

Extending a lexical ontology by a combination of Distributional Semantics signatures ^{*}

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Abstract. Ontologies are a tool for Knowledge Representation that is now widely used, but the effort employed to build an ontology is high. We describe here a procedure to automatically extend an ontology such as WordNet with domain-specific knowledge. The main advantage of our approach is that it is completely unsupervised, so it can be applied to different languages and domains. Our experiments, in which several domain-specific concepts from a book have been introduced, with no human supervision, into WordNet, have been successful.

1 Introduction

Lexical semantic ontologies are now widely used for Natural Language Processing, and several of them are available for English and other languages, such as WordNet [Miller, 1995] and EuroWordNet [Vossen, 1998]. However, they are usually very general, and their enrichment with domain-specific information requires a high degree of supervision. This has motivated the appearance of knowledge acquisition methods for building domain-specific ontologies automatically.

Maedche and Staab [2001] define *Ontology Refinement* (OR) as the adaptation of an ontology to a specific domain or to some user's requirements, without altering its overall structure. An important problem inside OR is the placement of the domain-dependent concepts in the ontology. Applied to lexical ontologies, if we have an ontology \mathcal{W} and a set of domain-specific documents \mathcal{D} containing some unknown concepts and instances $\mathcal{U} = \{u_1, u_2, \dots, u_n\}$, we have to find, for every unknown concept or instance u_i , its maximally specific hypernym s_i in the ontology.

This paper reports a system that extended WordNet with new synsets learnt both from Tolkien's *The Lord of the Rings* and Darwin's *The Voyages of the Beagle*. The unknown concepts that were learnt include locations, rivers, seas, animals, races and people. The classification of these concepts in the taxonomy is performed in a fully unsupervised way. The only input it requires is an initial ontology (we use WordNet) and a collection of documents. It will find unknown concepts in the documents and attach them to WordNet. We show that a Distributional Semantic (DS) model can be a good starting point for locating the right places in the ontology for placing the learnt synsets, and we present a way in which different DS metrics can be combined.

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1.1 Related work

We can group related systems in two groups. *Deterministic systems* are those that provide, for each unknown concept, one or several hypernyms all of which are supposedly correct. One of such systems, described by Hearst [1998], obtains regular expression patterns from free texts by looking at pairs of (hypernym, hyponym) that co-occur in the same sentence, and then uses them to learn new hypernymy relations. However, she notes that these extracted relations contain a high degree of noise. Kietz et al. [2000] quantified the error rate of hand-coded patterns as 32%, so he concludes that the concepts had to be ultimately revised and placed in the hierarchy by the user. A different approach is that described by Grefenstette and Hearst [1992].

Non-deterministic systems are those that provide a set of likely candidates, only some of which are correct. Hastings [1994] describes one such framework, Camille, that learns nouns and verbs. He has beforehand concept ontologies for nouns and verbs about the terrorist domain, and verbs are annotated with selectional preferences, e.g. the object of *arson* is known to be a *building*. If an unknown word was found being the direct object of *arson*, it can thus be classified as a building. Hahn and Schnattinger [1998] describes a similar approach. These systems do not return a single hypernym, but a set of plausible hypotheses.

2 Algorithm

Our aim is the enrichment of WordNet with new concepts learnt from general-purpose texts. Let us suppose that we have found a new term u that is not in WordNet. The aim is to find the place where it should be attached to the ontology. The algorithm we use performs a top-down search along the ontology, and stops at the synset that is most similar to u . The search starts at the most general synset s , and compares u with s and with all its immediate hyponyms. If s is more similar to u than any of s 's children, then u is classified as a hyponym of s . Otherwise, we proceed one step downwards to the most similar hyponym. For a detailed description please refer to [Alfonseca and Manandhar, 2002b].

2.1 Similarity metrics

The tools we used to compute the semantic distance between synsets are all based on the DS model, which assumes that there is a strong correlation between the semantics of a word and the set of contexts in which that word appears, and which has produced good results when applied to fields such as Information Retrieval and summarisation.

