A Multilingual Semantic Network as Linked Data: *lemon*-BabelNet

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Abstract

Empowered by Semantic Web technologies and the recent Linked Data uptake, the publication of linguistic data collections on the Web is, apace with the Web of Data, encouragingly progressing. Indeed, with its long-standing tradition of linguistic resource creation and handling, the Natural Language Processing community can, in many respects, benefit greatly from the Linked Data paradigm. As part of our participation to the Data Challenge associated to the Linked Data in Linguistics Workshop, this paper describes the *lemon*-BabelNet dataset, a multilingual semantic network published as Linked Data.

1. Introduction

Empowered by Semantic Web technologies and the recent Linked Data uptake, the continuously growing Web of Data offers new opportunities for a wide spectrum of domains, including Linguistics and Natural Language Processing. A grassroots effort by members of the Natural Language Processing (NLP) and Semantic Web (SW) communities, in particular the Open Linguistics subgroup[1] of the Open Knowledge Foundation[2], has initiated the development of a Linked Open Data sub-cloud: the *Linguistic* Linked Open Data (LLOD) cloud. Indeed, stimulated by initiatives such as the W3C Ontology-Lexica community group[3], the publication of linguistic data collections on the Web is progressing encouragingly. As defined by Chiarcos et al. (2013), the challenge is to "store, to connect and to exploit the wealth of language data", with the key issues of (linguistic) resource interoperability, i.e. the ability to syntactically process and semantically interpret resources in a seamless way (Ide and Pustejovsky, 2010), and information integration, i.e. the ability to combine information across resources. All types of linguistic resources are eligible for the LLOD cloud, ranging across lexical-semantic resources (such as machine-readable dictionaries, semantic knowledge bases, ontologies) to annotated linguistic corpora, repositories of linguistic terminologies and meta-data repositories (Chiarcos et al., 2011).

The benefits of such a 'Web of Linguistic Data' are diverse and lie on both Semantic Web and NLP sides. On the one hand, ontologies and linked data sets can be augmented with rich linguistic information, thereby enhancing web-based information processing. On the other hand, NLP algorithms can take advantage of the availability of a vast, interoperable and federated set of linguistic resources and benefit from a rich ecosystem of formalisms and technologies. In the medium term, a web-based integration of NLP tools and applications is inevitable; a few steps have already been taken in this direction with the recent definition of the NLP Interchange Format (NIF) (Hellmann et al., 2013). De facto, common initiatives between SW and NLP are multiplying[4].

This paper gives an overview of the *lemon*-BabelNet linked data set, as submitted to the Data Challenge associated to the Linguistics in Linked Data Workshop. BabelNet (Navigli and Ponzetto, 2012) is a very large multilingual encyclopedic dictionary and ontology whose version 2.0 covers 50 languages. Based on the integration of lexicographic and encyclopedic knowledge, BabelNet 2.0 offers a large network of concepts and named entities along with an extensive multilingual lexical coverage. Its conversion to linked data was carried out using the *lemon* model (**Le**xicon **M**odel for **On**tology) (McCrae et al., 2012a), a lexicon model for representing and sharing ontology lexica on the Semantic Web. Our hope is that the publication of BabelNet as linked data will increase its accessibility, enhance lexical-semantic resource integration and support the development of linked data-based NLP applications.

The remainder of the paper is organized as follows. After introducing the BabelNet resource in Section 2, we detail its conversion to linked data in Section 3. Next, in Section 4, we present its interconnections with other resources on the Web and provide an account for statistics and aspects related to publication. Finally, after a brief overview of the potential applications of the dataset (Section 5), we conclude in Section 6.

2. BabelNet 2.0

BabelNet[5] is a lexico-semantic resource whose aim is to provide wide-coverage encyclopedic and lexicographic knowledge in many languages. More precisely, BabelNet is both a multilingual encyclopedic dictionary, with lexicographic and encyclopedic coverage of terms, and an ontology which connects concepts and named entities in a very

[1] http://linguistics.okfn.org/2011/05/20/the-open-linguistics-working-group/

[2] http://okfn.org/

[3] http://www.w3.org/community/ontolex/

[4] See for example the Multilingual Web Linked Open Data and DBpedia&NLP workshops (http://www.multilingualweb.eu/en/documents/dublin-workshop and http://iswc2013.semanticweb.org/content/dbpedia-nlp-2013) respectively).

