Extracting Lexical Semantic Knowledge from Wikipedia and Wiktionary

Torsten Zesch and Christof Müller and Iryna Gurevych

Ubiquitous Knowledge Processing Lab
Computer Science Department
Technische Universität Darmstadt, Hochschulstraße 10
D-64289 Darmstadt, Germany

{zesch,mueller,gurevych} (at) tk.informatik.tu-darmstadt.de

Abstract

Recently, collaboratively constructed resources such as Wikipedia and Wiktionary have been discovered as valuable lexical semantic knowledge bases with a high potential in diverse Natural Language Processing (NLP) tasks. Collaborative knowledge bases however significantly differ from traditional linguistic knowledge bases in various respects, and this constitutes both an asset and an impediment for research in NLP. This paper addresses one such major impediment, namely the lack of suitable programmatic access mechanisms to the knowledge stored in these large semantic knowledge bases. We present two application programming interfaces for Wikipedia and Wiktionary which are especially designed for mining the rich lexical semantic information dispersed in the knowledge bases, and provide efficient and structured access to the available knowledge. As we believe them to be of general interest to the NLP community, we have made them freely available for research purposes.

1. Introduction

Currently, the world wide web is undergoing a major change as more and more people are actively contributing to the content available in the so called Web 2.0. Some of these rapidly growing web sites, e.g. Wikipedia (Wikimedia Foundation, 2008a) or Wiktionary (Wikimedia Foundation, 2008b), have the potential to be used as a new kind of lexical semantic resource due to their increasing size and significant coverage of past and current developments. In particular, the potential of Wikipedia as a lexical semantic knowledge base has recently started to get explored. It has been used in NLP tasks like text categorization (Gabrilovich and Markovitch, 2006), information extraction (Ruiz-Casado et al., 2005), information retrieval (Gurevych et al., 2007), question answering (Ahn et al., 2004), computing semantic relatedness (Zesch et al., 2007), or named entity recognition (Bunescu and Pasca, 2006). Wiktionary has not yet been exploited for research purposes as extensively as Wikipedia. Interest has nonetheless already arisen, as it has recently been employed in areas like subjectivity and polarity classification (Chesley et al., 2006), or diachronic phonology (Bouchard et al., 2007).

All these tasks require reliable lexical semantic information which usually comes from linguistic knowledge bases like WordNet (Fellbaum, 1998) or GermaNet (Kunze, 2004). They are usually shipped with easy-to-use application programming interfaces (APIs), e.g. JWNL\(^1\) or GermaNetAPI\(^2\), that allow for easy integration into applications. However, Wikipedia and Wiktionary have lacked this kind of support so far which constitutes a significant impediment for NLP research. Therefore, we developed general purpose, high performance Java-based APIs for Wikipedia and Wiktionary that we made freely available to the research community. In this paper, we first describe Wikipedia and Wiktionary from a lexical semantic point of view, and compare them with linguistic knowledge bases in Section 2. We review existing mechanisms of accessing Wikipedia and Wiktionary in Section 3. In Section 4, we introduce the system architecture that is used to provide structured access to the lexical semantic information contained in Wikipedia and Wiktionary. In Section 5, we show how selected NLP tasks can benefit from the improved access capabilities provided by the proposed APIs. We conclude with a summary in Section 6.

2. Collaborative Knowledge Bases

Wikipedia and Wiktionary are instances of knowledge bases that are collaboratively constructed by mainly non-professional volunteers on the web. We call such a knowledge base Collaborative Knowledge Base (CKB), as opposed to a Linguistic Knowledge Base (LKB) like WordNet (Fellbaum, 1998) or GermaNet (Kunze, 2004). In this section, we briefly analyze the CKBs Wikipedia and Wiktionary as lexical semantic knowledge bases, and compare them with traditionally used LKBs.

2.1. Wikipedia

Wikipedia is a multilingual, web-based, freely available encyclopedia, constructed in a collaborative effort of volunteer contributors. It grows rapidly, and with approx 7.5 million articles in more than 250 languages it has arguably become the largest collection of freely available knowledge.\(^3\) Articles in Wikipedia form a heavily interlinked knowledge base, enriched with a category system emerging from collaborative tagging, which constitutes a thesaurus (Voss, 2006). Wikipedia thus contains a rich body of lexical semantic information, whose aspects are thoroughly described in (Zesch et al., 2007). This includes knowledge about named entities, domain specific terms or domain specific word senses that is rarely available in LKBs. Additionally, the redirect system of Wikipedia articles can be used as a dictionary for synonyms, spelling variations and abbreviations.

