POLYGLOT: Multilingual Semantic Role Labeling with Unified Labels

Alan Akbik       Yunyao Li
IBM Research
Almaden Research Center
650 Harry Road, San Jose, CA 95120, USA
{akbika,yunyaoli}@us.ibm.com

Abstract
Semantic role labeling (SRL) identifies the predicate-argument structure in text with semantic labels. It plays a key role in understanding natural language. In this paper, we present POLYGLOT, a multilingual semantic role labeling system capable of semantically parsing sentences in 9 different languages from 4 different language groups. The core of POLYGLOT are SRL models for individual languages trained with automatically generated Proposition Banks (Akbik et al., 2015). The key feature of the system is that it treats the semantic labels of the English Proposition Bank as “universal semantic labels”: Given a sentence in any of the supported languages, POLYGLOT applies the corresponding SRL and predicts English PropBank frame and role annotation. The results are then visualized to facilitate the understanding of multilingual SRL with this unified semantic representation.

1 Introduction
Semantic role labeling (SRL) is the task of labeling predicate-argument structure in sentences with shallow semantic information. One prominent labeling scheme for the English language is the Proposition Bank (Palmer et al., 2005) which annotates predicates with frame labels and arguments with role labels. Role labels roughly conform to simple questions (who, what, when, where, how much, with whom) with regards to the predicate. SRL is important for understanding natural language; it has been found useful for many applications such as information extraction (Fader et al., 2011) and question answering (Shen and Lapata, 2007; Maqsud et al., 2014).

Figure 1: Example of POLYGLOT predicting English PropBank labels for a simple German sentence: The verb “kaufen” is correctly identified to evoke the BUY.01 frame, while “ich” (I) is recognized as the buyer, “ein neues Auto” (a new car) as the thing bought, and “dir” (for you) as the benefactive.

Not surprisingly, enabling SRL for languages other than English has received increasing attention. One relevant key effort is to create Proposition Bank-style resources for different languages, such as Chinese (Xue and Palmer, 2005) and Hindi (Bhatt et al., 2009). However, the conventional approach of manually generating such resources is costly in terms of time and experts required, hindering the expansion of SRL to new target languages.

An alternative approach is annotation projection (Padó and Lapata, 2009; Van der Plas et al., 2011) that utilizes parallel corpora to transfer predicted SRL labels from English sentences onto sentences in a target language. It has shown great promise in automatically generating such resources for arbitrary target languages. In previous work, we presented an approach based on filtered projection and bootstrapped learning to automatically generate Proposition Bank-style resources for 7 languages, namely Arabic, Chinese, French, German, Hindi, Russian and Spanish (Akbik et al., 2015).

Unified semantic labels across all languages.

One key difference between auto-generated PropBanks and manually created ones is that the former use English Proposition Bank labels for
all target languages, while the latter use language-specific labels. As such, the auto-generated PropBanks allow us to train an SRL system to consume text in various languages and make predictions in a shared semantic label set, namely English PropBank labels. Refer to Figures 1 and 2 for examples of how our system predicts frame and role labels from the English PropBank for sentences in German, English, Chinese and Spanish.

Similar to how Stanford dependencies are one basis of universal dependencies (De Marneffe et al., 2014; Nivre, 2015), we believe that English PropBank labels have the potential to eventually become a basis of “universal” shallow semantic labels. Such a unified representation of shallow semantics, we argue, may facilitate applications such as multilingual information extraction and question answering, much in the same way that universal dependencies facilitate tasks such as crosslingual learning and the development and evaluation of multilingual syntactic parsers (Nivre, 2015). The key questions, however, are (1) to what degree English PropBank frame and role labels are appropriate for different target languages; and (2) how far this approach can handle language-specific phenomena or semantic concepts.

Contributions. To facilitate the discussions of the above questions, we present POLYGLOT, an SRL system trained on auto-generated PropBanks for 8 languages plus English, namely Arabic, Chinese, French, German, Hindi, Japanese, Russian and Spanish. Given a sentence in one of these 9 languages, the system applies the corresponding SRL and visualizes the shallow semantic parse with predicted English PropBank labels. POLYGLOT allows us to illustrate our envisioned approach of parsing different languages into a shared shallow semantic abstraction based on the English Proposition Bank. It also enables researchers to experiment with the tool to understand the breadth of shallow semantic concepts currently covered, and to discuss limitations and the potential of such an approach for downstream applications.