[5] http://www.babelnet.org

large network of semantic relations, made up of more than 9 million entries, called *Babel synsets*. Adopting a structure similar to that of a WordNet (Fellbaum, 1998), each Babel synset represents a given meaning and contains all the synonyms, called *Babel senses*, which, in different languages, express that meaning. The resource provides, for example, lexical knowledge about the concept *apple* as a fruit, with its part of speech, its definitions and its set of synonyms in multiple languages, as well as encyclopedic knowledge about, among other entities, the *Apple Inc.* company, anew along with definitions in multiple languages. Thanks to the semantic relations, it is furthermore possible to learn that *apple* is an *edible fruit* (or a *fruit comestible*, a *frutta* an *essbare Früchte*) and that *Apple Inc.* is related to *server* and *Mountain View California*. While 6 languages were covered in the prime version 1.0, BabelNet 2.0 makes giant strides in this respect and covers 50 languages. This new version is obtained from the automatic integration of:

- *WordNet*, a popular computational lexicon of English (version 3.0),
- *Open Multilingual WordNet* (OMWN), a collection of wordnets available in different languages,
- *Wikipedia*, the largest collaborative multilingual Web encyclopedia, and
- *OmegaWiki*, a large collaborative multilingual dictionary.

BabelNet 2.0 covers, in addition to English, 50 languages belonging to diverse language families such as, among others, Indo-European, Indo-Iranian, Uralic and Semitic. Overall, the resource contains about 9.3 million concepts. These concepts gather around 50 million senses, are interconnected through more than 260 million lexico-semantic relations and are described by almost 18 million glosses. Further statistics about coverage per language, composition of BabelSynsets and polysemy are available on BabelNet's website[6].

The characteristics of BabelNet, as both a dictionary and an ontology, naturally led to the choice of the *lemon* model for achieving its conversion as linked data.

3. Rendering BabelNet as Linked Data with Lemon

3.1. The *lemon* Model

lemon (McCrae et al., 2011) is a model developed for the representation of lexica relative to ontologies in RDF format. In line with the principle of semantics by reference (Buitelaar, 2010), the model maintains a clean separation of the lexical and semantic layers, enabling lexica to be easily reused to describe different ontologies. As outlined in Figure 1, the core of the lemon model consists of the following elements:

- *Lexical entry*, which comprises all syntactic forms of an entry,

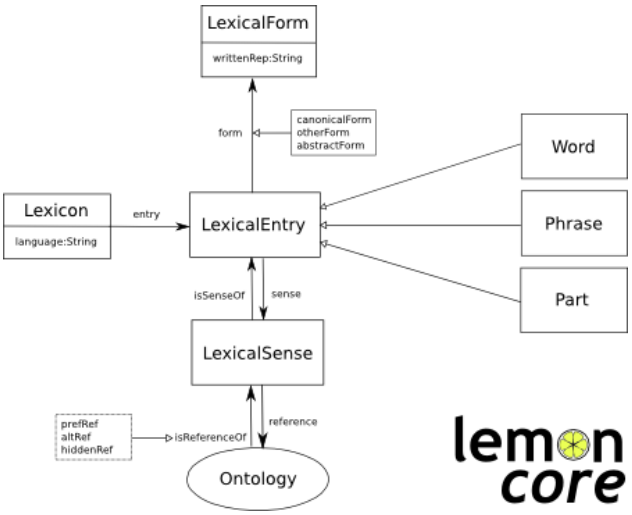

Figure 1: The core of the *lemon* model.

- *Lexical form*, which represents a single inflection of a word, with its *representation*(s), *i.e.*, the actual string(s) used for the word, and
- *Lexical sense*, which represents the usage of a word as a *reference* to a concept in the ontology.

As such the model has already been used for the representation of a number of lexica (Villegas and Bel, 2013; Eckle-Kohler et al., 2014) and proposals have been made to extend the model in new ways (Khan et al., 2013). Specifically designed as an interface between lexical and ontological knowledge and allowing the expression of linguistic information, *lemon* perfectly meets the needs of Babelnet as a candidate for the Linked Data Cloud.

