Considering a resource-light approach to learning verb valencies

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Abstract
Here we describe work on learning the subcategories of verbs in a morphologically rich language using only minimal linguistic resources. Our goal is to learn verb subcategorizations for Quechua, an under-resourced morphologically rich language, from an unannotated corpus. We compare results from applying this approach to an unannotated Arabic corpus with those achieved by processing the same text in treebank form. The original plan was to use only a morphological analyzer and an unannotated corpus, but experiments suggest that this approach by itself will not be effective for learning the combinatorial potential of Arabic verbs in general. The lower bound on resources for acquiring this information is somewhat higher, apparently requiring a part-of-speech tagger and chunker for most languages, and a morphological disambiguater for Arabic.

1 Introduction
When constructing NLP systems for a new language, we often want to know the valence of its verbs, which is to say how many and which types of arguments each verb may combine with. Some dictionaries may provide this information, but even assuming a broad-coverage machine-readable dictionary exists for a given language, that dictionary may not say whether arguments are optional for a given verb, or how likely they are to occur.

Knowing the selectional preferences and requirements of verbs is useful for systems that have explicit lexicalized grammars of the languages they cover, whether for parsing, generation, or both (Briscoe and Carroll, 1997), and of linguistic interest on its own (Gahl et al., 2004). The aim of this work was to build resources for use in L3 (Gasser, 2011), a rule-based machine translation system based on dependency grammars, which records the combinatorial possibilities for every word in its lexicon, and during parsing and generation constructs a graph describing the structure of the input and output sentences. We are particularly interested in linguistic resources for Quechua, which is spoken by roughly 10 million people in the Andean region of South America, and is thus the largest indigenous language of the Americas. However, evaluating the approach for Quechua is difficult, due to a lack of existing lexica and treebanks, so initial experiments have been carried out with Arabic.

An empirical approach based on a corpus or treebank allows us to learn the relative frequency with which a given verb takes specific types of arguments. As a simple example from English, we would like to be able to learn that while “eat” usually has a direct object, “put” nearly always has one. Verbs may also occur with clausal dependents in various ways. For some examples in English, see Figure [1].

In order to automatically learn this information for resource-scarce, morphologically rich languages, we set out to implement a system that requires only an unannotated corpus and a morphological analyzer; other recent approaches have made use of more linguistic knowledge, in the form of treebanks, parsers, or chunkers. In practice, our we will also require more resources to be fruitful; this may be addressed in the future.

2 Related work
Many other researchers have addressed the problem of documenting the properties of the different verbs in a given language, using evidence from corpora and manual lexicography. Automatic approaches have the potential to involve less manual work avoid human biases, giving a more objective
measure of the behavior of a given verb.

We see in the literature a few different terms that describe the combinatorial potential of a verb, including subcategorization, subcategorization frames, valence or valency. In any case, these terms describe which arguments and adjuncts may appear with a given verb, how often, and which ones are obligatory. While describing similar notions, these terms do not seem to be interchangeable; while this work is concerned with with “surface level” syntax, looking for arguments that are present in practice (such that a parser could find them), in Functional Generative Description (FGD), the term valency refers to a tectogrammatical notion; arguments might be known to the speaker but not expressed. This deeper notion cannot be readily observed from text alone, as pointed out by Bojar (2003).

2.1 Valency lexica for English

Gahl et al. (2004) describe a study in which they had a team of linguists annotate thousands of English sentences – 200 sentences for each of 281 English verbs of interest – and build a table of distributions of subcategorization frames that they observed for each of the verbs. They describe the difficulties that may be faced in trying to learn subcategorizations from a corpus: in a given body of text (even one as big as the Brown corpus), it may be that not all possible subcategorizations will be observed. Additionally, different genres of text may exhibit different verb usage. This paper also gives a good overview of the uses of valency information and a view on verb subcategorization from psycholinguistics, including elicitation experiments that psycholinguists have used to learn the relative frequencies of different uses of verbs.

Gahl’s group has made their results available in machine-readable form, providing a potentially useful resource for those interested in English verbs. However, their approach was very labor-intensive and required a large corpus.

Ushioda et al. (1993) describe earlier work on acquiring verb subcategorizations for English. Their method requires a tagged corpus, although an untagged corpus and an accurate tagger would work as well. On the basis of the tags, they perform partial parsing to identify noun phrases (chunking), and then use some simple rules specified in terms of regular grammars to identify common patterns of constituents in the sentences, which are marked with corresponding subcategorization frames. This approach does not require the use of a deep parser, but the rules had to be crafted specifically for English.

Ushioda explores the WSJ corpus with this extractor, and reports results on 33 randomly selected common verbs: the extraction rules achieve 86% accuracy over sentences from a test set taken from WSJ, where the correct subcategorization frames for the test set had been determined manually.

