Word Frame Disambiguation: Evaluating Linguistic Linked Data on Frame Detection

Aldo Gangemi[1], Mehwish Alam[1], Valentina Presutti[2]

1. Universite Paris 13, Paris, France, 2. National Research Council (CNR), Rome, Italy
{gangemi@lipn.univ-paris13.fr,alam@lipn.univ-paris13.fr,valentina.presutti@cnr.it}

Abstract. The usefulness of FrameNet is affected by its limited coverage and non-standard semantics. This paper presents some strategies based on Linguistic Linked Open Data to fully exploit and broaden its coverage. These strategies lead to the creation of a novel resource, *Framester*, which serves as a hub between FrameNet, WordNet, VerbNet, BabelNet, DBpedia, Yago, DOLCE-Zero, as well as other resources. We also present a Word Frame Disambiguation, an application performing frame detection from text using Framester as a base. The results are comparable in precision to the state-of-the-art machine learning tool, but with a much higher coverage.

Keywords: Frame Detection, Framester, FrameNet, FrameNet Coverage, Knowledge Graphs, Frame Semantics.

1 Introduction

Two of the most important linguistic linked open data resources are WordNet [6] and FrameNet [2]. FrameNet allows to represent textual resources in terms of Frame Semantics. The usefulness of FrameNet is affected by its limited coverage, and non-standard semantics. An evident solution would be to establish valid links between FrameNet and other lexical resources such as WordNet, VerbNet [12] and BabelNet [14] to create wide-coverage and multi-lingual extensions of FrameNet. By overcoming these limitations NLP-based applications such as question answering, machine reading and understanding, etc. would eventually be improved.

FrameNet and WordNet have already been formalized several times, e.g. in OntoWordNet [9], WordNet RDF [18], FrameNet RDF [15], etc. In this study, a new wide-coverage knowledge base is introduced referred to as Framester. It is a frame-based ontological resource acting as a hub between e.g. FrameNet, WordNet, VerbNet, BabelNet, DBpedia, Yago, DOLCE-Zero etc. It leverages the wealth of links between these resources to create an interoperable *predicate space* formalized according to frame semantics [7], and semiotics [8]. It includes a novel set of mappings between FrameNet frames, WordNet synsets, and BabelNet synsets generated using extensions allowing increased frame coverage using semantic relations from WordNet and FrameNet. Such a unification of these resources into a single hub will simplify the linking and mapping between linguistic RDF resources.

Based on Framester, a frame detection framework, Word Frame Disambiguation, has been introduced which is an API using several subsets of Framester built from the mappings between WordNet and FrameNet. Word Frame Disambiguation exploits classical Word Sense Disambiguation (WSD) as implemented in UKB [1] and Babelfy [13], and then uses Framester to create the closure to frames. It is therefore a new *detour* approach to frame detection aiming at complete coverage of the frames evoked in a sentence. This *frame detection by detour* [3] employing large linguistic linked open data is comparable to the state-of-the-art frame detection in precision, and better in recall.

2 Framester as a Linked Linguistic Predicate resource

Despite the active development of linguistic linked open data in recent years, there are still a few linguistic resources, and they are not linked as intensely as they could be. These datasets have heterogeneous schemas that pose inconvenience in their direct and interoperable use. Framester is a linked data resource, consisting of multiple datasets overcoming the stated challenges. It provides a dense interlinking between existing resources, adds many new ones, and provides a homogeneous formalization of those links under the hat of frame semantics. It is intended to work as a knowledge graph/linked data hub to connect lexical resources, NLP results, linked data, and ontologies. It is bootstrapped from existing resources, notably the RDF versions of FrameNet [15], WordNet, VerbNet, and BabelNet, by interpreting their semantics as a subset of (a formal version of) Fillmore's frame semantics [7], and semiotics [8], and by reusing or linking to off-the-shelf ontological resources including OntoWordNet, DOLCE-Zero, Yago, DBpedia, etc.

The closest resources to Framester are FrameBase [17] and Predicate Matrix [5]. *FrameBase* is aimed at aligning linked data to FrameNet frames, based on similar assumptions as Framester's: full-fledged formal semantics for frames, detour-based extension for frame coverage, and rule-based lenses over linked data. However, the coverage of FrameBase is limited to an automatically learnt extension (with resulting inaccuracies) of FrameNet-WordNet mappings, and the alignment to linked data schemas is performed manually. Anyway, Framester could be combined with FrameBase (de)reification rules so that the two projects can mutually benefit from their results.

