Gathering Lexical Linked Data and Knowledge Patterns from FrameNet

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ABSTRACT
FrameNet is an important lexical knowledge base featuring cognitive plausibility, and grounded in a large corpus. Besides being actively used by the NLP community, frames are a great source of knowledge patterns once converted into a knowledge representation language. In this paper we present our experience in converting the 1.5 XML version of FrameNet into RDF datasets published on the Linked Open Data cloud, which are interoperable with WordNet and other resources. In the conversion we have used Semion, a new tool that allows a rule-based, customized pipeline from XML to RDF and OWL data. In addition, we introduce a method to select and refactor part of the information related to frames as full-fledged OWL knowledge patterns. This last result has required non-trivial assumptions on how to interpret FrameNet relations as formal knowledge.

Categories and Subject Descriptors
I.2.4 [Knowledge Representation Formalisms and Methods]: Representations (procedural and rule-based), Frames and scripts; I.2.6 [Learning]: Knowledge acquisition

General Terms
Design, Experimentation, Theory

Keywords
Knowledge Extraction, FrameNet, OWL, Semantic Web, Knowledge Engineering

1. INTRODUCTION
The Web is evolving from a global information space of linked documents to one where both documents and data are linked. Underpinning this evolution is a set of best practices for publishing and connecting structured data on the Web known as Linked Data [3]. The Linked Open Data (LOD) project is bootstrapping the Web of Data by converting into RDF and publishing existing datasets available under open licenses. LOD is an ideal platform for empirical knowledge engineering research, since it has the critical amount of data for empirical research, data that are not necessarily clean, optimized, or extensively structured. In practice, it’s a perfect use case for making patterns emerge which can be studied by knowledge engineering and used for the design, maintenance, and consumption of data. In addition, LOD datasets often contain a lot of natural language text, which is also important in order to make advanced linking and exploration of data not only in the broad LOD cloud vision, but also in localized applications within large organizations that make use of linked data [2].

Hybridizing natural language processing and semantic web techniques has therefore become an important research area. Part of the hybridization research, as well as part of the exploitation of LOD data, is carried out by means of lexical resources that are represented directly as linked data. The major example is the WordNet RDF dataset [21], which provides concepts (called synsets), each representing the sense of a set of synonymous words [10]. WordNet RDF has a low level of concept linking, because synsets are linked mostly by means of taxonomic (hyponymy) relations, while LOD is mostly linked by means of domain relations, such as parts of things, ways of participating in events or socially interacting, topics of documents, temporal and spatial references, etc. Some lexical resources focus instead on domain relations as expressed in the lexicon of natural languages. This paper addresses hybridization research by porting the largest lexical resource for domain relations, FrameNet [1], to the LOD cloud.

FrameNet was previously available only as a lexical database, or as purely semantic web resources [8,20], derived from the lexical one: previous conversions to RDF are discussed in Sect. 5. After the release of version 1.5,
the Berkeley FrameNet group asked us to produce a new version of FrameNet in RDF that can be optimized for use in the growing lexical part of the LOD cloud.

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FrameNet is based on the notions of Semantic Frame, Lexical Unit (LU), and Frame Element (FE): for example, the **Apply heat** frame refers to situations involving a **Cook** using a **Heating instrument** on some **Food** within some **Container**, etc. These types of involved entities are called FEs, and situations are expressed by words (lexemes) that manifest a LU, e.g. **fry, cook, roast**, etc. All those LUs are lexical counterparts of the semantic frame.

Intuitively, this is a more pragmatic and effective representation of lexical meaning, because frames focus on actual usage of language in real world situations, rather than on decontextualized terms as in traditional dictionaries (detailed analyses of the cognitive plausibility of frames as meaning units, besides [1] itself, are [9,12]). FrameNet was previously available only as a lexical database, or as unlinked OWL resources [8,20], derived from former versions of the lexical database: such conversions are discussed in Sect. 5. After the release of version 1.5, the Berkeley FrameNet group asked us to produce a new version of FrameNet in RDF that can be optimized for use in the growing lexical part of the LOD cloud.