Brent (1993) addresses the seeming impasse that in order to get accurate parses automatically, one needs to know about the syntactic frames of different verbs, but in order to get the frame information from a corpus, the sentences must be parsed accurately. He handles this problem by crafting language-specific rules that initially only refer to closed-class words and do not require complete parses. This approach is somewhere between having no syntactic knowledge at all, and requiring a large grammar of the target language: to start out, it must first figure out which words in the corpus are verbs. He then uses statistics to infer previously unknown facts about the language, for example, which English verbs can occur with each of six different kinds of arguments.

While this appears to be an effective approach, one wonders how hard it would be to apply to an unfamiliar language. Producing the initial rules may require a lot of linguistic insight; for example, Brent relies on the fact that in English, verbs typically do not appear immediately after determiners or prepositions. In a language with more free word order, or one without determiners or prepositions, what sorts of rules might one use?

Briscoe and Carroll (1997) describe a system that finds subcategorization frames for verbs in English, including relative frequencies for each
class for a given verb. They adopt a very detailed scheme for verb subcategories, in which each usage falls into one of 160 different classes, where each class includes specific information about particles and control of the arguments of the verb. Their system requires the use of a POS tagger, a lemmatizer, and a pre-trained probabilistic parser; after identifying and classifying the different subcategories of verb usages, they incorporate this information into another parser and demonstrate that it improves parsing accuracy.

2.2 Valency lexica for Slavic languages

The VALLEX project (Žabokrtský and Lopatková, 2007) has produced a large hand-curated database of valency frames for verbs in Czech, covering roughly the 2500 most common verbs in Czech and cataloging their various senses. VALLEX makes use of Functional Generative Description as the background linguistic theory for its account of verbs, and so records, at least, whether a verb sense takes an actor, addressee, patient, effect, and origin, and whether these must be specified, as well as a large number of other “quasi-valency complementations” and “free modifications”. VALLEX provides a very detailed account of the potential uses of each verb in its lexicon, much more detailed than what can currently be produced with automatic methods.

More recently, Przepiorkowski has done work focusing on Polish, comparing valence dictionaries built with the use of shallow parsing to those built with deep parsing (2009). Because his shallow parser may not handle all of the sentences in the corpus, his approach ends up ignoring more than half of the training data, but from the remaining 41% of the IPI PAN Corpus, he collects counts of the different frames in which each verb was observed, and uses a small number of Polish-specific rules to post-process the observations, then does statistical filtering to try to reduce noisy observations.

Przepiorkowski evaluates the extracted lexical information in two different ways, making use of both pre-existing valence dictionaries and sentences hand-annotated by linguists, finding that his shallow-parsing technique actually produces results that agree more closely with frames that were observed in the texts by linguists than the existing valence dictionaries.

Debowski (2009) presents a procedure for extracting valence information and frame weights for Polish that makes use of a non-probabilistic deep parser and a novel use of EM, which he says is simpler than the more traditional repeated inside-outside approach to optimizing weights for a probabilistic grammar. Additionally, in his EM formulation, the weight-optimization problem is convex, so he can start with uniform prior probabilities and be guaranteed to get a globally optimum solution. Debowski also includes an approach for filtering incorrect frames that were found in the parsed text.

When analyzing his results, Debowski notes that some of his observed “false positives” described valid uses of the verbs in question, but were not included in the compiled valence dictionaries that he used in evaluating his approach.

2.3 Valency Lexica for Arabic

Informed by the Prague Arabic Dependency Treebank and the Functional Generative Description (FGD) theory of syntax, Bielický and Smrž (2008) describe desiderata for a valency lexicon for Arabic. They do not describe the production of such a lexicon in practice, but lay out a framework for discussing one, proposing a structure for lexical entries in the valence dictionary. Their structure is based on VALLEX, which seems to have a broadly applicable formalism for describing verbs. They also describe some tools useful for the task, including an FST-based morphological analyzer for Arabic, and explain FGD’s account of verbal arguments/adjuncts.

2.4 Resources for Quechua

Rios et al. (2009) address the more general problem of acquiring enough linguistic knowledge to build effective NLP systems for under-resourced languages such as Quechua, with a more labor-intensive approach. They describe their construction of a phrase-aligned treebank for Quechua and Spanish, which covers about 200 sentences, with text from the Declaration of Human Rights (available in many languages, including Spanish and Quechua) and the website of La Defensoría del Pueblo, a Peruvian government organization that advocates for citizens rights. Aside from the morphological analysis of Quechua, the treebanking and alignment process currently require human attention, though this may be partially automated in the future.

The treebank so far is small, but it may be increasingly useful for machine translation as their
treebanking process becomes more automated. Rios et al. note a surprising number of available bitexts for Spanish/Quechua, including political texts, news, translated novels and poetry.