3.2. BabelNet as Linked Data

BabelNet contains a lot of information; yet, its conversion into RDF mainly involves the consideration of its two core elements, namely Babel senses and Babel synsets. As advocated above, ontological and lexical layers should be kept separated. Therefore, while *lemon* provided us with the means of representing lexical information, i.e., Babel senses, we chose to represent collections of equivalent senses, i.e., Babel synsets, using the class *Concept* of the SKOS (Simple Knowledge Organization System) model[7]. We additionally reused the existing vocabulary of *LexInfo 2* (Buitelaar et al., 2009; McCrae et al., 2012b) to encode some of the semantic relations between Babel synsets. Finally, when no existing vocabulary element was available, we defined our own classes and properties. At the lexical level, Babel sense lemmas are encoded as *lemon* lexical entries. Each lexical entry receives a language tag via the *rdfs:label* property, the indication of its part of speech (*lexinfo:partOfSpeech*) and is further described by means of a lexical form encoding the Babel sense lemma as written representation of the entry. According to their language, these entries are assembled into different *lemon* lexicons (51 in total). In accordance with the principle of semantics by reference applied in *lemon*,

[6] http://babelnet.org/stats.jsp

[7] http://www.w3.org/TR/skos-reference

possible meanings of lexical entries are expressed by way of lexical senses pointing to adequate Babel synsets encoded as SKOS concepts. Besides pointing to a referent, lexical senses[8] encode meta-data information with, first, the source of the sense (WordNet, OMWN, Wikipedia or OmegaWiki) and, when relevant, the way it was obtained: *via* automatic translation or thanks to a Wikipedia redirection page (boolean properties). Additionally, these *lemon* senses support the expression of translation variants between Babel senses; indeed, translations pertain to lexical sense relations as they should be stated between disambiguated words (i.e., the lexical senses of lexical entries), which do not necessarily refer to the same concept. As an illustration of the encoding of these lexical elements, Figure 2 depicts the *lemon* representation of the Italian Babel sense 'Web semantico' in Turtle format[9] (prefixes are defined in the Figure). Encoded as a *lemon:LexicalEntry* (bn:Web_semantico_n_IT) this entry is part of the Italian *lemon:Lexicon* (bn:lexicon_IT), it shows a *lemon:Form* (bn:Web_semantico_n_IT/canonicalForm), as well as a *lemon:LexicalSense* (bn:Web_semantico_IT/s02276858n).

From the ontological perspective, we used *skos:Concept(s)* to represent our 'units of thought', i.e., Babel synsets. These Babel SKOS concepts encode two types of information: regarding the concept itself, and regarding its semantic relations with other concepts. As a base, Babel SKOS concepts are linked back to the entries of the *lemon* lexica thanks to the property *isReferenceOf*. Next, a BabelNet property (*bn-lemon:synsetType*) indicates whether the Babel synset is a concept or a named entity (NE). Most importantly, multilingual glosses which provide a description of the concept in up to 50 languages, are specified through a *bn-lemon:definition* property referring to a *bn-lemon:BabelGloss*. Although the *skos:definition* would have been the ideal candidate to represent this piece of information, it nevertheless does not enable the expression of additional (meta-data) information about the definition. We therefore defined a class, namely *BabelGloss*, so as to be able to specify the source of the definition (WordNet, OMWN, Wikipedia or OmegaWiki), as well as its license. This is the only BabelNet component for which we could not reuse an element of an existing vocabulary. As regards the semantic relations between Babel synsets, these are encoded as *skos:narrower* and *skos:broader* for hyponyms and hypernyms, respectively, as *lexinfo* relations when adequate (member meronym, member holonym, participle, *etc.*), and as *skos:related* when less specified. Finally, Wikipedia categories (in dozens of languages) and their DBpedia twin (in English) are reported for each concept *via* a dedicated property. Following up with the 'Web semantico' example, Figure 2 shows the concept to which this entry refers, i.e. the *skos:Concept* bn:s02276858n. It holds the above mentioned properties, and links to a *BabelGloss* (here the German one, bn:s02276858n_Gloss1_DE).

[8]Lexical senses URIs are based on the 'full' lemma of Babel senses; when originating from Wikipedia, they are thus made up from the sense-tagged lemmas as in 'Apple_(Fruit)' and Apple_(Computer).