Among lexical resources, FrameNet has been successfully employed in NLP applications that demonstrate its potential to improve the quality of question answering [23] or recognizing textual entailment [6]. Frames as a cognitive, linguistic, or knowledge representation primitive have been studied many times in the last century (see [9] for an overview). For example [13] introduced frames into AI as a hub to factual and procedural knowledge: systems of interconnected frames would provide the shifting perspectives or time-dependent change in a situation. The intended meaning of a frame across the different theories can be summarized as from [12]:

**a (small-sized and richly interconnected) structure, used to organize our knowledge, as well as to interpret, process or anticipate information.** In ontology design, frames are called knowledge patterns [7,12], as a special kind of design patterns. Following the approach outlined in [12], we study frames as “units of meaning” for LOD and semantic web ontologies.

The contribution of this paper is twofold: (i) the production and publishing of a LOD dataset for the FrameNet lexical database, and (ii) the description of a method to produce knowledge patterns out of FrameNet frames. For both contributions we use Semion [15]:

- a tool for “triplifying” non-RDF data into RDF models, and
- for refactoring RDF into other RDF or OWL customized models. The transformation process includes two main steps: (i) a syntactic triplification of the original source and (ii) a rule-based refactoring for adding semantics to triples.

FrameNet as a LOD dataset provides new blood to the lexical grounding of semantic knowledge [12], and boosts the “lexical linked data” section of LOD, by linking FrameNet to other LOD datasets such as WordNet RDF (section 3.1).

As a further contribution, we introduce a rule-based method to select and refactor part of FrameNet as full-fledged OWL knowledge patterns to be used for ontology design and advanced exploration of LOD. We discuss some non-trivial assumptions on how to interpret FrameNet relations as formal knowledge (section 4).

The structure of the paper is the following. In section 2 we summarize the conceptual design of FrameNet. In section 1 we present the production of FrameNet as a LOD dataset. Section 4 describes experiences in refactoring frames as knowledge patterns. Final sections contain related work and conclusions.

## 2. FRAMENET

FrameNet [1] is a lexical knowledge base, consisting of a set of frames, which have proper frame elements and lexical units, which pair words (lexemes) to frames. As described in the FrameNet Book [19]:

- a lexical unit (LU) is a pairing of a word with a meaning. Typically, each sense of a polysemous word belongs to a different semantic frame, a script-like conceptual structure that describes a particular type of situation, object, or event along with its participants and properties. For example, the **Apply Heat** frame describes a common situation involving a **Cook**, some **Food**, and a **Heating Instrument**, and is evoked by words such as *bake, blanch, boil, broil, brown, simmer, steam*, etc.

We call these roles frame elements (FEs) and the frame-evoking words are LUs in the Apply heat frame.

FrameNet has a rich internal structure and makes some cognitive and semantic assumptions that makes it unique as a lexical resource. Some of them are discussed in Sect. 4 in view of logical formalization. The basic assumptions are reported here: frame elements are mostly unique to their frame; a frame usually has only some of its roles actually lexicalized in texts; frames can be lexicalized or not: non-lexicalized ones typically encode schemata from cognitive linguistics; frames, as well as frame elements, are related between them, e.g. through the subframe compositional relation, through inheritance relations, etc.

The semantic part of FrameNet is enriched by semantic types assigned to frames (e.g. Artifact), frame elements (e.g. Sentient), and lexical units (e.g. Biframal_LU).
FrameNet also contains a huge amount of manual annotations (annotation sets) of sentences from textual corpora with frames, frame elements and lexical units, which make word valences (syntactic and semantic combinatory of words) emerge.