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\(^1\)http://sourceforge.net/projects/wordnet

\(^2\)http://projects.villa-bosch.de/nlpsoft/gn_api/index.html

\(^3\)http://en.wikipedia.org/wiki/Wikipedia:Size_comparisons
Wiktionary consists of approximately 3.5 languages and size complementary. It has 5 million entries in 172 language editions. Wiktionary is a multilingual, web-based, freely available dictionary information, as this kind of information is contained in speech, but excludes in-depth factual and encyclopedic information, as this kind of information is contained in Wikipedia. Thus, Wikipedia and Wiktionary are largely complementary.

Languages and size | Wiktionary consists of approx. 3.5 million entries in 172 language editions. Unlike most LKBs each Wiktionary edition also contains entries for foreign language terms. Therefore, each language edition comprises a multilingual dictionary with a substantial amount of entries in different languages (cf. Table 2). For instance, the English Wiktionary contains the German entry Haus, which is explained in English as meaning house. The size of a particular language edition of Wiktionary largely depends on how active the corresponding community is (see Table 1). Surprisingly, the English edition (682,982 entries), started on December 12, 2002, is, though the oldest, not the largest one. The French Wiktionary (730,193 entries), which was launched over a year later, is, the largest. Other major languages like German (71,399 entries) or Spanish (31,652 entries) are included as well. On top of that, the English Wiktionary edition offers a remarkable amount of information not typically found in LKBs, including compounds, abbreviations, acronyms and initialisms, common misspellings (e.g. basically vs. basically), simplified spelling variants (e.g. thru vs. through), contractions (e.g. o’ vs. of), proverbs (e.g. no pain, no gain), disputed usage words (e.g. irregardless vs. irrespective or regardless), protologisms (e.g. iPodian), onomatopoeia (e.g. grr), or even colloquial, slang and pejorative language forms. Most of these lexical semantic relations are explicitly encoded in the structure of a Wiktionary entry. This stands in clear contrast to Wikipedia, where links between articles usually lack clearly defined semantics.

Lexical semantic information | Entries in Wiktionary are accompanied with a wide range of lexical and semantic information such as part of speech, word sense, gloss, etymology, pronunciation, declension, examples, sample quotations, translations, collocations, derived terms, and usage notes. Lexically or semantically related terms of several types like synonyms, antonyms, hypernyms and hyponyms are included as well. On top of that, the English Wiktionary edition offers a remarkable amount of information not typically found in LKBs, including compounds, abbreviations, acronyms and initialisms, common misspellings (e.g. basically vs. basically), simplified spelling variants (e.g. thru vs. through), contractions (e.g. o’ vs. of), proverbs (e.g. no pain, no gain), disputed usage words (e.g. irregardless vs. irrespective or regardless), protologisms (e.g. iPodian), onomatopoeia (e.g. grr), or even colloquial, slang and pejorative language forms. Most of these lexical semantic relations are explicitly encoded in the structure of a Wiktionary entry. This stands in clear contrast to Wikipedia, where links between articles usually lack clearly defined semantics.

2.2. Wiktionary

Wiktionary is a multilingual, web-based, freely available dictionary, thesaurus and phrase book, designed as the lexical companion to Wikipedia. It is also collaboratively constructed by volunteers with no specialized qualifications necessary.

Wiktionary targets common vocabulary and matters of language and wordsmithing. It includes terms from all parts of speech, but excludes in-depth factual and encyclopedic information, as this kind of information is contained in Wikipedia. Thus, Wikipedia and Wiktionary are largely complementary.

Languages and size

| Language | Rank | Entries |
|----------|------|---------|
| French   | 1    | 730,193 |
| English  | 2    | 682,982 |
| Vietnamese| 3   | 225,380 |
| Turkish  | 4    | 185,603 |
| Russian  | 5    | 132,386 |
| Ido      | 6    | 128,366 |
| Chinese  | 7    | 115,318 |
| Greek    | 8    | 102,198 |
| Arabic   | 9    | 95,020  |
| Polish   | 10   | 85,494  |
| German   | 12   | 71,399  |
| Spanish  | 20   | 31,652  |

Table 1: Size of Wiktionary language editions as of February 29, 2008.