We have used the following tools:

- A *topic signature* of a concept c is the list of the words that simply co-occur with c in the same context (we have used the same sentence), and their frequencies.
- A *subject signature* of a nominal concept c is the list of verbs for which c appears as a subject.
- An *object signature* of a nominal concept c is the list of verbs and prepositions for which c appears as an argument.
- A *modifier signature* of a nominal concept c is the list of adjectives and determiners that modify c inside a Noun Phrase.

Topic signature			Subject signature			Object signature			Modifier signature		
Word	Freq	weight	Word	Freq	weight	Word	Freq	weight	Word	Freq	weight
Rights	314	23.16	be	23	0.71	of	77	0.38	innocent	16	8.28
Human	162	12.89	have	14	4.24	to	54	3.15	contact	10	9.51
that	161	0.00	use	10	15.09	for	45	3.31	live	8	3.34
Resources	136	19.19	write	6	20.51	in	29	1.11	own	6	5.62
Irights	109	19.94	live	5	4.59	be	23	0.32	indignous	6	7.28
Department	102	21.77	make	5	6.37	with	15	0.82	other	5	0
Chromosome	96	24.82	kill	4	24.60	on	14	1.30	same	5	6.70
information	65	11.04	work	4	24.60	from	14	2.23	controlling	5	10.25
Center	63	16.04	hold	3	12.65	that	11	0.00	first	3	7.57
Health	63	15.86	produce	3	5.14	as	10	0.06	human	3	2.76
not	56	0.00	suffer	3	11.29	by	9	0.35	right	3	6.36
has	56	3.75	wish	3	16.56	say	6	12.45	whole	3	6.88
have	55	1.98	get	3	12.65	seek	6	13.41	particular	3	5.15

Table 1. Topic, subject, object and modifier signatures of the concept $\langle person \rangle$. The words shown are the top frequency words and their weights.

The intuition behind our procedures is that, if two words are semantically related, their signatures will also be similar. They can be automatically collected for every concept in an ontology, by collecting documents from Internet and collecting the frequencies as described by Agirre et al. [2000]; therefore, the classification procedure can be made fully unsupervised. As an example, Table 1 shows the highest frequency words in the signatures of the concept $\langle person \rangle$.

In order to compare the topic signature of an unknown concept u and the signatures of a set of WordNet synsets $\{s_1, s_2, \dots, s_n\}$, the raw frequencies of the synsets' signatures have been changed into weights, to decide which words do provide support that they are in the context of a synset, and which ones are equally frequent for all synsets [Alfonseca and Manandhar, 2002b]. In a few words, for each decision of the algorithm, the following steps are followed:

- Take the synsets that will be compared to u .
- For each synset, add up the frequencies of the context vectors of all its hyponyms in WordNet, and smooth the frequencies by adding 1 to every frequency value.
- For each one of them, use the rest as a contrast set to change its frequencies into weights. We have obtained the best results with χ^2 (see [Agirre et al., 2000]).
- To calculate the

$$f_{sS} = \frac{S^1 \cdot S^*}{\sum_{s \in S} f_{sS}}$$

distance metric. These weights are calculated with a simulated annealing procedure. They are initialised as $\frac{1}{m}$, and then we proceeded changing them, slowing down, until the distances $D(P_{sig_j} || P)$ all converge to the same value (if possible). Finally, the synset chosen by the algorithm is $\text{argmax}_i P(s_i)$. Table 2 shows the similarity metrics produced in the first two decisions when classifying the concept $\langle ore \rangle$, using the topic, subject and object signatures.

3 Experiments and Results

We have calculated the topic, subject, object and modifier signatures for the top 1,200 synsets of the WordNet taxonomy which is rooted by *entity*. This was done automatically by downloading the documents from Internet using them

First decision: entity						Second decision: being					
synset	synset Id	P_{sig_1}	P_{sig_2}	P_{sig_3}	total	synset	synset Id	P_{sig_1}	P_{sig_2}	P_{sig_3}	total
being, organism	n00002908	0.40	0.23	0.29	0.3207	human	n00005145	0.64	0.80	0.40	0.6161
causal agency	n00004753	0.38	0.24	0.23	0.3121	animal	n00010787	0.24	0.18	0.41	0.2790
location	n00018241	0.11	0.17	0.17	0.1383	host	n01015823	0.00	0.01	0.05	0.0243
body of water	n07411542	0.09	0.12	0.20	0.1112	parasite	n01015154	0.01	0.00	0.04	0.0192
thing (anything)	n03781420	0.00	0.11	0.02	0.0457	flora	n00011740	0.00	0.00	0.04	0.0169
thing (object)	n00002254	0.00	0.11	0.02	0.0442	(34 more)	...	...	...	...	...
(16 more)	...	...	...	...	...	