3. BRINGING FRAMENET TO LOD

FrameNet stores lexical data into an XML database. We pulled out the semantics of FrameNet and its data by using Semion [15], a tool grounded on a method with two main steps: (i) a syntactic and completely automatic transformation of the data source to RDF datasets according to an OWL ontology that represents the data source structure, i.e. the source meta-model, (ii) a semantic refactoring that allows to express the RDF triples according to specific domain ontologies e.g. SKOS, DOLCE, FOAF, the Gene Ontology, or anything indicated by the user. This last action results in a RDF dataset, which expresses the knowledge stored in the original data source, according to a set of assumptions on the domain semantics, as selected and customized by the user. The refactoring step is the result of a non-trivial knowledge engineering work that requires a good knowledge of the target domain semantics. For that reason the refactoring is semi-automatic as it requires the design of transformation rules by the user. More exhaustively, the refactoring is performed by means of transformation rules of the form “condition → consequent” whose aim is to apply a transformation (specified in the consequent) in the RDF graph only if the condition is satisfied with respect to the knowledge expressed in the source RDF graph. A set of rules which co-occur for the finalization of a transformation process is called a transformation recipe.

Figure 1 exemplifies the approach followed in this work for the production of both the LOD dataset and a set of knowledge patterns from the FrameNet lexical database. That approach grounds completely on the transformation method that the Semion tool implements. The leftmost part of the figure depicts the logical layers of the original source, i.e. FrameNet, which contains XML data, whose structure is defined by some XSD, which has its own standard meta-model [25]. The second leftmost part contains the result of step i): syntactic transformation of FrameNet to pure RDF triples, whose aim is twofold: (a) extracting data into RDF and (b) flattening the distinction between the original schema and data in order to provide, via the refactoring, a customized, task-oriented way to address domain semantics. Those RDF triples are refactored according to transformation recipes, either as a LOD dataset (ABox Refactoring, second rightmost column in the figure) or as Knowledge Patterns (TBox Refactoring, rightmost column).

3.1 FrameNet linked data

The approach followed for the creation of a LOD dataset from FrameNet\(^1\) is both derived from the transformation method implemented by Semion [15] and based on an iterative evaluation of the quality of the output produced with respect to the semantics of FrameNet formalized into a “gold standard” ontology\(^2\) that we have used for the evaluation. Based on that, the transformation of FrameNet v.1.5 from XML to RDF consisted into two steps: (i) the syntactic transformation of the XML source to RDF according to the OWL meta-model that describes the structure of the source\(^3\), (ii) the design and the application of a refactoring recipe for the ABox refactoring on the RDF produced in the first step. The recipe was derived generalizing and revising some of the common transformation practices from existing tools (i.e. XML2OWL [4], TopBraid Composer\(^4\), Rhizomik ReDeFeR [18]). For example we used the following mappings: (i) a xsd:ComplexType is mapped to an owl:Class, (ii) a xsd:SimpleType is mapped to an owl:DatatypeProperty and (iii) a xsd:Element is mapped either to an owl:ObjectProperty or to a owl:DatatypeProperty. Further details can be found in [4].

As an example, according to the syntax of the rules for the Semion refactoring, we have that the mapping (i) is expressed as

\[
is(\text{oxsd:ComplexType}, \text{?type})\rightarrow
\]

\[
is(\text{owl:Class}, \text{?classNode})
\]

and maps any individual of the class oxsd:ComplexType to a owl:Class. We refer to the Semion wiki\(^5\) for more information about the tool and the syntax of the rules. The relevance of a syntactic transformation and a following refactoring can be clarified saying that it is designed as a semi-automatic approach which allows, via

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\(^1\)The dataset can be accessed through the SPARQL endpoint at http://bit.ly/hsparql as framenet_dataset

