

Towards Automatic Verb Acquisition from VerbNet for Spoken Dialog Processing

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Abstract

This paper presents experiments on using VerbNet as a resource for understanding unknown verbs encountered by a spoken dialog system. Coverage of unknown verbs in a corpus of spoken dialogs about computer purchasing is assessed, and two methods for automatically integrating representations of verbs found in VerbNet are explored. The first identifies VerbNet classes containing verbs already defined in the system, and generates representations for unknown verbs in those classes, modelled after the existing system representation. The second method generates representations based on VerbNet alone. The second method performs better, but gaps in coverage and differences between the two verb representation systems limit the success of automatic acquisition.

1 Introduction

TRIPS (The Rochester Interactive Planning System) is a collaborative dialog assistant that performs full loop intelligent dialog processing, from speech understanding and semantic parsing through intention recognition, task planning and natural language generation. In recent years the system has undergone rapid expansion to several new domains. Traditionally the system has used a hand-constructed lexicon, but increased demand for coverage of new domains in a short time period together with the availability of online lexical resources has prompted investigation into incorporating existing lexical resources.

The ability to handle spontaneous speech demands broad coverage and flexibility. Verbs are a locus of information for overall sentence structure and selectional restrictions on arguments, so their representation and organization is crucial for natural language processing.

There are numerous approaches to verb classification. For example, Levin (1993) defines semantic verb classes that pattern according to syntactic alternations. The Levin classes are the basis of the online lexical resource VerbNet (Kipper, Dang and Palmer, 2000; Kipper 2003). However FrameNet (Baker, Fillmore and Lowe, 1998), another hand-crafted lexical resource, classifies verbs using core semantic concepts, rather than syntactic alternations (see Baker and Ruppenhofer (2002) for an interesting comparison of the two approaches). Machine learning techniques have been used to induce classes from distributional features extracted from annotated corpora (e.g., Merlo and Stevenson, 2001; Schulte im Walde, 2000).

This paper reports experiments on using VerbNet as a resource for verbs not defined in TRIPS. VerbNet coverage of unknown verbs occurring in a corpus of spoken dialogs about computer purchasing is evaluated. VerbNet coverage has been previously evaluated in (Kipper et al, 2004b) by matching syntactic coverage for selected verbs in PropBank (Kingsbury and Palmer, 2002). In the present evaluation, TRIPS obtains representations from VerbNet for use during parsing to automatically generate semantic representations of utterances that can be used by the system to reason about the computer purchasing task.

The experiments explore methods for automatically acquiring VerbNet representations in TRIPS. The verb representations in TRIPS and VerbNet were developed independently and for different purposes, so successfully integrating the two presents some challenges. Verb classification in TRIPS is organized along semantic lines similar to FrameNet (see section 2) instead of the diathesis-based classification of VerbNet. Dzikovska (2004) has noted that there is a good deal of overlap between the two in terms of the representation of predicate argument structure and

