First steps towards a Predicate Matrix

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Abstract

This paper presents the first steps towards building the Predicate Matrix, a new lexical resource resulting from the integration of multiple sources of predicate information including FrameNet (Baker et al., 1997), VerbNet (Kipper, 2005), PropBank (Palmer et al., 2005) and WordNet (Fellbaum, 1998). By using the Predicate Matrix, we expect to provide a more robust interoperable lexicon by discovering and solving inherent inconsistencies among the resources. Moreover, we plan to extend the coverage of current predicate resources (by including from WordNet morphologically related nominal and verbal concepts), to enrich WordNet with predicate information, and possibly to extend predicate information to languages other than English (by exploiting the local wordnets aligned to the English WordNet).

1 Introduction

Predicate models such as FrameNet (Baker et al., 1997), VerbNet (Kipper, 2005) or PropBank (Palmer et al., 2005) are core resources in most advanced NLP tasks, such as Question Answering, Textual Entailment or Information Extraction. Most of the systems with Natural Language Understanding capabilities require a large and precise amount of semantic knowledge at the predicate-argument level. This type of knowledge allows to identify the underlying typical participants of a particular event independently of its realization in the text. Thus, using these models, different linguistic phenomena expressing the same event, such as active/passive transformations, verb alternations, nominalizations, implicit realizations can be harmonized into a common semantic representation. In fact, lately, several systems have been developed for shallow semantic parsing an explicit and implicit semantic role labeling using these resources (Erk and Pado, 2004), (Shi and Mihalcea, 2005), (Giuglea and Moschitti, 2006), (Laparra and Rigau, 2013).

However, building large and rich enough predicate models for broad-coverage semantic processing takes a great deal of expensive manual effort involving large research groups during long periods of development. In fact, the coverage of currently available predicate-argument resources is still far from complete. For example, (Burchardt et al., 2005) or (Shen and Lapata, 2007) indicate the limited coverage of FrameNet as one of the main problems of this resource. In fact, FrameNet1.5 covers around 10,000 lexical-units while for instance, WordNet3.0 contains more than 150,000 words. Furthermore, the same effort should be invested for each different language (Subirats and Petruck, 2003). Moreover, most previous research efforts on the integration of resources targeted at knowledge about nouns and named entities rather than predicate knowledge. Well known examples are YAGO (Suchanek et al., 2007), Freebase (Bollacker et al., 2008), DBPedia (Bizer et al., 2009), BabelNet (Navigli and Ponzetto, 2010) or UBY (Gurevych et al., 2012).

Following the line of previous works (Shi and Mihalcea, 2005), (Burchardt et al., 2005), (Johansson and Nugues, 2007), (Pennacchiotti et al., 2008), (Cao et al., 2008), (Tonelli and Pianta, 2009), (Laparra et al., 2010), we will also focus on the integration of predicate information. We start from the basis of SemLink (Palmer, 2009). SemLink aimed to connect together different predicate resources such as FrameNet (Baker et al., 1997), VerbNet (Kipper, 2005), PropBank (Palmer et al., 2005) and WordNet (Fellbaum, 1998). However, its coverage is still far from complete.

The Predicate Matrix, the resource resulting from the work presented in this paper, will allow to extend the coverage of current predicate resources (by including from WordNet closely related nominal and verbal concepts), to discover in-
herent inconsistencies among the resources, to enrich WordNet with predicate information, and possibly to extend predicate information to languages other than English (by exploiting the local wordnets aligned to the English WordNet). Moreover, the Predicate Matrix uses WordNet as a central resource. In that way, each row (or line) in the matrix presents partial predicate information related to a particular WordNet word sense.

First, as SemLink takes VerbNet as the central resource, we present a complete study of the coverage of the mappings between each resource included in SemLink to VerbNet. We describe the coverage and gaps of these mappings with respect to the lexical entries and the role structures of each resource. Second, we exploit WordNet to propose straightforward methods to discover inconsistencies among the resources as well as to extend their coverage towards a more complete and robust predicate lexicon.

2 Sources of Predicate information

As a starting point for building the Predicate Matrix, we consider the sources of predicate knowledge connected to SemLink.