\(^2\)http://ontologydesignpatterns.org/cp/owl/fn/framenet.owl

\(^3\)http://www.ontologydesignpatterns.org/ont/iks/oxml.owl

\(^4\)http://www.topbraidcomposer.com

\(^5\)http://stlab.istc.cnr.it/stlab/Semion
the refactoring rules, for better addressing the domain semantics of the original source. As an example, we can consider a simple frame-to-frame relation like \textit{Inherits from} (\texttt{Abounding with}, \texttt{Locative relation}) which expresses the fact that the frame \texttt{Abounding with} inherits the schematic representation of a situation involving various participants, properties, and other conceptual roles from the frame \texttt{Locative relation}. This relation is expressed in the XML FrameNet notation as:

\begin{verbatim}
<frame name="Abounding with" ... ID="262">
  ...
  <frameRelation type="Inherits from">
    <relatedFrame>
      Locative relation
    </relatedFrame>
  </frameRelation>
  ...
</frame>
\end{verbatim}

and, with most of the existing tools, it is transformed to the RDF schematized in Figure 2. It is easy to notice how the \textit{Inherits from} frame-to-frame relation is realized through the reification of the relation \texttt{RelatedFrame}, that expresses its type and the related frames, i.e. \textit{Inherits from} and \texttt{Locative relation}, as literals.

Instead, adopting the syntactic transformation of Semion, we have produced firstly an RDF graph, which is depicted in Figure 3\(^6\).

In the figure, \texttt{fnabox:Frame} is no longer an \texttt{owl:Class}, but an \texttt{oxsd:Element} and \texttt{fnabox:Abounding+with} is an \texttt{oxml:XMLElement} related to \texttt{fnabox:Frame} through \texttt{oxsd:hasElementDeclaration}.

After having was syntactically converted FrameNet from XML to RDF, we applied the general recipe with the Semion Refactorer, in order to derive a LOD dataset for FrameNet. As the recipe is based on a general conversion from XML to OWL, the result was far from being a good formalization of the semantics of FrameNet. For that reason, we have incrementally refined the recipe in order to fill the gap between the semantics expressed by the output produced by the refactoring and the gold standard we had previously defined. We remark that the aim of the refactoring is to transform one RDF source to another trying to preserve either explicit or implicit domain semantics of the original source without information loss.

For example, the rule which allows to avoid the reification of frame-to-frame relations is shown in Figure 4. The rule shown in Figure 4 transforms all the frame-to-frame relations into binary relations between frames. The rule extracts the type of the relation from the \texttt{nodeValue} associated with the \texttt{type} attribute of a frame. Then it creates a new object property as a subproperty of \texttt{hasFrameRelation}, and resolves the name of the related frame that is expressed as a literal in the \texttt{relatedFrame} element, as shown in the XML code before. We remark that the model accessed by rules is

\begin{verbatim}
... values(oxml:nodeValue, ?xmlAttr, ?value) .
  values(oxml:nodeName, ?xmlAttr, "type"^^xsd:string).
  hasComposite(child, ?xmlElem, ?child) .
  values(oxml:nodeValue, ?child, ?childValue) .
  let(?relationURI, concat(namespace(?frame), trim(?value))) .
  let(?frameURI, concat("Frame/", ?childValue)) .
  newNode(?frameRelation, ?frameURI) .
  newNode(?relatedFrame, ?frameURI) .
  ...

  is(owl:ObjectProperty, ?frameRelation) .
  has(rdfs:subPropertyOf, ?frameRelation) .
  has(hasFrameRelation, ?frame) .
  has(?frameRelation, ?frame, ?relatedFrame) .
\end{verbatim}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{frame-to-frame-rule.png}
\caption{Rule which allows to express frame-to-frame relation as binary relations.}
\end{figure}
not anymore the original XML source, but its syntactic
translation to RDF. Figure 5 shows the RDF of the
inherits from relation between the frames Abounding
with and Locative relation obtained by applying the
refactoring recipe with Semion. Figure 6 shows the core
fragment of the OWL schema of FrameNet used as a
vocabulary for the data from FrameNet.