2.3. Comparison with LKBs

Wikipedia and Wiktionary are instances of collaborative knowledge bases (other examples are dmoz or Citizendium). The properties of such CKBs differ from LKBs in several ways – Table 3 gives an overview. LKBs are typically constructed by linguists following a thesaurus. LKBs are typically constructed by linguists following a thesaurus.
Table 3: Comparison of linguistic and collaborative knowledge bases.

|                              | Linguistic Knowledge Bases (LKBs)                                      | Collaborative Knowledge Bases (CKBs)                                    |
|------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------|
| Constructors                 | Linguists                                                             | Mainly non-professional volunteers                                    |
| Construction approach        | Following theoretical model or corpus evidence                        | Following non-binding guidelines                                       |
| Construction costs           | Significant                                                           | None                                                                  |
| Up-to-dateness               | Quickly out-dated                                                     | Mostly up-to-date                                                      |
| Size                         | Limited by construction costs                                        | Huge or quickly growing                                               |
| Data quality                 | Editorial control                                                     | Social control by the community                                       |
| Available languages          | Major languages                                                       | Many interconnected languages                                          |

To our knowledge, there is no other API for Wiktionary APIs. Collaboration can be avoided by directly accessing the database dumps. For example, the Perl module Parse::MediaWikiDump (Riddle, 2006) parses the Wikipedia XML dump to retrieve articles. As Wikipedia dumps are very large (over 3 GB of compressed data for the snapshot of the English Wikipedia from Feb 2008), the performance of parsing is not sufficient for large-scale NLP tasks (it may take up to several seconds to retrieve a given article). Additionally, the time that is required to retrieve an article is not easily predictable, but depends on the article’s position in the XML dump.
Figure 1: System architecture of JWPL and JWKTL.

the database schema explicitly represents information about an article’s links or categories, which is only implicitly encoded in the HTML structure.

The system architecture is described in detail in the following section.

### 4. Extracting Knowledge from Wikipedia and Wiktionary

If Wikipedia or Wiktionary are to be used for large-scale NLP tasks, efficient programmatic access to the knowledge therein is required. Therefore, we developed general purpose, high performance Java-based APIs abbreviated as JWPL (Java-based Wikipedia Library) and JWKTL (Java-based Wiktionary Library). JWPL is already freely available for research purposes, JWKTL will be released by the time of the conference at the latest.¹⁴

#### 4.1. Java-based Wikipedia Library (JWPL)

The original structure of the Wikipedia database is optimized for searching articles by keywords which is performed by millions of users of the online Wikipedia every day. However, an API designed for NLP research has to support a wider range of access paths, including iteration over all articles, a query syntax, as well as efficient access to information like links, categories, and redirects. Thus, JWPL operates on an optimized database (as shown in Figure 1) that is created in a one-time effort from the database dumps available from the Wikimedia Foundation.¹⁵

The advantages of this system architecture are: (i) computational efficiency enabling large-scale NLP tasks, (ii) reproducible research results, and (iii) an easy to use object-oriented programming interface, that cannot be found in this combination by any of the competing approaches outlined in Section 3.

Reproducible experimental results are a direct consequence of using a fixed database dump instead of the online Wikipedia that is very likely to change between two runs of a certain experimental setting.

Computational efficiency is also a consequence of accessing the database using its indexing mechanisms for fast retrieval. The data from the database is directly mapped to Java objects using the Hibernate object-relational mapping framework (Bauer and King, 2004). This also means that JWPL is not restricted to using a certain database, but may run on top of the most common database systems.¹⁶

The design of the object-oriented programming interface is centered around the objects: `WIKIPEDIA`, `PAGE`, and `CATEGORY`. The `WIKIPEDIA` object is used to establish the connection with the database (as shown in Listing 1), and to retrieve `PAGE` and `CATEGORY` objects. JWPL supports retrieval by keywords or via a query interface that allows for wildcard matches as well as retrieving subsets of articles or categories depending on parameters like the number of tokens in an article or the number of incoming links. The `WIKIPEDIA` object also allows to iterate over articles, categories, redirects, and disambiguation pages.

A `PAGE` object represents either a normal Wikipedia article, a redirect to an article, or a disambiguation page. Each `PAGE` object provides access to the article text (with markup information or as plain text), the assigned categories, the in-going and outgoing article links, as well as all redirects that link to this article.

