The Knowledge Required to Interpret Noun Compounds

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Abstract

Noun compound interpretation is the task of determining the semantic relations among the constituents of a noun compound. For example, "concrete floor" means a floor made of concrete, while "gymnasium floor" is the floor region of a gymnasium. We would like to enable knowledge acquisition systems to interpret noun compounds, as part of their overall task of translating imprecise and incomplete information into formal representations that support automated reasoning. However, if interpreting noun compounds requires detailed knowledge of the constituent nouns, then it may not be worth doing: the cost of acquiring this knowledge may outweigh the potential benefit.

This paper describes an empirical investigation of the knowledge required to interpret noun compounds. It concludes that the axioms and ontological distinctions important for this task are derived from the top levels of a hierarchical knowledge base (KB); detailed knowledge of specific nouns is less important. This is good news, not only for our work on knowledge acquisition systems, but also for research on text understanding, where noun compound interpretation has a long history. A more detailed version of this paper can be found in [Fan *et al.*, 2003].

1 Introduction

Knowledge acquisition involves building knowledge bases (KBs) from the information provided by standard sources of expertise, such as people and texts. In addition to extracting relevant information, knowledge acquisition involves re-expressing the information in a formal language suitable for machines to reason with. In general, this is difficult because the information is initially expressed in natural languages, and these expressions are notoriously imprecise and incomplete. However, the goal of our project is to improve knowledge acquisition methods by automating the translation of some kinds of expressions from natural languages to formal ones. We call this task *loose-speak interpretation*.

Several kinds of expressions are good candidates for loose-speak interpretation by knowledge acquisition systems. For example, noun compounds omit information that can often be inferred, *e.g. concrete floor* is "a floor *made of* concrete", while *gymnasium floor* is "the floor *region* of a gymnasium". Another candidate is metonymic expressions. These expressions contain incompatible terms and must be expanded to make meaningful phrases. For example, the statement *Joe read Shakespeare*, means "Joe read *text written by* Shakespeare".

This paper focuses on the first kind of loose-speak: interpreting noun compounds in the context of knowledge acquisition. A noun compound is a sequence of nouns composed of a head noun and one (or more) modifiers. The head noun determines the type of the whole compound (with few exceptions), and the modifiers specialize the type from the head noun. Although we limit our study to only pairs of nouns, our results can be applied to longer noun compounds by bracketing them into pairs of nouns (with few exceptions), and then interpreting each pair [Liberman and Sproat, 1992; Pustejovsky and Bergler, 1993; Barker, 1998].

The computational linguistics community has studied noun compound interpretation extensively [Leonard, 1984; Downing, 1977; Levi, 1979; Finin, 1986; Fabre, 1996; Lauer and Dras, 1994; Barker, 1998; Vanderwende, 1994]. In these studies, the task is to select a single semantic category for each pair of nouns. The selection is usually made from a small list of semantic categories, for example category *part-of* is selected for noun compounds like *human lung*, category *material* for *marble statue*, and category *object-of* for *troop movement*.

Our task is more general. Rather than selecting a single semantic category, our task is to find a sequence of semantic relations that links two nouns in a compound. Semantic relations are a list of about 50 thematic roles such as *agent, object, has-part, location, ...,*. For example, given *animal virus*, a traditional interpretation may classify this as a location category (*animal virus* is a virus in an animal). A loose-speak interpretation may be composed of a combination of semantic relations, such as: "an *animal virus* is a virus that is the agent of an invade, such that the object of the invade is the cell part of an animal".

Furthermore, computational linguists approach the noun compound interpretation task armed with lots of examples, but little or no knowledge about the constituent nouns. Typical solutions are based on statistical patterns discovered in

the corpus of examples. In contrast, we approach the task in the context of the constituent nouns knowledge – their taxonomic classification, at least – but few examples of noun compounds, let alone a corpus.

2 Interpreting noun compounds during knowledge acquisition

During knowledge acquisition, the domain expert (or, more generally, the knowledge source) may provide a noun compound in any dialogue that expects a noun. Our knowledge acquisition system successfully interprets the noun compound if it finds a correct sequence of semantic relations between the head noun and its modifier and builds a correct formal representation of the noun compound.

If noun compound interpretation requires *a priori*, detailed knowledge of the head noun and its modifier, then the cost of acquiring this knowledge may overshadow the benefit of interpreting the compound. If, on the other hand, noun compounds can be successfully interpreted without much knowledge about the specific constituent nouns, then the problem is avoided, and a knowledge acquisition system might interpret one concept (the noun compound) while related concepts (the constituent nouns) are only skeletal. Knowledge bases tend to grow in this uneven way – following the lead of the knowledge sources providing expertise – and a knowledge acquisition system should support it.

The purpose of this study is to determine what sort of knowledge is required to interpret noun compounds, and how this knowledge might be obtained. Before delving into the details of the study, it's important to understand what we are *not* attempting to do.

We are not presenting a novel algorithm for noun compound interpretation. Our algorithm is quite simple and is derived from previous research. Also, we are not introducing a new type of knowledge representation or a novel technique of automated reasoning. Finally, we are not using a new, comprehensive knowledge base. We built a couple of them rather quickly and we're using another – not built for this task – "off the shelf."