2 System Overview

Figure 3 depicts the overall architecture of POLYGLOT. First, we automatically generate labeled training data for each target language with annotation projection (Akbik et al., 2015) (Figure 3 Step 1). We use the labeled data to train for each language an SRL system (Figure 3 Step 2) that predicts English PropBank frame and role labels. Both the creation of the training data and the training of the SRL instances are one-time processes.

POLYGLOT provides a Web-based GUI to allow users to interact with the SRL systems (Figure 3 Step 3). Given a natural language sentence, depending on the language of the input sentence, POLYGLOT selects the appropriate SRL instance and displays on the GUI the semantic parse, as well as syntactic information.
In the next sections, we briefly describe the creation of the labeled data and the training of the SRL systems, followed by a tour of the Web UI.

3 Auto-Generation of Labeled Data

We followed an annotation projection approach to automatically generate the labeled data for different languages. This approach takes as input a word-aligned parallel corpus of English sentences and their translations in a target language (TL). A semantic role labeler then predicts labels for the English sentences. In a projection step, these labels are transferred along word alignments onto the target language sentences. The underlying theory is that translated sentence pairs share a degree of semantic similarity, making such projection possible (Padó and Lapata, 2009).

Figure 4 illustrates an example of annotation projection: Using an SRL system trained with the English Proposition Bank, the English sentence is labeled with the appropriate frame (BUY.01) and role labels: “Diego” as the buyer (A0 in PropBank annotation), “some flowers” as the thing bought (A1) and “his girlfriend” as the benefactive (A4). In addition, “yesterday” is labeled AM-TMP, signifying a temporal context of this frame. These labels are then projected onto the aligned Spanish words. For instance, “compró” is word-aligned to “bought” and thus labeled as BUY.01. The projection produces a Spanish sentence labeled with English PropBank labels; such data can in turn be used to train an SRL system for Spanish.

State-of-the-art. Direct annotation projection often introduces errors, mostly due to non-literal translations (Akbik et al., 2015). Previous work defined lexical and syntactic constraints to increase projection quality, such as filters to allow only verbs to be labeled as frames (Van der Plas et al., 2011), heuristics that ensure that only heads of syntactic constituents are labeled as arguments (Padó and Lapata, 2009) and the use of verb translation dictionaries to guide frame mappings. In (Akbik et al., 2015), we additionally proposed a process of filtered projection and bootstrapped learning, and successfully created Proposition Banks for 7 target languages. We found the quality of the generated PropBanks to be moderate to high, depending on the target language. Table 1 shows estimated precision, recall and F1-score for each language with two evaluation methods. Partial evaluation counts correctly labeled incomplete constituents as true positives while exact evaluation only counts correctly labeled complete constituents as true positives. For more details we refer the reader to (Akbik et al., 2015).

4 Semantic Role Labeling

Using the auto-generated labeled data, we train the semantic role labeler of the MATE toolkit (Björkelund et al., 2009), which achieved state-of-the-art semantic F1-score in the multilingual semantic role labeling task of the CoNLL-2009 shared task (Hajič et al., 2009). The parser is implemented as a sequence of local logistic regression classifiers for the four steps of predicate identification, predicate classification, argument identification and argument classification. In addition, it implements a global reranker to rerank sets of local predictions. It uses a standard feature set of lexical and syntactic features.

Preprocessing. Before SRL, we execute a pipeline of NLP tools to extract the required lexical, morphological and syntactic features. To facilitate reproducability of the presented work, we use publicly available open source tools and pre-

![Figure 4: Annotation projection for a word-aligned English-Spanish sentence pair.](image-url)
trained models where available. A breakdown of the preprocessing tools used for each language is given in Table 2.