Predicate Matrix is an alignment between predicates existing in FrameNet, VerbNet, WordNet, and PropBank. It does not assume a formal semantics, and its coverage is limited to a subset of lexical senses from those resources. Predicate Matrix uses SemLink [16], a resource containing partial mappings between the existing resources having predicate information as a base, and then extends its coverage via graph-based algorithms. It provides new alignments between the semantic roles from FrameNet and WordNet. A RDF version of Predicate

Matrix has been created in order to add it to the Framester linked data cloud, and (ongoing work) to check if those equivalences can be reused in semantic web applications.

2.1 Frame Semantics in OWL

Both FrameBase and Framester interpret frames as classes and frame elements as properties. However, Framester goes deeper into the semantics for frames, semantic roles, semantic types, selectional restrictions, and the other elements existing in lexical resources. Due to the expressivity limitations of OWL, some refactoring is needed to represent frame semantics: frames are represented as both classes and individuals, semantic roles and co-participation relations as both (object or datatype) properties and individuals, selectional restrictions and semantic types as both classes and individuals. Frames and other predicates are represented as individuals when a schema-level relation is needed (e.g. between a frame and its roles, or between two frames), which cannot be represented by means of an OWL schema axiom (e.g. subclass, subproperty, domain, range, etc.).

Framester preserves the information about the Frame Element inheritance originally present in FrameNet through `skos:subsumedUnder`. Additionally, it provides a mapping to generic frame elements which further connects to a more abstract subsumption hierarchy of roles provided by Framester.

WordNet synsets are interpreted in a twofold way: as specialized frames, and as semantic types. As equivalence classes of word senses, whose words can evoke one or more frames, they are cloned as instances of `framester:SynsetFrame`, which inherits their semantic roles from the core frames cloned from FrameNet. As equivalence classes of word senses, and following the OntoWordNet semantics, they are promoted as OWL classes.

2.2 FrameNet Coverage

The extensions to FrameNet were created using the semantic relations already present in WordNet. [3] addresses the issue of FrameNet coverage by extending the Lexical Units already present in FrameNet with the corresponding sysnsets from WordNet alongwith the semantic relations between the synset i.e., hypernymy and anotnymy. On the other hand, in Framester, a set of *base-mappings* were generated by deeply revising existing FrameNet-WordNet mappings (eXtended WordFrameNet [5], FrameBase [17], and other existing sources found on the Web), and enriching them with new ones. This dataset, called Framester Base, has been manually curated to rectify mapping errors and evocations. Further extensions were automatically performed based on the following paradigm:

1. WordNet hyponymy relations between noun and verb synsets, where each frame is extended with direct hyponyms of the noun or verb synsets mapped to frames in the Framester Base dataset
2. "Instance-of" relations between WordNet noun synsets

3. Adjective synset similarity
4. Same verb groups including verb synsets
5. Pertainymy relations between adverb synsets and noun or adjective synsets
6. Participle relations between adjective and verb synsets
7. Morphosemantic links between adjective and verb synsets
8. Transitive WordNet hyponymy relations
9. Unmapped siblings of mapped noun or verb synsets
10. Derivational links between different kinds of synsets

2.3 Framester Subset for Word Frame Disambiguation

The part of Framester to measure the effect of different mappings and their extensions were used in Word Frame Disambiguation. This subset was bootstrapped by cloning a subset of FrameNet frames (the *core frames*) and its relations, and extending them by means of a manually curated mapping to WordNet synsets. The current experiments used four different Framester profiles to firstly check the impact of automatic extensions on precision and recall of Word Frame Disambiguation (see next section). The subset of Framester consists of:

- **Base (B)**: just the manually curated mappings.
- **Direct (D)**: the B profile plus extensions (1) to (7). For example, the frame *Reshaping* will be evoked for the word "curl" as well as"crimp" which is direct hyponym of "curl".
- **Transitive (T)**: the D profile plus extensions (8) to (10). The word "flute" will evoke the frame Reshaping under Profile-T but not under Profile-D as it is obtained after following the hyponymy relation transitively.
- **FrameNet (F)**: a subset of the B profile that only contains the mappings whose synsets have a direct mapping in FrameNet lexical units. For example, the frame *"Reshaping"* will be evoked by the lexical units already given in FrameNet such as bend, crumple, crush, curl etc.