SemLink\(^1\) (Palmer, 2009) is a project whose aim is to link together different predicate resources establishing a set of mappings. These mappings make it possible to combine the different information provided by the different lexical resources for tasks such as inferencing, consistency checking, interoperable semantic role labelling, etc. Currently, SemLink provides partial mappings to VerbNet (Kipper, 2005), PropBank (Palmer et al., 2005), FrameNet (Baker et al., 1997) and WordNet (Fellbaum, 1998).

FrameNet\(^2\) (Baker et al., 1997) is a very rich semantic resource that contains descriptions and corpus annotations of English words following the paradigm of Frame Semantics (Fillmore, 1976). In frame semantics, a Frame corresponds to a scenario that involves the interaction of a set of typical participants, playing a particular role in the scenario. FrameNet groups words or lexical-units (LUs hereinafter) into coherent semantic classes or frames, and each frame is further characterized by a list of participants or frame-elements (FEs hereinafter). Different senses for a word are represented in FrameNet by assigning different frames.

PropBank\(^3\) (Palmer et al., 2005) aims to provide a wide corpus annotated with information about semantic propositions, including relations between the predicates and their arguments. PropBank also contains a description of the frame structures, called framesets, of each sense of every verb that belong to its lexicon. Unlike other similar resources, as FrameNet, PropBank defines the arguments, or roles, of each verb individually. In consequence, it becomes a hard task obtaining a generalization of the frame structures over the verbs.

VerbNet\(^4\) (Kipper, 2005) is a hierarchical domain-independent broad-coverage verb lexicon for English. VerbNet is organized into verb classes extending (Levin, 1993) classes through refinement and addition of subclasses to achieve syntactic and semantic coherence among members of a class. Each verb class in VerbNet is completely described by thematic-roles, selectional restrictions on the arguments, and frames consisting of a syntactic description and semantic predicates.

WordNet\(^5\) (Fellbaum, 1998) is by far the most widely-used knowledge base. In fact, WordNet is being used world-wide for anchoring different types of semantic knowledge including wordnets for languages other than English (Gonzalez-Agirre et al., 2012a). It contains manually coded information about English nouns, verbs, adjectives and adverbs and is organized around the notion of a synset. A synset is a set of words with the same part-of-speech that can be interchanged in a certain context. For example, \(<\text{learn}, \text{study}, \text{read}, \text{take}>\) form a synset because they can be used to refer to the same concept. A synset is often further described by a gloss, in this case: \"be a student of a certain subject\" and by explicit semantic relations to other synsets. Each synset represents a concept that are related with an large number of semantic relations, including hypernymy/hyponymy, meronymy/holonymy, antonymy, entailment, etc.

Obviously, we can also exploit the existing SemLink mappings to aid semi-automatic or fully automatic extensions of the current mapping coverage, in order to increase the overall overlapping.

\(^1\)http://verbs.colorado.edu/~mpalmer/projects/ace.html
\(^2\)http://framenet.icsi.berkeley.edu/
\(^3\)http://verbs.colorado.edu/˜mpalmer/ projects/verbnet.html
\(^4\)http://verbs.colorado.edu/˜mpalmer/ projects/ace.html
\(^5\)http://wordnet.princeton.edu/
3 SemLink coverage

As SemLink uses VerbNet as the central resource, we present a complete study of the coverage of the mappings between each resource included in SemLink to VerbNet.

3.1 WordNet and VerbNet alignment

Although VerbNet is one of largest verb lexicons available it does not reach the coverage of the verbal part of WordNet. While WordNet contains 25,047 different verb senses there are just 6,293 predicates in VerbNet classes. This means that the mapping between both resources is, obviously, incomplete. Specifically there are 18,559 senses of WordNet, corresponding to 9,995 different lemmas, that have not been assigned to any VerbNet predicate. Many of these cases appear because of the distinct granularities of both resources. In fact 6,120 WordNet senses (corresponding to 2,099 lemmas) that are not mapped to VerbNet belong to lemmas that have at least another WordNet sense properly mapped to VerbNet. For instance, Table 1 shows the mapping between the verb drown in WordNet and VerbNet. Note that only two of the five WordNet senses are assigned to VerbNet.