`CATEGORY` objects represent Wikipedia categories and allow access to the articles within this category. As categories in Wikipedia form a thesaurus, a `CATEGORY` object also provides means to retrieve parent and child categories, as well as siblings and all recursively collected descendants. JWPL also provides a `CATEGORYGRAPH` object that e.g. allows to find the shortest path between two given categories (as shown in Listing 2).

Listing 3 presents a more complex example showing how to retrieve a list of “towns in Germany” from Wikipedia. Executing the given Java code using the English Wikipedia from 9th Feb 2007 yields a list of almost 3,000 towns in Germany.

The next release of JWPL – scheduled for April 2008 – will also contain a parser for the Wikipedia markup language. The parser allows to easily identify and access even more fine-grained information within Wikipedia articles, e.g. sections, paragraphs, templates, links, link texts, link contexts, lists, and tables. Figure 2 visualizes the structure of the Wikipedia article “Natural Language Processing” as analyzed by the parser.

#### 4.2. Java-based Wiktionary Library (JWKTL)

The Wiktionary API (JWKTL) follows a similar system architecture as the Wikipedia API (JWPL), as shown in Figure 1. JWKTL is based on freely available Wiktionary dumps¹⁷ of different language editions in XML format. In order to provide a fast and easy access to the lexical semantic knowledge in Wiktionary, the output of the parser is stored using the Berkeley DB database library.¹⁸ For each Wiktionary entry, the API returns a Java object which contains the extracted information.

The word entries in Wiktionary use the same mark-up language as Wikipedia. As the different language editions of Wiktionary use different structural elements for encoding the lexical semantic information, the Wiktionary parser

¹⁴http://www.ukp.tu-darmstadt.de/software/
¹⁵http://download.wikipedia.org/
¹⁶http://www.hibernate.org/80.html
¹⁷http://dumps.wikimedia.org/
¹⁸http://www.oracle.com/technology/products/berkeley-db/index.html
needs to be adjusted to each language edition. For most language editions, the user community has introduced a layout standard acting as a data schema to enforce a uniform structure of entries. However, as schemas evolve over time, older entries are possibly not updated. Moreover, as no contributor is forced to follow the schema, the structure of entries is fairly inconsistent. Therefore, the parser is designed to be robust against errors of incorrect usage of the markup language.

The API is centered around the Java object Wiktionary. It wraps the underlying database and allows to query the contained entries simultaneously. For example, the API maps each entry to the corresponding words for different languages and parts of speech and one language. The available information of a word’s grapheme as query argument (see Listing 4). Additionally, the desired part of speech or word language can also be specified. The API allows to combine several language editions of Wiktionary into one Wiktionary object and query the contained entries simultaneously. For each grapheme, Wiktionary contains a page with entries of corresponding words for different languages and parts of speech. In order to allow a structured access to the information available for each word, the API maps each entry to the object WiktionaryWord. Thus, each WiktionaryWord object contains the information for exactly one part of speech and one language. The available information of the entries can be accessed by calling the object’s methods, which return the specified information on word or sense level (see Listing 5).

Currently, the proposed API provides robust parsing of the English and the German Wiktionary editions and extracts structured information, including glosses, etymology, examples, quotations, translations, derived terms, characteristic word combinations, lexical relations, as well as links to other language editions of Wiktionary, Wikipedia articles, and external web pages. The parser can be easily adjusted to work with other language editions of Wiktionary.

5. Example Usage in NLP

The APIs for access to Wikipedia and Wiktionary proposed in this paper have already been put into service for large-scale NLP research, such as analyzing and accessing the structure of the Wikipedia category graph (Zesch and Gurevych, 2007), computing semantic relatedness between words (Zesch et al., 2007), and semantic information retrieval (Gurevych et al., 2007).

When analyzing the structure of the Wikipedia category graph, categories assigned to the articles of Wikipedia are viewed as nodes in a directed graph, where the subcategory relation between two categories is cast as a directed edge between the corresponding nodes in the graph. The CategoryGraph object in JWPL offers means to retrieve graph parameters like diameter, cluster coefficient, or average shortest path length.

