sense of the word Pen is to be disambiguated. Therefore, the target word is Pen. The context bag is then formed by taking the neighbour words of the target word after removing the article, preposition and pronoun. Thus, the context bag (say C) contains only the two words ”writing” and ”poem”.

Case I: Let us form the sense bag using only the gloss of the sense. We removed the preposition, article or any pronoun used in the gloss. The Fig. 2b shows the sense bags S_1, S_2, S_3, S_4 and S_5 for the five senses of the Pen.

In this case, there is only one overlap of words in the context bag with the sense bag of sense 1 of Pen while there is no any overlap of words of context bag with any other remaining sense bags of Pen. Therefore, this method outputs the sense 1 of Pen as a correct sense for the given context. Obviously, this number of overlaps does not look as a good decisive one.

Case II: In this case, we kept all the settings same as in Case I except the formation of sense bags. Now each sense bag is formed by including the gloss from all their hypernyms. The words in sense bags S_1, S_2 and S_3 are shown in Fig. 3b, 3c and 3d respectively. For simplicity, we have only considered three senses S_1, S_2 and S_3 for Case II and Case III.

This inclusion of glosses from hypernyms in the sense bags increased the overlaps by one for sense 1. However, there is no any overlap for remaining senses of Pen.

Case III: At this time, we kept all the settings same as in Case II except the formation of context bag. The conte-

C = {**writing,** poem, verse, form, composition, written, metrical, feet, forming, rhythmical, lines, literary, composition, literary, work, imaginative, creative, writing, writing, written, material, piece, writing, work, writer, anything, expressed, letters, alphabet, especially, when, considered, point, view, style, effect, writing, novels, excellent, editorial, fine, piece, writing, written, communication, written, language, communication, means, written, symbols, communication, something, communicated, people, groups, abstraction, general, concept, formed, extracting, common, features, specific, examples, abstract, entity, entity, exists, only, abstractly, entity, which, perceived, known, inferred, have, own, distinct, existence, living, nonliving }

(a) Context bag

S1= { **writing**, **implement**, instrumentation, piece, equipment, tool, used, effect, end, instrumentality, instrumentation, artifact, system, artifacts, instrumental, accomplishing, some, end, artifact, artefact, man-made, object, taken, whole, whole, unit, assemblage, parts, regarded, single, entity,how, big, part, compared, whole, team, unit, object, physical, object, tangible, visible, entity, entity, cast, shadow, full, rackets, balls, objects, physical, entity, entity, physical, existence, entity, perceived, known, inferred, own, distinct, existence, living, nonliving, **point, which**, **ink**, liquid, used, printing, writing, drawing, liquid, substance, liquid, room, temperature, pressure , flows}

(b) Sense bag for sense 1 of ***Pen***

S2 = {**enclosure,** artifact, consisting, space, enclosed, some, purpose, artifact, artefact, man-made, object, taken, whole, whole, unit, assemblage, parts, regarded, single, entity, how, big, part, compared, whole, team, unit, **object**, physical, object, tangible, visible, entity, entity, cast, shadow, full, rackets, balls, objects, physical, entity, entity, physical, existence, entity, perceived, known, inferred, own, distinct, existence, living, nonliving, **confining, livestock**, stock, farm, animal, used, technically, any, animals, kept, use, profit, placental, placental, mammal, eutherian, eutherian, mammal, mammals, having, placenta, all, mammals, except, monotremes, marsupials, mammal, mammalian, any,warm-blooded, vertebrate, having, skin, more, less, covered, hair, young, born, alive, except, small, subclass, monotremes, nourished, milk, vertebrate, craniate, animals, having, bony, cartilaginous, skeleton, segmented, spinal, column, large, brain, enclosed, skull, cranium, **chordate**, any, animal, phylum, Chordata, having, notochord, spinal, column, animal, animate, being,beast, brute, creature, fauna, living, organism, characterized, voluntary, movement, organism, being, living, thing, has, develop, ability, act, function, independently, living, thing, animate, thing, living, once, living, entity, **object**, physical, object, tangible, visible, entity, entity, cast, shadow, full, rackets, balls, objects, physical, entity, entity, physical, existence, entity, perceived, known, inferred, own, distinct, existence, living, nonliving }