**Data sets.** In order to generate training data for POLYGLOT, we used the following sources of parallel data: The UN corpus of official United Nations documents (Rafalovitch et al., 2009), the Europarl corpus of European parliament proceedings (Koehn, 2005), the OpenSubtitles corpus of movie subtitles (Lison and Tiedemann, 2016), the Hindencorp corpus automatically gathered from web sources (Bojar et al., 2014) and the Tatoeba corpus of language learning examples1. The data sets were obtained from the OPUS project (Tiedemann, 2012) and word aligned using the Berkeley Aligner2. Table 2 lists the data sets used for each language and the combined number of available parallel sentences.

<table>
<thead>
<tr>
<th>LANGUAGE</th>
<th>NLP PREPROCESSING</th>
<th>PARALLEL DATA SETS</th>
<th>#SENTENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arabic</td>
<td>STANFORDCORENLP, KHOJASTEMMER, STANFORDPARSER</td>
<td>UN, OpenSubtitles</td>
<td>24.5M</td>
</tr>
<tr>
<td>Chinese</td>
<td>STANFORDCORENLP, MATEPARSER</td>
<td>UN, OpenSubtitles</td>
<td>12.2M</td>
</tr>
<tr>
<td>English</td>
<td>CLEARNLP</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>French</td>
<td>STANFORDCORENLP, MATETRANSITIONPARSER</td>
<td>UN, OpenSubtitles</td>
<td>36M</td>
</tr>
<tr>
<td>German</td>
<td>STANFORDCORENLP, MATETRANSITIONPARSER</td>
<td>Europarl, OpenSubtitles</td>
<td>14.1M</td>
</tr>
<tr>
<td>Hindi</td>
<td>TnTTAGGER, MATEPARSER</td>
<td>Hindencorp</td>
<td>54K</td>
</tr>
<tr>
<td>Japanese</td>
<td>JIST</td>
<td>Tatoeba, OpenSubtitles</td>
<td>1.7M</td>
</tr>
<tr>
<td>Russian</td>
<td>TREETAGGER, MATEPARSER</td>
<td>UN, OpenSubtitles</td>
<td>22.7M</td>
</tr>
<tr>
<td>Spanish</td>
<td>STANFORDCORENLP, MATEPARSER</td>
<td>UN, OpenSubtitles</td>
<td>52.4M</td>
</tr>
</tbody>
</table>

Table 2: NLP tools and source of parallel data used for each language. Since English is the source language for annotation projection, no parallel data was required to train SRL.

In order to generate training data for POLYGLOT, we used the following sources of parallel data: The UN corpus of official United Nations documents (Rafalovitch et al., 2009), the Europarl corpus of European parliament proceedings (Koehn, 2005), the OpenSubtitles corpus of movie subtitles (Lison and Tiedemann, 2016), the Hindencorp corpus automatically gathered from web sources (Bojar et al., 2014) and the Tatoeba corpus of language learning examples. The data sets were obtained from the OPUS project (Tiedemann, 2012) and word aligned using the Berkeley Aligner. Table 2 lists the data sets used for each language and the combined number of available parallel sentences.

5 POLYGLOT User Interface

The Web-based GUI of POLYGLOT allows users to enter sentences in one of 9 languages and request a shallow semantic analysis. Figure 5 presents a screenshot of the GUI. Users begin by entering a sentence in the text field and clicking on the “parse sentence” button. As indicated in Figure 3, it is then passed to a language-specific NLP pipeline based on the associated language that is detected automatically by default or specified by the user. The pipeline tokenizes and lemmatizes the sentence, performs morphological analysis, dependency parsing and semantic role labeling.

**Output.** The syntactic and semantic parsing results are displayed below the input field, following the design of (Björkellund et al., 2010): The topmost result table is the semantic analysis, presented as a grid in which each row corresponds to one identified semantic frame. The grid highlights sentence constituents labeled with roles and includes role descriptions for better interpretability of the parsing results.