The structure of the resulting graph (as defined by the graph parameters) is indicative of the possible performance of graph-based NLP applications, e.g., computing the semantic relatedness between words. This task requires to retrieve the corresponding Wikipedia article for each word, and then to compute the minimum path length between the categories of the two articles (see Listing 2). On this basis, efficient algorithms for computing semantic relatedness using Wikipedia can be easily implemented using JWPL.

Another NLP related task that directly benefits from the capabilities of JWPL and JWKTL is semantic information retrieval. Gurevych et al. (2007) describe work in which electronic career guidance is used to support school leavers in their search for a profession or vocational training. One special challenge in this task is the vocabulary gap between the language of the (expert-authored) documents from the database and the language of the school leavers. JWPL has been successfully used to bridge this vocabulary gap by using knowledge extracted from Wikipedia in the retrieval process. Currently, we are working on the integration of knowledge from Wiktionary into information retrieval using JWKTL.

6. Conclusion

Recently, the collaboratively created resource Wikipedia was discovered as a lexical semantic knowledge base that has the potential to trigger major performance increases in such diverse NLP areas as text categorization, information extraction, question answering, computing semantic relatedness, or named entity recognition. Its younger sister project, Wiktionary, has lately emerged as a valuable resource complementing it. We have shown that these collaborative knowledge bases contain lexical semantic knowledge which is not commonly encountered in linguistic knowledge bases. The need of appropriate programmatic access to the knowledge therein is self-evident.

This paper presented Java based APIs that allow for efficient access to Wikipedia and Wiktionary, and demonstrated cases of their usage. As the APIs are freely available for research purposes, we think that they will foster NLP research using the collaborative knowledge bases Wikipedia and Wiktionary.\(^{19}\)

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\(^{19}\)JWPL is already available at http://www.ukp.tu-darmstadt.de/software. JWKTL will be released by the time of the conference at latest on the same website.
German Research Foundation under the grant GU 798/1-2. We thank the students Lizhen Qu and Christian Jacobi for implementing important parts of JWKTL and JWPL, and our colleague Konstantina Garoufi for her valuable contributions to the final version of this paper.

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A Java code examples

Listing 1: Establishing the database connection.

```java
// configure the database connection parameters
DatabaseConfiguration dbConfig = new DatabaseConfiguration();
dbConfig.setDatabase("DATABASE");
dbConfig.setHost("SERVER_URL");
dbConfig.setUser("USER");
dbConfig.setPassword("PASSWORD");
dbConfig.setLanguage("LANGUAGE");
```

Listing 2: Getting the path length between two categories.

```java
// Assuming that a Wikipedia object was already instantiated.
CategoryGraph cg = new CategoryGraph(wiki);
Category c1 = wiki.getCategory("Germany");
Category c2 = wiki.getCategory("France");
int pathLength = cg.getPathLength(c1, c2);
```

Listing 3: Getting a list of all towns in Germany that are listed in Wikipedia.

```java
// Get the category 'Towns in Germany',
// assuming that a Wikipedia object was already instantiated.
Category topCat = wiki.getCategory("Towns in Germany");

// Add the pages categorized under 'Towns in Germany' to the list.
Set<String> towns = new TreeSet<String>();
for (Page p : topCat.getPageList()) {
    towns.add(p.getTitle().getPlainTitle());
}

// Add the pages categorized under all subcategories of 'Towns in Germany' to the list.
for (Category townCategory : topCat.getDescendants()) {
    for (Page p : townCategory.getPageList()) {
        towns.add(p.getTitle().getPlainTitle());
    }
}
```

Listing 4: Working with a Wiktionary object.

```java
// create object representing the German edition of Wiktionary
Wiktionary wiktionary = new Wiktionary(DB_PATH, Language.GERMAN);

// add the English edition of Wiktionary
wiktionary.addWiktionary(DB_PATH, Language.English);

// take only entries for German words into account
wiktionary.setWordLanguage(Language.German);

// query Wiktionary for "bank"
List<WiktionaryWord> wordList = wiktionary.getWords("bank");
```

Listing 5: Working with a WiktionaryWord object.

```java
// get first word from the wordList retrieved in Listing 4
WiktionaryWord word = wordList.get(0);

// get part-of-speech
PartOfSpeech pos = word.getPartOfSpeech();

// get the gloss of the first sense
String gloss = word.getGloss(0);

// get hyponyms for the first sense
List<String> hyponyms = getRelatedTerms( Relation.HYPONYMY, 0);
```