| WordNet sense | VerbNet member class |
|---------------|---------------------|
| drown%2:30:00:: | drown 40.7 |
| drown%2:31:00:: | drown 42.2, drown 40.7 |
| drown%2:35:00:: | - |
| drown%2:42:00:: | - |

Table 1: WordNet to VerbNet alignment for drown,

The rest of missing senses correspond to those cases where the lemma does not exist in the VerbNet lexicon (7,320 lemmas and 11,201 senses). For example the verb abort does not appear in VerbNet since its three WordNet senses are not part of SemLink. The remaining cases (1,443 WordNet senses and 576 lemmas) correspond to lemmas that exist in both resources but there is no sense mapping between them. For instance, there is no mapping between the WordNet sense harm%2:29:00:: and the VerbNet verb that belongs to the class 31-1.

Moreover, SemLink does not provide mappings to WordNet senses for 1,077 VerbNet predicates. 304 of these VerbNet predicates share the same lemma with some other VerbNet sense that is already mapped to a WordNet sense. This is the case of reveal as shown in Table 2.

| VerbNet member class | WordNet sense |
|----------------------|---------------|
| reveal 29.2-32:00    | reveal%2:32:00 |
| reveal 37.7-32:00    | reveal%2:32:00 |
| reveal 37.10-32:00   | reveal%2:32:00 |
| reveal 48.1-32:00    | - |
| reveal 78-32:00      | - |

Table 2: VerbNet to WordNet alignment for reveal,

From the rest of missing members, 574 correspond to those cases the lemma of the predicate also exists in WordNet (like the example of harm explained previously). Finally, there are only 199 verb senses in VerbNet whose lemmas do not exist in WordNet. For example: africanize, backfill, or carbonify.

3.2 PropBank and VerbNet alignment

The mapping between PropBank and VerbNet introduces additional complexity to the comparison of both resources. In this case, aligning the lexicon means that the arguments of the PropBank predicates must be aligned to the VerbNet thematic-roles.

First, regarding the lexicon mapping, once again, the differences in the coverages of the resources impede to obtain a complete alignment. From the 6,181 different PropBank predicates (comprising 4,552 lemmas), just 3,558 have their corresponding VerbNet predicate in SemLink. That is, 2,623 PropBank predicates have no correspondances to VerbNet. However, all the lemmas of PropBank are contained within the VerbNet lexicon. This means that for each one of the 2,623 missing predicates from PropBank there exists at least another predicate with the same lemma that is mapped to VerbNet. That is the case of the PropBank predicate abandon.02, shown in Table 3.

| PropBank predicate | VerbNet member class |
|--------------------|----------------------|
| accept.01          | accept 13.5-2         |
| accept.1-1         | accept 29.2-1-1       |
| accept.02          | accept 77             |
| abandon.01         | abandon 51.2          |
| abandon.02         | -                     |

Table 3: PropBank to VerbNet alignments for accept and abandon

On the other hand, we found that the num-
ber of VerbNet predicates that are not aligned to PropBank is smaller than the number of PropBank predicates not aligned to VerbNet. That is, up to 4,736 of the 6,293 VerbNet predicates are aligned to PropBank while only 1,557 VerbNet predicates are not aligned to PropBank. Moreover, 298 of these VerbNet predicates do not exist in the PropBank lexicon, for instance arrogate\textsubscript{v}, deconstruct\textsubscript{v}, mewl\textsubscript{v} or sprint\textsubscript{v}. Finally, there are 312 VerbNet predicates whose lemmas (265 in total) are actually part of the PropBank lexicon but there is no alignment for them. For example, the predicate \textit{offload\textsubscript{v}} of the VerbNet class wipe\textsubscript{manner-10.4.1} is not connected to the PropBank predicate \textit{offload.01}. Table 4 shows some alignments from VerbNet to PropBank.

| VerbNet predicate | PropBank predicate |
|-------------------|-------------------|
| laugh.01          | laugh.01          |
| flow.01           | flow.01           |

Table 4: VerbNet to PropBank alignments for \textit{laugh\textsubscript{v}} and \textit{flow\textsubscript{v}}.