Figure 5: The “Inherits from” frame-to-frame
relation between the frames “Abounding with”
and “Locative relation” after the refactoring.

Figure 6: A fragment of the FrameNet OWL
schema.

The complete refactoring recipe\(^7\) is composed by 58
transformation rules in forward-chaining inference mode.
An important feature of FrameNet as a dataset in the
LOD cloud, that will be investigated as part of our on-
going work, is the mapping of its frames and frame
elements to other lexical resources, e.g. WordNet. Word-
Net is available as a LOD dataset since 2006 as a result
of the W3C working draft \([21]\). Such mappings can
be obtained from VerbNet \([22]\), a lexical resource that
incorporates both semantic and syntactic information
about English verb semantics. The VerbNet 3.1 XML
database provides mappings between VerbNet classes,
FrameNet frames, and WordNet synsets.

For example, from the VerbNet mappings converted to
RDF:\(^8\)

\[
\text{vnclass:accompany skos:exactMatch}
\text{wndata:synset-accompany-verb-2}
\]

The VerbNet dataset excerpt is intended to demonstrate
linkings between lexical resources. An official release
will be published in the near future.

4. FROM FRAMES TO KNOWLEDGE PAT-
TERTNS

In addition to the production of FrameNet as a LOD
lexical dataset that can be accessed and queried over
the Web of Data, our aim is to provide an interpre-
tation of frames as Knowledge Patterns (KP), as they
are defined by \([7]\) and \([12]\). In other words, following
\([12]\), we promote frames to relevant units of meaning for
knowledge representation.

With reference to Figure 1, we have called this process
TBox refactoring, because a new ontology schema (a
TBox), is obtained starting from data (ABox).

The main problem with TBox refactoring is deciding the
formal semantics to assign to the classes from the Fra-
meNet LOD dataset schema. Since this is a relatively
arbitrary process, SemionRules and recipes are useful
to configure alternative choices or to compare the dif-
ferent assumptions made by knowledge engineers. Here
we present a refactoring experience that exemplifies the
design method behind such process, and how Semion is
useful in supporting it. The recipe exemplified here is
part of a larger project carried out together with Fra-
meNet developers in Berkeley in order to optimize the
refactoring from lexical frames to knowledge patterns:
as such, it certainly bears validity, but it is mainly inten-
ded as a methodological and pragmatical description of
refactoring recipes (also called correspondence patterns
in \([24]\)).

Besides the basic assumptions reported in section 2, this
process is guided by the Book \([19]\), which is quite expli-
cit about possible formal semantic choices:

\(^7\)http://stlab.istc.cnr.it/stlab/FrameNetKCAP2011#
tab=ABoxRefactoring

\(^8\)prefixes: skos: http://www.w3.org/2004/02/skos/core#; vn-
class: http://www.ontologydesignpatterns.org/ont/vn/class/
wndata: http://www.w3.org/2006/03/wn/wn20/instances/
frame: http://www.ontologydesignpatterns.org/ont/framenet/
frame/
classes that are arguments of the Frame classes. An annotation set for a sentence generally describes an instance of the subclass associated with an LU as well as instances of each of its associated FE classes (...) The term “Frame Element” has two meanings: the relation itself, and the filler of the relation. When we describe the Coreness status of an FE (...) we are describing the relation; when we describe the Ontological type on an FE (...) we mean the type of the filler.