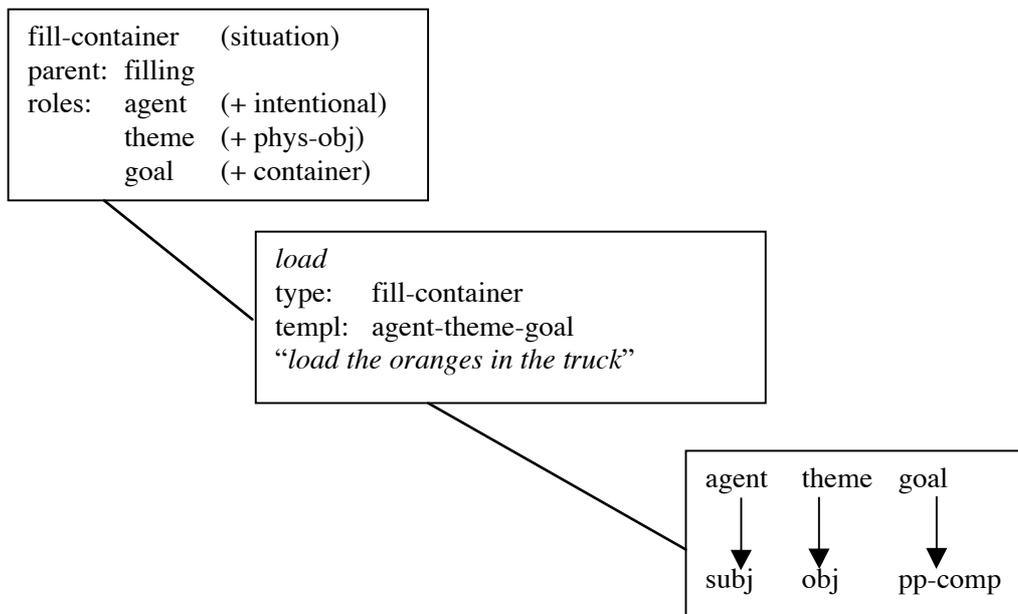


Figure 1: Schematic of the three main components of a TRIPS lexical definition: semantic type, lexical entry, and linking template for one sense of the verb *load*.

associated thematic roles. The experiments reported here provide a more detailed comparison between the two systems and show that in spite of the similarities, there are enough differences to make the integration challenging.

Two automatic acquisition methods are explored. The first creates definitions for verbs in VerbNet classes containing verbs already defined in TRIPS, using the existing definition as a model. The second method generates lexical definitions based on VerbNet information alone. The methods are evaluated by integrating the new definitions into the system and parsing a corpus of transcribed utterances containing the new verbs. Deriving verb definitions directly from VerbNet provides a greater number of acceptable definitions than basing new definitions on existing representations in TRIPS, highlighting some of the difficulties in reconciling independently developed verb representation systems.

2 Verb representation in TRIPS

A lexical representation in TRIPS consists of an orthographic form, part of speech, morphological specifications (if the standard paradigm does not apply), and sense definitions. A lexeme may have one or more sense definitions, which consist of a semantic type with associated thematic roles and semantic features (Dzikovska 2004), and a template that specifies the linking between the thematic roles and syntactic arguments.

The current semantic verb hierarchy takes FrameNet frames (Baker, Fillmore and Lowe, 1998) as its starting point, but incorporates characteristics that streamline it for use in practical spoken dialog processing, such as hierarchical structure and a reduced set of role names (Dzikovska, Swift and Allen, 2004). Each sense definition also includes an example of usage and a meta-data vector that records the origin and date of entry, date of change, and comments. A (simplified) schematic representation for the definition for the verb *load* is shown in Figure 1.

The semantic hierarchy classifies verbs in terms of semantic types that describe the predicate-argument structure. Syntactic frames for licensed constructions are not part of the class specification, as they are in VerbNet. Rather, they are enumerated in the lexical entry itself, as a component of a sense entry.

At the time of this evaluation there are 522 verb lemmas in the TRIPS lexicon. Roughly half of these are also found in VerbNet, although the sense distribution for identical lemmas do not always correspond, as the evaluation in section 4 shows.

3 VerbNet

VerbNet is a hierarchical verb lexicon that uses the Levin verb classes to systematically group verbs into “semantically coherent” classes according to the alternations between the different syntactic frames in which they appear. VerbNet expands on

the Levin classes by providing explicit syntactic and semantic information, including thematic roles annotated with semantic features, and syntactic frames for each verb. VerbNet frames use the thematic role names to describe the syntactic constructions in which a verb can appear. For example, the frame Agent V Patient describes a transitive construction for change of state verbs, as in *Floyd broke the vase*.

The experiments reported here are based on VerbNet v1.5,¹ consisting of 191 main classes subsuming more than 4000 verb senses and approximately 3000 verb lemmas.

4 Evaluation

A new corpus in a computer purchasing domain is used for the evaluation. The corpus data consist of human-human dialogs collected as a basis for development of a new computer purchasing domain. The interlocutors model a scenario in which users interact with an intelligent assistant to purchase computer equipment. The corpus comprises 23 dialogs totalling approximately 6900 utterances. At the time of the evaluation there are 139 verbs in the computer purchasing corpus that are not defined in TRIPS (henceforth ‘target verbs’). Of these, 66 have definitions in VerbNet.