3 Word Frame Disambiguation: Evaluation setting and results

A frame detection API called Word Frame Disambiguation (WFD), has been implemented as an application of Framester for evaluation purposes. It is implemented as a pipeline including tokenisation, POS tagging, lemmatization, word sense disambiguation, and finally frame detection by detour using the four WFD profiles. It follows detour based approach to *frame detection* meaning that it performs frame detection via WordNet or BabelNet word senses along with the extensions using the profiles from section 2.3. Framester frames have been expanded (when applicable) by using the semantic relations present in FrameNet using the predicates `fn`[1]`:uses`, `fn:isPerspectivizedIn`, `fn:seeAlso`, `fn:inheritsFrom`

[1] PREFIX fn:⟨http://www.ontologydesignpatterns.org/ont/framenet/tbox/⟩

and `fn:perspectiveOn`. An API for Word Frame Disambiguation along with SPARQL endpoint, data dumps, reports etc. are available from http://lipn.univ-paris13.fr/framester/.

The four WFD profiles have been evaluated in a frame detection task, and compared to other sets of mappings (eXtended WordFrameNet [5] and FrameBase [17]), as well as to Semafor [4], the state of the art in machine-learning-based frame detection tools, whose model has been learnt on the annotations of the FrameNet annotated lexicon (see below).

Two textual corpora are used for evaluation: the FrameNet annotated lexicon version 1.5 released in 2010 (78 documents with 170,000 manually annotated sentences), and a corpus (called here the "independent corpus") of 100 heterogeneous texts taken from New York Times news, tweets, Wikipedia definitions, and scientific articles. The texts in the corpora were disambiguated by using two WSD algorithms: (i) Babelfy [13] and (ii) UKB [1]. The word senses provided by the WSD algorithms were then matched against Framester, and the evoked Framester frames were retrieved by following the links provided by the different profiles introduced in Sect. 2.3.

The annotated FrameNet corpus is considered a gold standard, since FrameNet developers have a rigorous manual procedure to annotate it. All words that are listed as FrameNet lexemes, and are found in the text, are annotated with exactly one frame. This contrasts with the fact that multiple frames might be evoked by a same word, and that many words that are not FrameNet lexemes can actually evoke a frame.

The independent corpus has been collected for machine reading evaluation purposes [10], and is not a gold standard for frame detection. This means that frame annotations (its ground truth) should be provided from scratch. In this experiment we used the tools intended to be compared, merged their results, asked two experts to judge the correctness of the detected frames, as well as any missing detection, and a third expert to take decisions when the two raters had different opinions.

On one hand, we expected that Semafor would be highly performant on the annotated FrameNet lexicon (since it has been trained on it), and we wanted (Experiment 1) to verify how close we can perform with a detour approach. On the other hand, the second corpus was used to verify (Experiment 2) if any difference in performance between Semafor and detour-based approaches is sensible to the specific Semafor training, or not.

3.1 Experiment 1: FrameNet Annotated Corpus

For Experiment 1, the frames already present in the FrameNet annotated lexicon were used as ground truth. The performance of Framester based Word Frame Disambiguation with all its profiles, as well as Semafor's, were computed. The performance of the detour approach are shown in Table 1, where the left and right hand side of the table show the results based on the two WSD algorithms UKB and Babelfy respectively. In both the cases, There was a significant increase in the newly annotated words in Profile-D and Profile-T as these two profiles extend the coverage of FrameNet. This leads to higher recall for these two profiles. The best recall was obtained for the profile created using transitive hyponymy relation (Profile-T). On the other hand, the precision decreases.

	UKB			Babelfy		
Framester Profiles	Recall	Precision	F_1	Recall	Precision	F_1
Base (B)	0.671	**0.799**	**0.729**	0.662	**0.780**	**0.715**
Direct (D)	0.750	0.641	0.690	0.790	0.569	0.660
Transitive (T)	**0.860**	0.520	0.648	**0.870**	0.444	0.588
FrameNet (F)	0.688	0.777	0.702	0.673	0.749	0.704

Table 1: Results for different WFD profiles mappings applied to frame detection setting against the FrameNet 1.5 full text annotations. Values in **bold** represent the best results.