Regarding the PropBank arguments and the VerbNet thematic-roles, 7,915 out of 15,871 arguments from PropBank\textsuperscript{6} are mapped to a thematic-role from VerbNet\textsuperscript{7}. That is, around a half of the total PropBank arguments, leaving out the remaining 7,956 arguments. From the opposite point of view, 9,682 out of 17,382 thematic-roles from VerbNet are included in the SemLink mapping. This means that 7,700 thematic-roles are not aligned to any PropBank argument. Table 5 contains some examples of existing and also missing mappings between PropBank arguments and VerbNet thematic-roles.

### 3.3 FrameNet and VerbNet alignment

The alignment between FrameNet and VerbNet proves to be very incomplete. For example, only 1,730 lexical-units from FrameNet\textsuperscript{8} are aligned to, at least, one VerbNet predicate\textsuperscript{9}. This number represents only 16% out of the total 10,195 lexical-units of FrameNet. Table 6 presents some alignments between VerbNet predicates and FrameNet lexical-units.

| VerbNet predicate | FrameNet lexical-unit |
|-------------------|-----------------------|
| 13.1-1 sell       | Commerce\_sell        |
| 13.5.1 buy        | Commerce\_buy         |
| 53.1-1 delay      | Hindering\_delay      |
| 13.5.3 employ     | Employing             |
| 105 employ        | Using                 |

Table 6: Some alignments between VerbNet predicates and FrameNet lexical-units (LUs).

SemLink also includes the alignment between the roles of both resources. However, unlike PropBank the roles of FrameNet, that are called frame-elements, are defined at frame-level and not at predicate level. Therefore, the mapping of the VerbNet thematic-roles and the frame-elements of FrameNet is defined between VerbNet classes and FrameNet frames. Table 7 presents an example of the alignment of some roles from both resources for the VerbNet class 54.1. A VerbNet predicate member of this class has been aligned to the WordNet sense total\%2:42:00.

| VerbNet thematic-role | FrameNet frame-element |
|-----------------------|------------------------|
| Agent                 | Adding\_up Cognizer    |
| Theme                 | Adding\_up Numbers     |
| Value                 | Adding\_up Result      |

Table 7: Some alignments between VerbNet thematic-roles and FrameNet frame-elements (FEs).

Once again, the mapping between VerbNet and FrameNet presents significant gaps and miss-

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\textsuperscript{6}Arguments of particular PropBank predicates. For instance, Arg0 of \textit{paint.01}.

\textsuperscript{7}Thematic-roles of particular VerbNet predicates. For instance, Agent of \textit{paint\textsubscript{v}}.

\textsuperscript{8}Lexical-units of particular FrameNet frames. For instance, \textit{sell\textsubscript{v}} from the frame \textit{Commerce\_sell}.

\textsuperscript{9}Predicate of a particular VerbNet class. For instance, \textit{sell\textsubscript{v}} from 13.1-1 VerbNet class.
matches. For instance, just 825 of the 7,124 frame-elements of FrameNet\textsuperscript{10} are linked to a VerbNet thematic-role. That is, 88% of the frame-elements from FrameNet are not aligned to any VerbNet thematic-role. Moreover, only 262 frames out of 795 have at least one frame-element aligned to a VerbNet thematic-role. That is, just a few frames are used in the mapping. However, it also seems that, at a class level, most of the VerbNet thematic-roles appear to be aligned to at least one frame-element. VerbNet covers 787 different thematic-roles\textsuperscript{11}. From these, 541 appear to be aligned to a FrameNet frame-element. In other words, it seems that just 246 thematic-roles are missing from the mapping provided by SemLink. Table 8 presents some class level alignments between VerbNet thematic-roles and FrameNet frame-elements (FEs).