Two methods (described in sections 4.1.1 and 4.1.2) were used to automatically acquire target verb definitions from VerbNet, which were then used to parse a test corpus of transcribed utterances in which the target verbs occur extracted from the computer purchasing corpus.

4.1 Method

The primary test set focuses on the 49 target verbs in VerbNet that are in classes that also contain TRIPS exemplars: *accelerate, admit, bet, bump, clog, concern, count, detect, differ, disappoint, expand, filter, fold, freeze, grow, guarantee, install, intend, invest, investigate, knock, lean, listen, melt, oppose, overwhelm, paste, plug, print, punch, render, roll, sacrifice, satisfy, scan, serve, settle, shop, spill, stick, strip, subtract, suffer, surprise, tack, tempt, void, weigh, wrap*.

A test corpus of 82 transcribed utterances containing instances of target verbs was extracted from the main corpus. In some cases there is a single instance of a target verb, such as *void* in *That voids the warranty*, while other verbs appear frequently, as is the case with *print*.

For the evaluation, the test corpus was parsed with two different versions of the lexicon, one that included target verb definitions based on existing

TRIPS structures and the other included target verb definitions based on VerbNet data alone.

When target verb representations were not based on a TRIPS class match, representations for 17 additional verbs were generated: *advance, exit, fax, interest, package, page, price, rate, set, slow, split, supply, support, train, transfer, wire, zip*. These verb representations were evaluated on a separate corpus of 32 transcribed target utterances.

4.1.1 Acquiring verbs based on TRIPS representations

The first method automatically generated verb definitions for the target words by identifying VerbNet classes that contained verbs for which definitions already existed. If a VerbNet class contained a verb already defined in TRIPS, the frames associated with the VerbNet class were compared to the linking templates for all senses defined for the TRIPS verb. If a match was found, lexical entries based on the existing representations were generated for the target verb(s) in that VerbNet class. The new verbs were defined using existing semantic types, their associated thematic roles, and the linking template(s) corresponding to the matching sense entry. An example of a successful match is target verb *subtract* found in VerbNet class *remove-10.1*, which includes the frames Agent V Theme and Agent V Theme (prep src)² Source. The verb *remove* is in this class, and it is also defined in TRIPS as semantic type REMOVE with the roles Agent, Theme and Source.

Although 49 target verbs are in VerbNet classes that contained TRIPS exemplars, this method resulted in just 33 target verb definitions since the frame comparison procedure failed to find a sense match for several of the target verbs.

Identifying a sense match for a given verb by matching linking templates to VerbNet syntactic frames is not straightforward (see also Kipper et al. (2004a, 2004b) for a similar discussion of issues in matching VerbNet and PropBank representations). The verb classes and associated roles used in the two systems were developed independently and for different purposes. Currently TRIPS distinguishes 30 roles for verbs,³ and VerbNet distinguishes 21 (Kipper 2003). TRIPS roles and their (potentially) corresponding VerbNet roles are listed below.

² A class of prepositions that can introduce a Source.

³ Only roles that appear in the linking templates for verbs are discussed. TRIPS also assigns role names to common general modifying phrases (for example, the *for* phrase in *He studied for the test* is assigned the role Reason) and distinguishes roles for nouns, adverbs, and adjectives to aid in parsing and interpretation (see Dzikovska (2004) for discussion).

¹ www.cis.upenn.edu/group/verbnet/download.html

<u>TRIPS</u>	<u>VerbNet</u>
Core	
Addressee	Recipient
Agent	Agent, Actor(1)
Beneficiary	Beneficiary
Cause	Agent
Cognizer	Agent, Experiencer
Experiencer	Experiencer
Instrument	Instrument
Recipient	Recipient
Theme	Theme(1), Patient(1), Cause, Stimulus
Spatial Location	
Container	Location
Goal	Destination/Location
To-loc	Destination/Location
Source	Source/Location
From-loc	Source/Location
Path	Location
Spatial-loc	Location
Trajectory	
Along	--
Via	--
Co-Roles	
Co-Agent	Actor2
Co-Theme	Theme2, Patient2
Sentential complements (primarily)	
Action	--
Effect	--
Other	
Affected	Patient
Assoc-Info	Topic
Cost	Asset, Extent
Part	--
Predicate	Predicate
Property	Attribute
Result	Product
Time-Duration	Time