[9]http://www.w3.org/TeamSubmission/turtle/

```
@prefix bn: <http://babelnet.org/2.0/> .
@prefix bn-lemon: <http://babelnet.org/model/babelnet#>
@prefix lemon: <http://www.lemon-model.net/lemon#> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
@prefix wikipedia-da: <http://da.wikipedia.org/wiki/Kategori/> .
@prefix wikipedia-it: <http://it.wikipedia.org/wiki/Categorie/> .
@prefix dcterms: <http://purl.org/dc/terms/> .
 ...
bn:lexicon_IT
      a   lemon:Lexicon;
      dc:source   <http://babelnet.org/>;
      lemon:entry   bn:Web_semantico_n_IT, ... ;
      lemon:language   "IT".

bn:Web_semantico_n_IT
      a   lemon:LexicalEntry;
      rdfs:label   "Web_semantico"@IT;
      lemon:canonicalForm   bn:Web_semantico_n_IT/canonicalForm;
      lemon:language   "IT";
      lemon:sense   bn:Web_semantico_IT/s02276858n ;
      lexinfo:partOfSpeech   lexinfo:noun.

bn:Web_semantico_n_IT/canonicalForm
      a   lemon:Form ;
      lemon:writtenRep   "Web_semantico"@IT.

bn:Web_semantico_IT/s02276858n
      a   lemon:LexicalSense ;
      dc:source   <http://wikipedia.org/>;
      dcterms:license  <http://creativecommons.org/licenses/by-sa/3.0/>;
      bn-lemon:wikipediaPage   wikipedia-it:Web_semantico;
      lemon:reference   bn:s02276858n .

bn:s02276858n
      a   skos:Concept;
      bn-lemon:synsetType   "NE";
      bn-lemon:synsetID   "bn:02276858n";
      bn-lemon:wikipediaCategory   wikipedia-da:Kategori:Internet;
      lemon:isReferenceOf   bn:Web_semantico_IT/s02276858n ...;
      skos:exactMatch   dbpedia:Semantic_Web;
      bn-lemon:definition   bn:s02276858n_Gloss1_DE ... ;
      dcterms:license  <http://creativecommons.org/licenses/by-nc-sa/3.0/>;
      skos:related   bn:s00076736n , bn:s03586460n ... .

bn:s02276858n_Gloss1_DE
      a   bn-lemon:BabelGloss;
      bn-lemon:gloss   "Das Semantische Web ist... "@DE ;
      lemon:language   "DE" ;
      dc:source   <http://wikipedia.org/>;
      dcterms:license  <http://creativecommons.org/licenses/by-sa/3.0/> .
```

Figure 2: An excerpt of BabelNet as RDF in Turtle format.

Based on a *lemon*-SKOS model, the RDF edition of BabelNet is able to render most of the information contained in the stand-alone version, offering a large multi-domain and linguistic linked dataset, associated with an extensive multilingual lexical coverage. Yet, beyond its content, one of the key features of a linked dataset is to set connections to other datasets and to be accessible over the Web.

4. Interlinking and Publishing on the Web

4.1. Interlinking *lemon*-Babelnet

Generated from the integration of various existing resources, the most natural way of linking *lemon*-BabelNet is to consider the RDF versions, if available, of these resources. *lemon*-BabelNet includes in the first place links to encyclopedic resources: links to Wikipedia pages are established at the sense level (when originating from Wikipedia), and links to Wikipedia *category* pages at the SKOS concept level. These links are set up from the Wikipedia dump from which the resource is derived. Regarding DBpedia, links are set at the SKOS level only, with pointers to DBpedia English pages and English category pages. The URIs of these links are set up by swapping Wikipedia names-

Resource	
# SKOS concepts	9,348,287
# babel glosses	17,961,157
# semantic relations	262,663,251
# lemon senses	50,282,542
# lemon lexical entries	44,486,335
# lemon lexicons	51
Outgoing links	
# Wikipedia page	35,784,593
# Wikipedia category	45,520,563
# DBpedia category	15,381,861
# DBpedia page	3,829,053
# lemon WordNet 3.0	117657
# lemon OmegaWiki (En)	15140
Total number of outgoing links	100,648,867
Total number of triples	1,138,337,378

Table 1: Statistics concerning the *lemon*-BabelNet 2.0 RDF dataset.

pace for the DBpedia one[10]; no links are provided towards localized versions of DBpedia for now. Additionally, we provide links to lexical resources by setting connections to the *lemon* versions of WordNet 3.0[11] and OmegaWiki[12] (English version), both at the SKOS concept level. In both cases, URIs are taken from the RDF dumps of these datasets, using the synsets IDs to match the resources.

4.2. Statistics

The RDF version of BabelNet 2.0 features an overall number of 1.1 billion triples. Table 1 gives further details about the nature of these triples, which naturally reflect the standalone version, especially for SKOS concepts and lemon lexical senses. Most importantly, the resource contains a significant number of outgoing links, with around 80 million connections to either Wikipedia pages or categories, 19 million similar relations to DBpedia and, at the level of genuine lexical knowledge, a complete linkage to the *lemon* edition of Princeton WordNet 3.0 and 15k links to the English OmegaWiki edition of *lemon*-UBY. These connections to other *lemon* resources are of particular interest as they lay the foundations for further linked data-based integration of ontology lexica.