The system used as a baseline in our experiments is Semafor [4]. It is a frame-semantic parser, which given a sentence aims at predicting frame-semantic representation using statistical models. As a first step, it extracts targets from the sentences and disambiguates it to a semantic frame. For doing so, it uses semi-supervised learning for frame disambiguation of unseen targets. Then the evoked frame is selected for each predicate. In the current evaluation, we provide the sentences from the FrameNet 1.5 corpus to Semafor, which generates frame-tagged output and the precision, recall and the $F_1 - measure$ of the system are computed. The results are reported in Table 2. The recall for Framester (Profile-T with Babelfy) is .87, higher than Semafor's (.76), as expected since the coverage of Framester is much wider. On the other hand, the precision of Semafor is very high (.96), but it cannot be compared to Framester on this corpus, since Framester can give multiple frames for a same word, and also annotates the words that are not annotated in the FrameNet corpus: all these annotations would be calculated as false positives, just because the gold standard did not address them. In order to investigate if the precision of Framester is comparable to Semafor, and if Semafor performs well also on an independent corpus, we have performed the experiment in Sect. 3.2.

	Recall	Precision	$F_1 - Measure$
Semafor	0.76	0.96	0.85

Table 2: Results for the baseline (Semafor) on FrameNet 1.5.

3.2 Experiment 2: Independent Unannotated Corpus

In the second experiment, we wanted to assess the portability of Semafor results out of the training corpus, as well as the accuracy of Framester profiles. We used an independent corpus collected for machine reading evaluation purposes [10]. Frame annotations have been collected by merging the results of all the compared frame detection methods, then asking two experts to judge the correctness of the detected frames, as well as any missing detection, and asking a third expert to take decisions when the two raters had different opinions. The raters were asked to judge the frames detected on a scale including Valid, Metaphorical[2], or Invalid.

The inter-rater agreement before the third judgement has been measured by using weighted Cohen's K (WKAPPA) in order to adjust for the different weight of disagreement between absolute differences (valid vs. invalid evocation), and nuanced differences (valid/invalid vs. metaphorical evocation), and its value is 0.532, which is acceptable considering that frame annotation rating is difficult, and semantic annotations in general are accompanied by typically low inter-rater agreement.

The results are in Table 3, and show the performance of Framester profiles as well as Semafor. As expected, and noticed in Experiment 1, the recall grows significantly with extended profiles, but it's in general lower than with the FrameNet annotated corpus, except for the Profile-T. There is anyway a confirmation that Framester and the detour by WSD approach seems more appropriate for optimizing recall in frame detection. The doubt on the ability of Semafor to be very precise also on an independent corpus is confirmed: Semafor is still precise, but only at .79 against .96 on the corpus used for training. In addition, the best precision for Framester (Profile-B) is close to Semafor's, and both Profile-D and Profile-T outperform Semafor on F1-measure.

Framester Profiles	TP	FP	Precision	Recall	F1
Base (B)	435	126	0.776	0.366	0.571
Direct (D)	825	346	0.705	0.622	0.663
Transitive (T)	1204	664	0.644	**0.781**	**0.713**
FrameNet (F)	452	151	0.750	0.377	0.564
Semafor	365	95	**0.794**	0.334	0.564

Table 3: Results for our resource based on different extensions on the data set from Newspaper. Values in **bold** represent the best results.

4 Conclusion

Framester is a novel linguistic linked data resource. It is based on frame semantics, and provides a whole new set of formally represented and linked lexical resources. Because of its adherence to frame semantics, FrameNet is the entry point for Framester, but it needs a well-built mapping to WordNet, which is at the core of existing lexical resources. Unfortunately, the quality of FrameNet-WordNet mappings is not high and is largely incomplete.

In this work, we have described a new mapping between FrameNet and WordNet, and shown that this mapping is so good that a simple detour-based

[2] Many frames are not really wrong, but they are evoked as metaphorical or metonymical interpretations, e.g. the frame *Travelling* in a sentence like *Our love traveled distances.*

frame detector performs comparably to the state-of-the-art machine-learning-based frame detector.

Ongoing work is about extending the experiments, and making use of the many linked datasets composing Framester with inferences provided by the full frame semantics of Framester's. Abstractive text summarisation, machine understanding and text similarity are some of the tasks that are being attempted.

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