In summary, what we *are* doing is evaluating the knowledge requirements of a standard search algorithm applied to a variety of typical knowledge bases through a series of ablation studies.

3 Experiments

The challenge in measuring an algorithm's sensitivity to knowledge base content is that the results may vary across domains and across knowledge bases. We attempt to neutralize these factors by replicating our study in three domains with quite different knowledge bases.

The noun compound interpretation task can be viewed as follows: given a knowledge base encoded as a conceptual graph, and a pair of nouns corresponding to two nodes in the graph, find a path of semantic relations between them. The algorithm we used is a breadth-first search algorithm on a knowledge base. The algorithm is given a noun compound of the form $< C_1, C_2 >$ where C_1 and C_2 are the KB concepts that are mapped from the constituents of the given noun compound. Each of the first two steps conducts a breadth-first search of the knowledge base along all semantic relation arcs. The first search starts from C_1 and looks for C_2 or any superclass or subclass of it. The second search starts from C_2 and looks for C_1 or any superclass or subclass of it. Step 3 combines the results, sorted by path length.

To avoid getting results that are skewed to a particular domain or knowledge representation, we used a variety of quite different data sets. The first consists of 224 noun compounds from a college-level cell biology text [Alberts *et al.*, 1998]. The second consists of 294 noun compounds from a small engine repair manual. The third data set consists of 224 compounds from a Sun Sparcstation manual. The nouns used in these data sets are mapped to the corresponding concepts in knowledge bases on these topics.

Despite these commonalities, the KBs differ significantly. First they differ in terms of how they were built. The knowledge base for the biology text was built using the generic Component Library [Barker *et al.*, 2001] to answer end-of-the-chapter style questions, as one of the challenge problems for DARPA's Rapid Knowledge Formation project [Clark *et al.*, 2001]. The knowledge bases for the other two data sets (the small engine repair manual and the Sparcstation manual) were built "on top of" the knowledge in WordNet [Fellbaum, 1998]. We augmented WordNet with the upper ontology of the generic Component Library plus about ten concepts that are important to each of the two domains whose partonomies are not complete in WordNet. Through this process, we encoded 416 concepts in about 50 man-hours. The advantage of using WordNet as the foundation for these knowledge bases is two-fold: it includes most of the terms used in the data sets, linked with both taxonomic and partonomic relations, and it is widely available and well used. The KBs also differ in content. Other than the shared upper ontology of the generic component library, they have few concepts in common.

The importance of each level of the ontology is measured through a series of ablations. When a level is ablated, the concepts on that level and all their axioms are deleted from the knowledge base. The superclasses of the subclasses of these concepts are changed to the superclasses of the concepts being deleted. As a special case, when the $0th$ level (the root level concept) is deleted, it is replaced by a generic concept of "Thing". Because the root level concept is vacuous, deleting it has no affect.

4 Results

Ablating levels of the ontology shows that they differ in their importance for the noun compound interpretation task. Without any ablation, both precision and recall of the noun compound interpretation are around 80% across all three knowledge bases. Ablating level one causes a big drop in both precision and recall. Ablating level two introduces a big gap between precision and recall because the algorithm does not find interpretations for many noun compounds. As lower levels in the ontology are ablated one at a time, the impact diminishes and performance improves to the level of a knowledge base with no ablations.

The contribution of the first two levels of the ontology is

observed across all three data sets and knowledge bases. This pattern strongly suggests that top levels of the ontology are most important for the noun compound interpretation task, which is likely due to some combination of two factors:

1. Top levels of the ontology include concepts that make important ontological distinctions. For example, ablating the level that introduces *Entity* and *Event* blurs the distinction between obviously different concept, which causes the search to stop with erroneous results. Consequently, many more interpretations are returned, and because we only use the first interpretation, the possibility of it being correct is reduced.
2. Although they contain relatively few axioms, these axioms are important for the task. The top-level ontology contains the most frequently used axioms, such as that "every Action involves an object that is acted upon". These axioms are used in the search as a step along the way. Deleting these axioms makes it difficult to find an interpretation for many of the noun compounds, thereby causing recall to lag behind precision.

5 Conclusion

This paper reports an encouraging result: interpreting noun compounds does not require detailed knowledge of the constituent nouns. Rather, it requires only that the nouns be correctly placed in a taxonomy, and that the taxonomy include the ontological distinctions and axioms commonly found in domain independent upper levels. These requirements are easily met in the context of knowledge acquisition, which is our focus.

We reached this conclusion using a novel experimental method. We measured the contribution of each level of the ontology to the task of interpreting noun compounds. We ablated successive levels of the ontology one at a time, thereby conflating ontological distinctions and removing the axioms associated with concepts at each level. We found that the upper levels of the ontology for the KBs we used are the most important for noun compound interpretation. As lower levels in the ontology are ablated one at a time, the impact diminishes to nil. A more detailed version of this paper can be found in [Fan *et al.*, 2003].

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