(c) Sense bag for sense 2 of ***Pen***

S3 = {**portable**, small, light, typewriter, usually, case, which, be, carried, typewriter, hand-operated, character, printer, printing, written, messages, one, character, time, character, printer, character-at-a-time, printer, serial, printer, printer, prints, single, character, time, printer, printing, machine, machine, prints, machine, any, mechanical, electrical, device, transmits, modifies, energy, perform, assist, performance, human, tasks, device, instrumentality, invented, particular, purpose, device, small, enough, wear, wrist, device, intended, conserve, water, **instrumentality**, instrumentation, artifact, system, artifacts, instrumental, accomplishing, some, end, artifact, artefact, man-made, object, taken, whole, whole, unit, assemblage, parts, regarded, single, entity, how, big, part, compared, whole, team, unit, object, physical, object, tangible, visible, entity, entity, cast, shadow, full, rackets, balls, objects, physical, entity, entity, physical, existence, entity, perceived, known, inferred, own, distinct, existence, living, nonliving, **enclosure,** artifact, consisting, space, enclosed, some, purpose, artifact, artefact, man-made, object, taken, whole, whole, unit, assemblage, parts, regarded, single, entity, how, big, part, compared, whole, team, unit, **object,** physical, object, tangible, visible, entity, entity, cast, left, shadow, full, rackets, balls, objects, physical, entity, entity, physical, existence, entity, perceived, known, inferred, own, distinct, existence, living, nonliving, which, babies, be, play}

(d) Sense bag for sense 3 of ***Pen***

Figure 3: (a) Words in the context bag when the hypernyms of ”poem” are included, (b), (c) and (d) Words in sense bags of senses S1, S2 and S3 respectively when their hypernyms are included. These context and sense bags are formed by taking the glosses and hypernyms from WordNet 2.1 [22].

-xt bag is formed by including the gloss from all the hypernyms of each word in context bag.

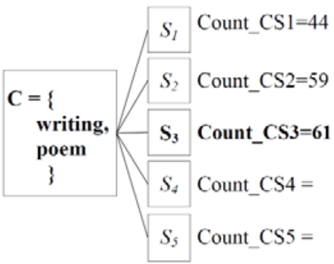


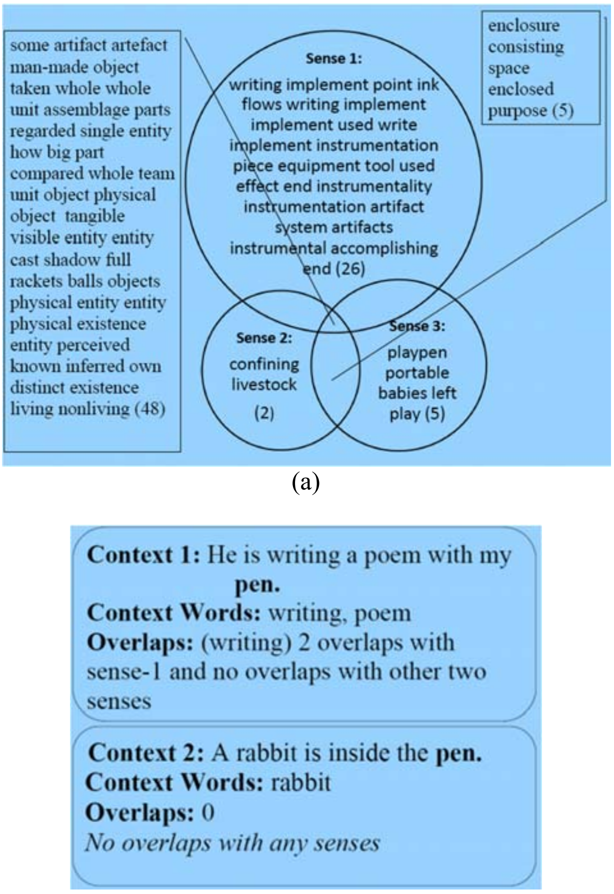
Figure 4: Overlaps between the words of context bag with each sense bag when the gloss from the hypernyms are taken for both bags. Here, Count CS1 denotes the no. of overlaps of words between C and S1 and so on.

However, the word ”writing” is again a polysemy word, to keep the example simple, we have taken only the hypernyms of ”poem”. The words in the context bag in this case are shown in Fig. 3a. The Fig. 4 shows the overlaps between the words of context bag with the words in each sense bag for Case III. We saw the maximum overlaps 61 for the sense S3 of Pen and it is the incorrect sense for the given context C.

IV. ANALYSIS OF ILLUSTRATION AND DISCUSSION

From the illustrations in previous section, we saw that the information only from the definitions contains less information as in case I. When we increased the information including the hypernyms for the sense bags as in case II, more overlaps are found for the correct sense.