4.3. Publication on the web

BabelNet 2.0 and its Linked Data edition is published under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License. Additionally, as it is based on a collection of independent resources, special attention must be paid to the licensing policies of these grounding works. *lemon*-BabelNet respects the copyrights of the original resources, and reproduces the different licenses under which they were issued, in two different ways: by releasing different RDF dump files according to groups of compatible licenses in the first place, by specifying a license property (dcterms:license) on triples in the second. As advocated by Rodríguez-Doncel et al. (2013), our aim is to achieve maximum transparency, which such explicit rights declarations should guarantee.

On a more concrete standpoint, BabelNet is served on the Web in three ways, *via*:

- a set of RDF dump files (URIs and IRIs) in n-triples format downloadable at the following URL: `http://babelnet.org/download.jsp`,
- a public SPARQL endpoint set up using the Virtuoso Universal Server[13] and accessible from the following URL: `http://babelnet.org:8084/sparql/`, and
- dereferenceable URIs, supported by the Pubby Web application, a Linked Data frontend for SPARQL endpoints[14] (`http://babelnet.org/2.0/`).

Since BabelNet is released on a periodiocal basis, it is important to enable the tracking of different versions. To this end, the version number is explicitely mentioned in the URL; URIs are therefore fixed for each version, and the previous can easily be mapped to the next.

5. Possible applications of the dataset

We anticipate several uses of the *lemon*-BabelNet linked dataset. The resource can, in the first place, be used for multilingual ontology lexicalization. In this regard, a recent work by Unger et al. (2013) proposes a *lemon* lexicon for the DBpedia ontology; it covers the most frequent classes and properties of the DBpedia schema, and provides manually created lexical entries for English. The continuation of such a work for other languages could benefit greatly from the availability of a resource such as *lemon*-BabelNet. Besides enriching the lexical layer of ontologies, *lemon*-BabelNet can help in manipulating this information, e.g. for cross-lingual ontology mapping. Another application is, naturally, Word Sense Disambiguation. In this respect, we can mention the work of Elbedweihy et al. (2013), which uses BabelNet to bridge the gap (by performing query disambiguation) between natural language queries and linked data concepts. Furthermore, because it focuses both on word senses and named entities (what is more cross-lingually interconnected in many languages), BabelNet opens up the possibility to perform jointly the tasks of Word Sense Disambiguation and Entity Linking, as demonstrated by (Moro et al., 2014). With the additional knowledge that can be discovered and gathered on the (L)LODs, *lemon*-BabelNet can potentially increase the performance of such disambiguation process. Finally, one could also consider to take advantage of the LLOD to improve some of its components: in the frame of lexical-semantic resources for example, one could consider the possibility of cross-resource validation of sense alignments over linked data.

[10] http://dbpedia.org/resource/

[11] http://lemon-model.net/lexica/pwn/

[12] http://lemon-model.net/lexica/uby/ow_eng/

[13] http://virtuoso.openlinksw.com/

[14] http://wifo5-03.informatik.uni-mannheim.de/pubby/

6. Conclusion

In this paper we presented *lemon*-BabelNet, such as submitted to the Data Challenge. Based on the *lemon* model, the dataset features about 1 billion triples which describe 9 million concepts with encyclopedic and lexical information in 50 languages. The resource is interlinked with several other datasets of encyclopedic (DBpedia) and lexicographic (WordNet, Uby) nature. We believe that this wide, multilingual and interconnected lexical-semantic dataset, together with other linguistic resources in the LLOD, represent a major opportunity for Natural Language Processing. Indeed, if carefully published and interlinked, those resources could, potentially, turn into a huge body of machine-readable knowledge. Future work naturally includes the upgrading of *lemon*-BabelNet to take account of any expansion of BabelNet itself, e.g., its full taxonomization (Flati et al., 2014) and validation (Vannella et al., 2014), as well as the diversification and integration of links to other resources (Pilehvar and Navigli, 2014).

Acknowledgments

Sapienza affiliated authors gratefully acknowledge the support of the ERC Starting Grant MultiJEDI No. 259234.

The authors also acknowledge support from the LIDER project (No. 610782), a support action funded by the European Commission under FP7. Warm thanks go to Victor Rodríguez-Doncel for the helpful discussion on (linked data) copyrights.

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