| VerbNet class | VerbNet thematic-role | FrameNet frame | FrameNet frame-element |
|---------------|----------------------|----------------|------------------------|
| 10.10         | Agent                | -              | -                      |
| 10.10         | Attribute            | -              | -                      |
| 10.10         | Source               | -              | -                      |
| 48.3          | Theme                | Catastrophe    | Undesirable_Event      |
|               |                      | Catastrophe    | Place                  |
|               |                      | Catastrophe    | Time                   |
|               |                      | Catastrophe    | Cause                  |
|               |                      | Catastrophe    | Circumstances          |
|               |                      | Catastrophe    | Degree                 |
|               |                      | Catastrophe    | Manner                 |
|               |                      | Catastrophe    | Undergoer              |
|               |                      | Addiction      | Addict                 |
|               |                      | Addiction      | Addictant              |
|               |                      | Addiction      | Compeller              |
|               |                      | Addiction      | Degree                 |
|               |                      | Addiction      | State                  |

Table 8: Some alignments between VerbNet thematic-roles and FrameNet frame-elements (FEs)

4 Using WordNet to cross-check predicate information

In this section, as a proof-of-concept, we will show a simple way to exploit WordNet for validating the predicate information appearing in SemLink. We apply a very simple method to check the consistency of VerbNet. Consider the following WordNet synset<understand, read, interpret, translate> with the gloss “make sense of a language” and the example sentences “She understands French; Can you read Greek?”. As synonyms, these verbs denote the same concept and are interchangeable in many contexts. However, in SemLink read\%2:31:04 appears aligned with the VerbNet class learn-14-1\textsuperscript{12} while one of its synonyms understand\%2:31:03 appears aligned to the VerbNet class comprehend-87.2\textsuperscript{13}. Moreover, the thematic-roles of both classes are different. Learn-14-1 has the following thematic-roles Agent (with semantic type [+animate]), Topic and Source while comprehend-87.2 has Experiencer (with semantic type [+animate or +organization]), Attribute and Stimulus. Are both sets of thematic-roles compatible? Complementary? Is one of them incorrect? Should we joint them? Maybe is the alignment incorrect? Is perhaps the synset definition?

Following with this example, the VerbNet predicate understand\textsuperscript{14} has no connection to FrameNet, but its VerbNet class comprehend-87.2-1 has some other verbal predicates aligned to FrameNet. For instance, apprehend\textsubscript{i}, comprehend\textsubscript{d}, and grasp\textsubscript{e} are linked to the Grasp\textsuperscript{14} FrameNet frame. Among the lexical-units corresponding to the Grasp frame it appears also the verbal predicate understand\textsubscript{d}. This means that possibly, this verbal predicate should also be aligned to the FrameNet frame Grasp. The core frame-elements (roles) of this frame are Cognizer (with semantic type Sentient), Faculty and Phenomenon. Is this set of roles compatible with the previous ones?

5 Using WordNet to extend SemLink

As we have seen in Section 3, the mapping between the different sources of predicate information is far from being complete. However, the existing alignments also offer a very interesting source of information to be systematically exploited. In fact, we are devising a number of simple automatic methods to extend SemLink by exploiting simple properties from WordNet. As a proof-of-concept, we present in this section two very simple approaches to extend the coverage of the mapping between VerbNet predicates and

\textsuperscript{10}Frame-elements of a particular FrameNet frame. For instance, the frame-element Cognizer for the Adding\_up frame
\textsuperscript{11}Role of a particular VerbNet class. For instance, Agent of VerbNet class 10.10
\textsuperscript{12}http://verbs.colorado.edu/verb-index/vn/learn-14.php#learn-14-1
\textsuperscript{13}http://verbs.colorado.edu/verb-index/vn/comprehend-87.2.php#comprehend-87.2-1
\textsuperscript{14}https://framenet2.icsi.berkeley.edu/fnReports/data/frame/Grasp.xml
WordNet senses. Moreover, we also plan to use additional semantic resources that use WordNet as a backbone. For instance, exploiting those knowledge resources integrated into the Multilingual Central Repository\(^ {15}\) (MCR) (Atserias et al., 2004; Gonzalez-Agirre et al., 2012a) to extend automatically the alignment of the different sources of predicate information (VerbNet, PropBank, FrameNet and WordNet). Following the line of previous works, in order to assign more WordNet verb senses to VerbNet predicates, we also plan to apply more sophisticated word-sense disambiguation algorithms to semantically coherent groups of predicates (Laparra et al., 2010).