However, when we increased the information including hypernyms to make the context larger as in case III, correctly disambiguated sense is also now incorrectly disambiguated due to the entry of the more common information in the context and in the incorrect sense 3. This case is supported by the work of Dhungana and Shakya in [20]. They argued that when deeper levels of the hypernyms are used, the correctly disambiguated sense is also incorrectly disambiguated. In such case, the inclusion of hypernymy is not only the waste of computational effort and memory of the system but also this produces the incorrect result. Similar result is also found in the work by Fragos et al. [13] for the relation hyponymy. They tested their system including the hyponymy relation but the experiment showed that there was no improvement in accuracy. The Fig. 5a shows the distinct and common words among the hypernyms of three senses of Pen. Here, the duplicate words are not removed. Only very few words are distinct for each sense; two words for sense 2, five words for sense 3 and twenty six words for sense 1.



(b)

Figure 5: (a) Distinct and common words in the three senses of Pen and (b) Two contexts in which the Pen has been used.

The Fig. 5b shows the two contexts ”He is writing a poem with my pen.” and ”A rabbit is inside the pen.” and their overlaps with the words in the three sense bags of Pen. For the first context, there are two overlaps with the words in the sense 1 and no overlap with Sense 2 and Sense 3. However, there is no overlap with any senses for the context 2. There are 48 words which are common to all three senses and 5 words are common to the two senses Sense 2 and Sense 3. This indicates that only very few words are distinct for different senses. To increase the relatedness between the context and the correct sense, we need to increase the number of distinct words among the different senses. They must not only be distinct but must also be such words which can describe the actual context of a particular sense from the other senses. From the illustration, it is proved that only the inclusion of many levels of hypernyms do not provide such distinct information which is necessary and sufficient for disambiguation.

Most important point is that such few words are insufficient to determine the correct sense of a polysemy word as in the Case III. When we took the more information from the hypernymy relation in both context and sense bag, this also induced the noise information in the bags. Due to this, the correctly disambiguated sense in the Case II is also incorrectly disambiguated in Case III. We define the noise information in context or sense bag as the information which is produced in such a way that more common information are inserted into the context bag and at least into one of the incorrect sense of a polysemy word making the more overlaps between the context and the incorrect sense of the polysemy word. This induced noise in the context and in the incorrect sense(s) of polysemy word causes the incorrect disambiguation. The two factors are responsible for induction of this noise. The first is that the senses of a polysemy word that is to be disambiguated falls in the same class in the ”..is a ..” hierarchy in the WordNet and the second is that the senses of a polysemy words have at least the common parent or child after or before some classes in the hierarchy. In the first situation, the senses contain all the common hypernyms while in the second situation, they contain not all but some common hypernyms. Therefore, same information is retrieved for all senses and most of time, this induces the noise in the information. Due to the common hypernyms for all senses, there is a huge amount of common information for all senses which cannot be used to determine the correct sense in a given context. All the efforts such as processing and storing such large volume of unused information are only the burden for the system.

Only increasing the information from the hypernymy relation does not increase the relatedness of the context with the correct sense of a polysemy word. This is because the hypernymy shows the ”... is a kind of ...” relation. That is, it shows the inheritance hierarchy in the

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word relation. Therefore, the senses of a polysemy word which fall under the same class have the common hypernyms. These common hypernyms for the multiple senses, therefore, cannot be used to disambiguate the correct sense. The noise in the information is the unwanted, common and repeated information which leads to the incorrect disambiguation. The senses of a polysemy word which have all the common hypernyms are very difficult and most of time impossible to disambiguate using the hypernymy information. In such case, only the gloss of first hypernym is different for the senses and does not contain the sufficient information to disambiguate the sense. It is because the average length of a gloss in the WordNet is seven words [12] and these short definitions are, therefore, insufficient to disambiguate the senses.

V. CONCLUSIONS

Hypernymy relates the words in a ”is a” relationship [23]. Therefore, this relation in WordNet orgnizes the words in inheritance hierarchy. The senses which fall in the same class, they have the same hypernyms. If the senses of a polysemy word have the common hypernyms, the information from such hypernyms cannot be used to disambiguate the senses of the polysemy word. The distinct information in the gloss of hypernyms are also found to be insufficient in the WordNet to disambiguate the senses of polysemy words. Another important point noticed is that when deeper levels of the hypernymy from the WordNet are used, the correctly disambiguated polysemy words are also found to be incorrectly disambiguated due to the induced noise in the context and in the incorrect sense of polysemy word.

Only very few words from the hypernym relations are used to disambiguate the sense. These very few words are not also sufficient to determine the correct sense of a polysemy word. A huge amount of information containing the noise is produced with the use of common hypernymy relations and this noisy information causes the WSD approaches fail to disambiguate the correct sense.

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