Below the results of the semantic analysis the GUI shows two more detailed views of the parsing results. The first visualizes the dependency parse tree generated using WHATS WRONG WITH MY NLP3, while the second (omitted in Figure 5 in the interest of space) displays the full syntactic-semantic parse in CoNLL format, including morphological information and other features not present in the dependency tree visualization. These two views may be helpful to users that wish to identify possible sources of SRL errors. For instance, a common error class stem from errors in dependency parsing, causing incorrect constituents to be labeled as arguments.

**Example sentence.** Figure 5 illustrates the result visualization of the tool. A user enters a sentence “Hier, je voulais acheter une baguette, mais je n’avais pas assez d’argent” (engl. “Yesterday I wanted to buy a baguette but I didn’t have enough money”) into the text field. As indicated in the top left corner, this sentence is auto-detected to be French.

The results of semantic analysis is displayed below the input field. The first column in the grid indicates that three frames have been identified: WANT.01, BUY.01 and HAVE.03. The second row in the grid corresponds to the WANT.01 frame, which identifies “je” (engl. “I”) as the wanter and “acheter une baguette” (engl. “buy a baguette”) as the thing wanted. The arguments are color-coded by PropBank argument type for better readability. For instance, in the PropBank annotation scheme, 1http://tatoeba.org/eng/ 2https://code.google.com/archive/p/berkeleyaligner/ 3https://code.google.com/archive/p/whatswrong/
the agents of the three frames in the example (the wanter, the buyer and the owner) are all annotated with the same role (A0). They are thus highlighted in the same yellow color in the visualization. This allows a user to quickly gauge whether the semantic analysis of the sentence is correct⁴.

6 Demonstration and Outlook

We present POLYGLOT as a hands-on demo where users can enter sentences and request shallow semantic analyses. We also plan to make it publicly accessible in the future. We are currently working on improving the annotation projection approach to generate higher quality data by experimenting with further constraints, language-specific heuristics and improved frame mappings. We are particularly interested in how far English Proposition Bank labels are suitable for arbitrary target languages and may serve as basis of a “universal semantic role labeling” framework: we are qualitatively analysing auto-generated PropBanks in comparison to manual efforts; meanwhile, we are evaluating POLYGLOT in downstream applications such as multilingual IE. Through the presentation of POLYGLOT, we hope to engage the research community in this discussion.

⁴The example sentence in Figure 5 contains one error: The word “hier” (engl. “yesterday”) should be labeled AM-TMP instead of AM-DIS. All other labels are correct.

References


Ondřej Bojar, Vojtěch Diatka, Pavel Rychlý, Pavel Straňák, Vit Suchomel, Aleš Tamchyna, Daniel Ze- 
man, et al. 2014. Hindencorp–hindi-english and hindi-only corpus for machine translation. In Pro- 
cceedings of the Ninth LREC.

ence on Applied natural language processing, pages 224–231. Association for Computational Linguis- 
tics.

Jinho D. Choi and Andrew McCallum. 2013. Transition-based dependency parsing with selec- 
tional branching. In Proceedings of the 51st Annual Meeting of the Association for Computational Lin- 
guistics.

Marie-Catherine De Marneffe, Timothy Dozat, Na- 
talia Silveira, Katri Haverinen, Filip Ginter, Joakim Nivre, and Christopher D Manning. 2014. Univer- 
sal stanford dependencies: A cross-linguistic typol- 

Anthony Fader, Stephen Soderland, and Oren Etzioni. 
2011. Identifying relations for open information ex- 
traction. In Proceedings of the Conference on Em- 
pirical Methods in Natural Language Processing, pages 1535–1545. Association for Computational Linguis- 
tics.

Spence Green and Christopher D Manning. 2010. Bet- 
ter arabic parsing: Baselines, evaluations, and anal- 

Jan Hajič, Massimiliano Ciaramita, Richard Johans- 


Pierre Lison and Jörg Tiedemann. 2016. Opensub- 
titles2016: Extracting large parallel corpora from movie and tv subtitles.

Christopher D. Manning, Mihai Surdeanu, John Bauer, 
Jenny Finkel, Steven J. Bethard, and David Mc- 
closky. 2014. The Stanford CoreNLP natural lan- 
guage processing toolkit. In Association for Computa-
tional Linguistics (ACL) System Demonstrations, pages 55–60.