3 Proposed Approach

Our approach starts by processing each sentence in the corpus with the morphological analyzer, thus finding all of the verbs. For sentences with only one verb, we then count the occurrences of nouns that seem to be, because of inflection, the arguments of the verb. Here plausible verb arguments will need to be identified with a small number of language-specific heuristics. For example, a noun inflected with the accusative case in a sentence with a verb and a clear subject will likely be the object of that verb. This approach throws away the information from sentences with multiple verbs and embedded clauses, but it does not require syntactic analysis. We had hoped that the frequencies learned with this approach will approximate the frequencies that would be learned using deeper syntactic analysis, but this does not bear out empirically.

Noisy observations could be filtered out using an approach similar to the one described in (Przepiórkowski, 2009). In the long run, for consistency, we would like to build a lexicon in the VALLEX style, discovering whether each given verb usage contains an explicit Actor, Addressee, Patient, Effect, and Origin, when these roles can be identified by the morphological cues.

3.1 Evaluating Valency Learning Techniques

When building a system that builds valency lexica for the verbs of a given language, we would like both good recall, meaning that the system identifies a many of the verb usages that are actually present in the training text, and high precision, meaning that the answers the system returns are actually correct. To measure both of these, we can take some preexisting lexicon to be the gold standard, but good valency lexica are not available for most languages.

What we can do instead is take the verb usages in a treebank, and consider the subcategorization lexicon constructed in that way to be the gold standard. We have an Arabic treebank (Arabic Treebank Part 1, v3.0) available from the LDC (Maamouri et al., 2005), so for this work we make use both of that treebank and the associated flat text. We chose Arabic for its rich morphology, and for the somewhat convenient, though not freely redistributable, treebank. If the results were good for Arabic, then that would be evidence that it might be helpful for constructing valency lexica for other languages as well.

4 Experiments with Arabic

We carried out experiments with the text of the Arabic treebank, using both the transliterated text with syntactic annotations and the unannotated Unicode text in Arabic script. Given the treebank annotations, we can find the verbs in each sentence, as well as the other components of the verb phrases, quite easily by traversing the parse trees. For initial experiments due to the sparsity of the data, we pass over the problem of deciding whether a constituent is an argument or adjunct of the verb.

To find all of the verb subcategory frames in the treebank, we traverse the tree of each sentence and record the immediate children of the verb phrase that are not the verb itself. These are considered a set, and recorded with the stem of the verb in question. The process is described in more detail in Figure 2.

Considering the entire treebank, which consists of 734 news documents, there are 5845 sentences, containing 14115 verb phrases. The majority (92%) of these verb phrases have a verb that can be found with the rules described. The most common verb stems, presented in Buckwalter transliteration, were: “kAn”, “qAl”, “aEolan”, “aDAf”, “ak ad”, “kuwn”, “awoDaH”, “*akar”, “mokin”, “afAd”. Each of these occurred at least 100 times in the corpus. Not all of these can be translated sensibly to English without context by Google Translate, but using it as a glossing tool, we get: was, declared, added, confirmed, fact, clear, enabled, and reported. There were 1747 different verb stems observed altogether.

Adapting the approach of Przepiórkowski (2009), we then focus on the sentences from the corpus that contain only one verb. This allows us to avoid making attachment decisions, since deep parsers may not be available or reliable. Bojar (2003) does something similar, with the addition of a chunker that can find subordinate clause boundaries. This approach also seems sensible particularly for Quechua and Arabic, since case
• For each sentence in the treebank...
  – For each verb phrase in that sentence...
    * Look for a word in the VP with a tag that contains one of IV, PV, IV_PASS or PV_PASS (one may not be present; if so, skip this VP)
    * Find the stem for the verb, if present
    * Record the verb stem, along with the tags of the sibling constituents.

Figure 2: Process for finding verbs and arguments in the treebank

is typically marked on nouns for both languages, although this still leaves the problem of dropped arguments.

On its own, filtering out a large number of sentences is not a problem; that we include a nontrivial fraction of the sentences at all is promising. To improve coverage, we could simply feed the system more unannotated text. For Arabic, we could use the very large supply of Arabic news available on the web. This approach would be less plausible for Quechua, although of course unannotated Quechua text is more plentiful than Quechua treebanks.

4.1 Sentence Selection in Practice

We might wonder, however, whether our sampling of sentences leads to biases in the observed verbs and their usages. Considering English verbs such as “think”, “believe”, or “request”, which usually occur with some clausal argument that includes some other verb, we imagine that the analogous verbs in the language we are investigating would be under-represented or simply not learned at all.