According to these statements, a fragment of the Desiring frame is transformed into OWL as follows (in Manchester syntax):

Ontology: odpfn:desiring.owl
Annotations:
cpannoschema:specializes odp:situation.owl
Class: desiring:Desiring
  SubClassOf: desiring:hasEvent some desiring:Event,
             desiring:hasExperiencer some desiring:Experiencer,
             desiring:hasDegree some desiring:Degree,
             desiring:hasReason some desiring:Reason,
Class: desiring:covet.v
  SubClassOf: desiring:Desiring
Class: desiring:Event
  SubClassOf: semtype:State_of_Affairs
Class: desiring:Experiencer
  SubClassOf: semtype:Sentient

Notice that the uniqueness (locality) of frame elements and lexical units for a frame is obtained simply by means of a specific namespace (denoted by the desiring prefix in the example, see below for possible namespace policies), while a frame is interpreted as an owl:Class, lexical units as its subclasses, frame elements as both an owl:Class (e.g. Event) and an owl:ObjectProperty (e.g. hasEvent), the relation between a frame and a frame element as a rdf:s:subClassOf an owl:Restriction, and the semantic type assignments to frame elements as additional subclass axioms. All knowledge patterns derived from frames are considered specialization of the generic pattern odp:situation.owl⁹, which generalizes the situation semantics suggested by Berkeley linguists.

A central role in FrameNet is played by inheritance assumptions. In [19], inheritance is viewed as the strongest relation between frames, corresponding to is-a in many ontologies. With this relation, anything which is strictly true about the semantics of the Parent must correspond to an equally or more specific fact about the Child. This includes Frame Element membership of the frames (except for Extrathematic FEs), most Semantic Types, frame relations to other frames, relationships among the Frame Elements, and Semantic Types on the Frame Elements.

This means that additional axioms must be wrapped into ontologies derived from frames, e.g. these two sample axioms are derived from the inheritsFrom relation between the Aesthetics and Desirability frames as well as from the subFE relation between some of their frame elements:

Ontology: odpfn:aesthetics.owl
Annotations:
cpannoschema:specializes odpfn:desirability.owl
Class: aesthetics:Aesthetics
  SubClassOf: desirability:Desirability
Class: aesthetics:Degree
  SubClassOf: desirability:Desirability

The implementation of TBox refactoring is performed as a Semion refactoring, where the recipe includes rules for the mapping between FrameNet LOD dataset and KPs. Figure 7 shows an overview of TBox refactoring for deriving KPs from frames. The notation attempts to make rules intuitively understandable: arrows between the clouds represent mappings from entities in the cloud “FrameNet as LOD” to entities in the cloud “Knowledge Pattern”, classes are represented as circles, individuals as triangles, object properties as diamonds, and structural properties as labeled arcs. Each Frame is mapped both to an owl:Ontology that identifies the KP and to an owl:Class. The mapping takes into account the refactoring of the frame URI intended either as an ontology or as a class. Each FrameElement maps both to an owl:Class and to an owl:ObjectProperty. Again frame elements follow a renaming policy for the two interpretations, but in this case the situation is more complex. In fact, URI policy can follow from different interpretations:

1. Locality of frame elements within their frames

⁹odp:http://www.ontologydesignpatterns.org/cp/owl/,
odpf:http://www.ontologydesignpatterns.org/cp/owl/ln/
Lexical units are refactored as subclasses of the classes derived from the frames they are lexicalizations of, e.g. lexunit:cool.a SubClassOf: desirability:Desirability
Lexemes are refactored as individuals of the class semantics:Expression: each lexical unit is related to a lexeme through the property semantics:isExpressedBy.
Finally, each frame has owl:someValuesFrom restrictions accounting for the semantic roles implicit in frame elements (see example above). Locality and globality alternatives required two refactoring recipes each of one composed by 4 rules in forward-chaining inference mode. The complete TBox refactoring recipe can be found in the wiki page11.