5.1 VerbNet Monosemous predicates

Monosemous verbs from WordNet can be directly assigned to VerbNet predicates still without a WordNet alignment. This very simple strategy solves 240 alignments. In this way, VerbNet predicates such as *divulge*\(_v\), *exhume*\(_v\), *mutate*\(_v\), or *upload*\(_v\) obtain a corresponding WordNet word sense\(^ {16}\). Remember that only 576 lemmas from VerbNet were not aligned to WordNet.

5.2 WordNet synonyms

A very straightforward method to extend the mapping between WordNet and VerbNet consists on including synonyms of already aligned WordNet senses as new members of the corresponding VerbNet class. Obviously, this method expects that WordNet synonyms share the same predicate information. For instance, the predicate *desert*\(_v\), member of the VerbNet class *leave*-51.2-1 appears to be assigned to desert%2:31:00 WordNet verbal sense. In WordNet, this word sense also has three synonyms, *abandon*\(_v\), *forsake*\(_v\), and *desolate*\(_v\). Obviously, these three verbal senses can also be assigned to the same VerbNet class. This simple approach can create up to 5,075 new members of VerbNet classes (corresponding to 4,616 different WordNet word senses). For instance, Table 9 presents two productive examples. Moreover, applying this method 103 VerbNet predicates without mapping to WordNet in SemLink are aligned to a WordNet word sense.

| VerbNet   | WordNet          | New                          |
|-----------|------------------|------------------------------|
| leave-51.2.1 | desert%2:31:00   | abandon%2:31:00::forsake%2:31:00::desolate%2:31:00::|
| remove-10.1  | retract%2:32:00  | abjure%2:32:00::recant%2:32:00::forswear%2:32:00::resile%2:32:00::|

Table 9: New WordNet senses aligned to VerbNet

6 A first version of the Predicate Matrix

We already produced a preliminary version of the Predicate Matrix\(^ {17}\). The original SemLink in a Predicate Matrix form resulted in 36,174 rows (corresponding to 6,556 WordNet word senses). By applying the synonyms method described in the previous section the Predicate Matrix extended to 69,508 rows (10,984 WordNet word senses). Finally, by applying the monosemous method, the Predicate Matrix further extended to 70,391 rows (11,146 WordNet word senses).

Table 10 presents a full example of the information that is currently available in the Predicate Matrix including the new mappings obtained by the methods described in the previous section. Each row of this Table represents the mapping of a role over the different resources and includes all the aligned knowledge about its corresponding verb. The Table presents the cases obtained originally from SemLink, denoted as SEMLINK, and the cases inferred following the methods explained previously, identified as SYNONYMS or MONOSEMIC depending on the case. The Table also includes the following fields: the lemma and the class in VerbNet, the sense of the verb in WordNet, the thematic-role in VerbNet, the Frame of FrameNet, the corresponding lexical-entry and frame-element of FrameNet, the predicate in PropBank and its argument, the offset of the sense in WordNet and the knowledge associated with that sense in the MCR, such as the Adimen-SUMO (Álvarez et al., 2012) and the new WordNet domain aligned to WordNet 3.0 (González-Agirre et al., 2012b) features as well as the Base Level Concept (Izquierdo et al., 2007) of the sense. Finally, each line also includes the frequency and the number of relations of the WordNet word sense.

\(^{15}\)http://adimen.si.ehu.es/MCR

\(^{16}\)Obviously, these alignments can be considered just as suggestions to be revised later on manually.

\(^{17}\)http://adimen.si.ehu.es/web/PredicateMatrix
7 Conclusions and future work

We are now producing and studying initial versions of the Predicate Matrix by exploiting SemLink and applying very simple methods to extend and validate its content. By developing more advanced versions of the Predicate Matrix, we expect to provide a more robust and interoperable predicate lexicon. We plan to discover and solve inherent inconsistencies among the integrated resources. Moreover, we plan to extend the coverage of current predicate resources (by including from WordNet morphologically related nominal and verbal concepts, by exploiting also FrameNet information, etc.), to enrich WordNet with predicate information, and possibly to extend predicate information to languages other than English (by exploiting the local wordnets aligned to the English WordNet) and predicate information from other languages. For instance, the Ancora Spanish corpus and lexicon (Taulé et al., 2008).

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