Table 2. Similarity values for each of the decisions that have been taken when classifying the unknown concept $\langle orc \rangle$. The similarities correspond to the topic, subject and object signatures (in that order), and the combination of the three of them. In the first place, when deciding between $\langle entity \rangle$ and its children, the chosen one was $\langle being, life form \rangle$. In the second decision, the winner was $\langle human \rangle$ (both were correct)

Method	Accuracy strict	len.	L.A.	C.D.	C.P.
Uniform	13.04%	23.91%	0.34	71.09%	1.98
Entropy	13.04%	28.26%	0.38	73.44%	1.95

Table 3. Comparison of two methods to combine the results provided by the signatures.

acceptable results, and the best mark was attained by combining them all. Most of the errors were produced at the lowest levels of the ontology, when deciding between semantically similar synsets such as $\langle man \rangle$ and $\langle woman \rangle$, for which the context is not much help.

Some characteristics of WordNet complicate the task, such as the fine-grained senses and the lack of multiple inheritance. For example, geographical locations (e.g. continents) are classified as *object*, while political locations (e.g. countries) are classified as *location*. However, the context of these two kinds of entities are very similar, and they are very different to the context of other *objects* such as *artifacts*. Our algorithm “incorrectly” classified concepts such as mountains or woodlands as *locations*.

Table 4(b) shows results obtained by our system, labelled T+S+O, compared to similar work. There are some important differences, and thence the results are not really comparable. First, the ontologies used in each approach are different, which can have dramatic consequences on the evaluation. Secondly, the other systems are not deterministic. In Table 4(b), the column labelled **single accuracy** shows the percentage of outcomes in which the systems returned a unique hypernym and that one was correct (like our own algorithm); and the **set accuracy** is the percentage of times that the system returned several outcomes among which was the correct one.

4 Conclusions

We have presented here a fully unsupervised method for extending lexical ontologies with unknown concepts taken from domain-specific documents. It can be applied to different domains as it is; and, if we have a shallow parser available, to different languages. It allows the attachment of new concepts to any intermediate level in an ontology, not only at the leaves; and it can tackle large ontologies, such as WordNet. It has been used for generating hypermedia courses using text summarisation as described by Alfonseca and Rodríguez [2002].

Method	Accuracy		L.A.	C.D.	M.P.	System	Accuracy		L.A.
	strict	len.					strict	lenient	
Topic	6.52%	17.39%	0.30	68.21%	2.30	T+S+O	28.26%	36.96%	0.44
Modifiers	16.28%	21.74%	0.29	62.96%	4.47		single	set	
Subject	10.87%	23.91%	0.30	68.80%	3.06	[Hastings, 1994]	19%	41%	-
Object	17.39%	28.26%	0.38	71.43%	2.63	Hahn [1998]	21%	22%	0.67
T+S+O	13.04%	28.26%	0.38	73.44%	1.95	Hahn [1998]-TH	26%	28%	0.73
TSOM	10.87%	21.74%	0.35	70.31%	2.00	Hahn [1998]-CB	31%	39%	0.76

Table 4. (a) Results using different signatures. (b) Comparison with related systems.

Compared to previous approaches (c.f. [Hahn and Schnattinger, 1998, Hastings, 1994]), it requires less resources, as all the signatures are collected automatically, and it does not need a previous encoding of selectional restrictions or article scripts.

The main drawback of our system, as it is now, is that the signatures need to have a certain size in order to provide reliable classifications. An unknown concept that only is cited once will provide a signature with at most a few entries, and the classification will probably be wrong, so an open line for future work is to improve it for low-frequency terms. It has also low precision when classifying concepts that are semantically very related, such as *man* and *woman*. Finally, it still cannot discover whether an unknown word is a synonym of a word already in the ontology.

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