The mid-level thematic roles (cf. semantic roles that are frame-specific, such as those used in FrameNet, and macrorole cluster concepts such as Dowty's (1990) Proto-Agent and Proto-Patient) used in TRIPS and VerbNet are difficult to apply consistently, especially on a large scale.⁴ Attempts to use one such system to predict another can be problematic. In many cases TRIPS and VerbNet role correspondences are not unique. For example, TRIPS distinguishes a Cognizer role but VerbNet does not – for the verbs *think*, *believe*, and *assume*, the TRIPS Cognizer role corresponds to the VerbNet Agent role, but for the verb *worry*, the TRIPS Cognizer role corresponds to the VerbNet

Experiencer role. Conversely, VerbNet makes role distinctions that TRIPS does not, such as Theme and Patient. Furthermore, in the case of identical role names, parallel usage is not assured. For example, TRIPS and VerbNet both distinguish a Cause role but use it in different ways. In TRIPS the Cause role is used as a non-intentional instigator of an action, i.e. “Causer”, while in VerbNet it is used as the “Causee”, e.g., as the role of *the thunderstorm* in *Spike fears thunderstorms*. In another case, the TRIPS Instrument role is required to be a physical object, while VerbNet has a broader usage, as it assigns the Instrument role to *A murder* in *A murder began the book*.

Another difference of the TRIPS role system is the assignment of thematic roles to certain phrases in a verb's subcategorization frame that have no corresponding role in traditional thematic role schemes. For example, TRIPS identifies sentential complements with role names such as Action for the verbs *try* and *want*. In addition, TRIPS has a more finely articulated role set than VerbNet for locations and paths. TRIPS distinguishes roles such as Along for the trajectory of an action, as in *Route 31* in *The truck followed Route 31 to Avon* and Via for the location through which a motion trajectory (potentially) passes, as in *Avoid the mountains*.

Additional complexities are introduced into the frame matching task for prepositional complements (see Kipper et al., 2004a).

4.1.2 Acquiring verbs based on VerbNet representations

The second method for generating new target verb definitions used VerbNet data alone to generate the semantic type, thematic roles and linking templates necessary for the TRIPS lexical representation. For every VerbNet class containing a target verb, a new semantic type was defined using the VerbNet class name and roles as the type label and the associated thematic roles. The linking templates were generated from the VerbNet frames, which include syntactic category and thematic role information.

This method generated definitions for all 49 of the target verbs found in VerbNet, as well as for the additional 17 target verbs that appear in VerbNet, but in classes that did not include verbs defined in TRIPS.

4.2 Results

The two methods for generating new verb entries were evaluated by integrating the target verb definitions into the system (independently, in two conditions) and then parsing test utterances derived from the computer purchasing domain. The

⁴ PropBank (Kingsbury and Palmer, 2002) eschews such thematic role labels altogether, using numbered place holders such as Arg0 and Arg1.

analyses generated by the parser were then scored for accuracy. For the parser representation of an utterance to be counted as accurate, the analysis must contain both an appropriate sense (semantic type) for the target verb and correct role assignments for its arguments. The results are shown in Table 1.

A greater number of acceptable verb representations were obtained by generating entries directly from VerbNet rather than trying to base them on an attempted match with existing TRIPS structures. This is in part due to the complexity of the matching process, and also because of the relatively small number of verbs in TRIPS. Only a few target verbs were successfully matched with the first method, such as *expand* in *You might want to expand it*, which was classified with TRIPS semantic type ADJUST, and has the roles of Agent and Theme.