5. RELATED WORK
The literature in reusing FrameNet for NLP tasks such as question-answering is too large to be covered here, and not central to the work described (see e.g. [23,16,6]). Work in using FrameNet jointly with other lexical resources, although not in the LOD way, include at least [5], which creates a linking from WordNet to FrameNet in a purely NLP context. Previous FrameNet conversions to RDF include [8,14,20]. [14] proposes a partial translation of FrameNet version 1.2 to RDF, and uses DAML both for the FrameNet meta-model, and the conceptual elements (frames, elements, etc.). They developed an automatic translator specific to that purpose. In 2003, the mixing of meta-model and FrameNet data made it difficult to be processed by reasoners for OWL (but it’d be acceptable in OWL2). For that reason, [20] applied an ad-hoc XSLT to move part of the FrameNet version 1.3 XML database to OWL. While the quality of the partial transformation is high, the process is not easily customizable. [20] also proposes a solution to deductive reasoning with natural language based on combining lexical resources with the world knowledge provided by ontologies.
After the release of version 1.5, the Berkeley FrameNet group asked us to produce a new version of FrameNet in RDF, optimized for publishing in the growing lexical part of the LOD cloud. This is what we describe in this paper.
From the viewpoint of formal semantic interpretation of FrameNet, [8] uses both ABox and TBox conversions to perform automatic enrichment of FrameNet with reference to a large corpus where frames are detected, new frames and elements are discovered and typed with a WordNet Supersense learner, and finally reengineered through a previous alignment to the LMM semiotic ontology [17] (used in this paper with the odp:semiotics.owl knowledge pattern).
[9] is a deeper analysis of the semiotic relations behind FrameNet, VerbNet and WordNet, and proposes a method to formalize their mappings. The semantics of the frames is put in perspective with the Descriptions and Situations knowledge pattern, partly reused in this paper to represent the situation-based semantics declared by [19]. The article also proposes to represent the full semantics of frames as n-ary polymorphic relations in FOL. This proposal is not directly implementable in OWL, but provides a useful abstraction across the different notions of a frame in cognitive science, AI, linguistics, knowledge engineering, etc. [16] is an attempt to formalize and “clean” the semantics of FrameNet version 1.3. The authors motivate the cleansing need by performing “ontological analysis”: e.g. they claim that frames do not always refer to situation classes because some of them actually represent abstract relations such as part of: since abstract entities should be assumed as non-localized, non-temporal entities, while situations should be interpreted as events occurring in time, frames should be formalized differently according to their ontological type. Frame to frame relations are also suggested an extensive revision on similar grounds. This work, besides the problem of sharing agreement on the general principles adopted for the analysis, could benefit from a customized refactoring of FrameNet, in order to perform their analyses directly on formal ontologies.

6. DISCUSSION
We have presented a conversion of FrameNet to RDF, published a dataset in the LOD cloud, linked to WordNet and other lexical datasets. We have also presented a method to convert FrameNet data into knowledge patterns. For both projects, we have employed the Semion tool with SemionRules, which allows a customized and explicit transformation from RDB or XML to RDF and OWL.
The intricate semantics of FrameNet, only partly described in this paper, gets to grips with the expressive

[10]An OWL2 alternative is also possible, with multiple interpretations for the same constant.

power of natural language. A fixed, ad-hoc transformation would be best for one, arbitrary for another, bad for a third. Customization is key with lexical data because there are use cases for maintaining the semantics of the original resource, often a purely intensional one (similar to the practice of using SKOS with thesauri), as well as for morphing the original semantics to something closer to the extensional formal semantics of web ontologies. In between these two ends, there are several intermediate cases and exceptions, which make the case for tools that minimize hard-coding of the transformation semantics, and preserve the opportunity to learn and share good practices for transforming lexical resources to linked data and domain knowledge. Current ongoing work concentrates on refinement of the RDF dataset with the Berkeley FrameNet group, the generation of new links to lexical datasets as well as other relevant LOD datasets (e.g. DBpedia), the creation of the FrameNet valence dataset, which will be a substantial (about 35 million triples) resource for hybridizing semantic web and linked data, and the refinement of a recipe to produce and automatically publish FrameNet-based knowledge patterns on the ODP portal\(^\text{12}\). These knowledge patterns implement a large section of the rich knowledge pattern structure envisaged by [12], with formal axioms, lexically motivated vocabulary, textual corpus grounding, and data grounding.

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7. REFERENCES