Experiments showed that both of these worries are well-founded: sentences that had only one verb had a substantially different distribution of verb stems. The verbs that were most common in the one-verb sentences were “saj al”, “qAl”, “>aEolan”, “$Arik”, “kAn”, “daEA”, “fAz”, “balag”, “>aHoraz”, and “lotaqiy”. These are glossed by Google Translate as: record, said, announced, was, called, beat, was, made, and assess, definitely a different sort of verb than the ones we see commonly in the in the text generally.

Even among the verbs that happen commonly in both the text in general and the one-verb sentences, we observe different usages. The most common verb in general, “kAn” (was), occurs with another verb phrase as an argument about 400 times in the treebank. The second-most common verb in general and in the one-verb sentences, “qAl” (“declared/said”), most often occurs with an SBAR (indicating a nested clause) in general, but of course these usages do not occur in the one-verb sentences.

4.2 Morphological ambiguity

In experiments with the nearly-unannotated text distributed with the treebank, we made use of AraMorph (Brihaye, 2004), a Free Software version of the Buckwalter morphological analyzer that handles Unicode text. The goal with the unannotated text was to see which subcategory frames we could observe in sentences with a single verb – the rich Arabic morphology usually marks frames on nouns, which should allow us to find many arguments to verbs. We could then compare the valencies learned from the unannotated corpus with those that are more easily observable from the treebank. If the valencies that we discover with the unannotated approach are close to those learned from the treebank, and we get a broad coverage over the verbs observed in the corpus, then this would provide an argument that the technique works fairly well for Arabic, and we could continue using it as we acquire more textual data for more under-resourced languages.

However, Buckwalter-style morphological analyzers do not account for morphological ambiguity, which would present difficulties in the long run. This problem is particularly dire because the Arabic script is an abjad, which is to say that it only records the consonants for each word. There is an optional system for annotating the vowel sounds as well, but it is often not used in practice. This presents a problem for Arabic-language NLP systems, though, since a word without context rarely has a unique morphological analysis. In fact, within the corpus, we observed a mean of about 7.5 possible Buckwalter analyses per word,

\(^1\)very lightly marked-up with SGML
with $\sigma = 8.4$, and a maximum of 86. \footnote{The word with 86 Buckwalter analyses can mean, at least, "one", "and scrutinize", "and sharpen", or "and be furious".}

We also briefly experimented with a Quechua morphological analyzer, Michael Gasser’s AntiMorfo system \cite{Antimorfo}; it can analyze Quechua verbs, nouns, and adjectives. We also see morphological ambiguity in Quechua words, although it is not nearly so striking, largely due to the orthography with vowels. We saw a mean of 1.7 analyses per word, with $\sigma = 1.3$, and a maximum of 10. For Quechua, we used a small corpus produced by the AVENUE project, described in \cite{Monson2006}, which includes bitext elicited from native speakers, and monolingual text, both from UN documents and local stories. Interestingly, with the FST-based morphological analysis, we cannot tell whether a word is definitely a verb. For example, *waqaychu* may be a verb, noun, or infinitive, as "waqa" is in AntiMorfo’s lexicon as a verb root, and "waqay" as a noun root. So to get good results for Quechua, we would need a POS tagger or other means to choose between analyses. As far as treebanks of Quechua, for evaluating an automatically-extracted Quechua verb lexicon, to our knowledge there is no large one available, although Rios \textit{et al.} are developing a small one \cite{Rios2009}.

5 Conclusions and future work

While the problem of discovering grammatical subcategories of verbs remains interesting, and solutions to that problem would be of practical use, it is almost definitely not enough to use only a morphological analyzer and a medium-sized unannotated corpus for this purpose; disregarding sentences with more than one verb leads to misleading view of the language as a whole, and selection preferences learned from these sentences would not be suitable for parsing most sentences. To make better use of the existing data, it would be helpful to have a chunker to find the boundaries of clauses and noun phrases, as in \cite{Przepiorkowski2009}. For Czech verbs, Bojar similarly used finite-state rules to find coordinated and subordinate clauses \cite{Bojar2003}.

While ambiguity in morphological analysis can be a hurdle in any language, the vowel-free nature of typical Arabic text presents a particularly serious one; we would like to be able to use any available unannotated text, but without morphological disambiguation, we are left with many possible interpretations for most tokens. This could be mitigated with software like MADA+TOKAN \cite{MadaTokan2009}, which chooses the most likely morphological analysis for a given context; for other languages, such as Quechua, similar tools will need to be developed.

Even with proper POS tagging, morphological disambiguation, and chunking, we are still faced with the problem of negative evidence; without a very large corpus, we cannot say with confidence that a given verb cannot appear with certain arguments, simply because it has not yet been observed with those arguments. This difficulty suggests an active learning approach, perhaps coupled with crowdsourcing. We could imagine a system that generates sentences to test the hypothesis that a given verb may be used with a given subcategorization frame, then presents those sentences to human users for grammaticality judgments.

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