Data	# verbs	Method	Utts	Acc
Target verbs with TRIPS exemplars	49	I: TRIPS	82	11%
Target verbs with TRIPS exemplars	49	II: VN	82	37%
Extra target verbs from VN	17	II: VN	32	37%

Table 1: Results for parsing test utterances with new verb definitions

The results indicate that it is somewhat easier to generate new linking templates based on VerbNet information than trying to match them with existing structures in TRIPS. Using VerbNet data alone, successful interpretations for a number of prepositional complements are generated, such as *What (Oblique) are you (Experiencer) interested (amuse-3.1) in?* However, in the interpretation of *He spilled coffee on it*, *coffee* is assigned to a location role. This type of error could be corrected by incorporating semantic features for selectional restrictions on argument selection, which are included in VerbNet, and integrating them into the lexical definitions is planned for future work. However, TRIPS has its own system of semantic features for the same purpose so additional analysis required before the VerbNet feature representation can be fully integrated with TRIPS.

In some cases there were idioms in the data for which a correct analysis could not reasonably be expected. For example, the target verb *roll* was reasonably mapped to the MOVE semantic type

with the first method, but the instance of *roll* in the test corpus is an idiomatic one, as in *Let's roll with that*, and the system incorrectly assigns *that* to an Instrument role. Predictably, neither method yielded an appropriate sense for this case, nor for other idiomatic usages such as *Let's stick with the twelve-inch powerbook*.

Missing senses and frames in VerbNet were an additional source of error for both methods of verb definition generation. For example, VerbNet lacks a frame with a sentential complement for *tempt*, as in *I'm tempted to get the flat screen monitor*. Another case of missing sense is for the target verb *support*, as in *That capability is only supported in Windows XP*. *Support* is found in two VerbNet classes, contiguous_location-47.8 and admire-31.2, neither of which are appropriate in this case.

The evaluation revealed that several of the target verbs occurred together with particles, such as *punch in* as in *Let me just punch in those numbers*, as well as *bump up*, *clog up*, *fold up*, *knock off*, *knock down*, *plug in*, *punch in*, *set up*, *split up*, *slow down*, and *wrap up*. These were a major source of error in this evaluation since particle verbs are not generally represented in VerbNet.⁵ 16 utterances from the primary target test corpus contain particle verbs, and failure to handle them accounts for 31% of the error for the condition in which the VerbNet derived definitions are tested. 7 utterances in the test corpus for the extra verbs contain particle verbs and these account for 35% of the error for that test set.

5 Summary and Conclusion

It had seemed that using TRIPS representations to model new verbs would yield better results, since in principle more of the information built into TRIPS could be used, but this turned out not to be the case. This method could be improved with additional comparative analysis along with expansion of the TRIPS lexicon, but there will still be enough differences to pose difficulties for automatic mapping between the systems. Automatically generating representations from VerbNet data alone produced better results, but adopting VerbNet classifications wholesale is impractical as they are not always an appropriate level of semantic representation for the parsing and reasoning performed by the system. For example, the class other_cos.45.4 has more than 250 members. Even though they are all change of state verbs, efficient parsing and effective reasoning require finer-grained distinctions to process

⁵ The clustering analysis reported in Kingsbury and Kipper (2003) identifies particle verbs, such as *pull out*, compatible with certain VerbNet classes.

meanings as disparate as, for example, *unionize* and *vaporize*.

The ability to use VerbNet representations directly is still only a partial solution to expanding the system's verb coverage. For these experiments, less than half of the unknown verbs were actually found in VerbNet. Verbs not found include *aim*, *apply*, *compromise*, *concentrate*, *customize*, *discuss*, *elaborate*, *format*, *manipulate*, *optimize*, *program*, *scroll*, *subscribe*, and *troubleshoot*. Of the target verbs found in VerbNet, an appropriate sense was not always represented.

The Levin verb classes are not exhaustive and focus on noun phrase arguments and prepositional complements, so for example verbs with sentential complements are underrepresented, although VerbNet has extended and modified the original classes on which it is based, and continues to be refined (Kipper et al., 2004a). There are still systematic gaps, most importantly for this evaluation, particle verbs.

With its rich syntactic and semantic representation, VerbNet promises to be a useful resource for extending lexical coverage in TRIPS. VerbNet representations also include links to corresponding senses in WordNet (Fellbaum 1998), which strengthens the network of lexical information available that can contribute to better handling of unknown words when they are encountered by the system. However, achieving a representation that combines the predictability of syntactic alternations together with the level of semantic classification needed for spoken dialog processing remains a challenge.

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