Linguistic Linked Data for Sentiment Analysis

Paul Buitelaar,
Mihael Arcan
DERI, Unit for NLP,
National University of Ireland, Galway
{paul.buitelaar, mihael.arcan}@deri.org

Carlos A. Iglesias,
J. Fernando Sánchez-Rada
Dept. Ing. Sist. Telemáticos,
Univ. Politécnica de Madrid,
Spain
{cif, jfernando}@gsi.dit.upm.es

Carlo Strapparava
Human Language Technology
FBK, Italy
strappa@fbk.eu

1 Introduction

In this paper we describe the specification of a model for the semantically interoperable representation of language resources for sentiment analysis. The model integrates 'lemon', an RDF-based model for the specification of ontology-lexica (Buitelaar et al. 2009), which is used increasingly for the representation of language resources as Linked Data, with 'Marl', an RDF-based model for the representation of sentiment annotations (Westerski et al., 2011; Sánchez-Rada et al., 2013).

In the EuroSentiment project, the lemon/Marl model will be used to represent lexical resources for sentiment and emotion analysis such as SentiWordNet (Baccianella et al. 2010) and WordNet Affect[1] (Strapparava and Valitutti 2004), as well as other language resources such as sentiment annotated corpora, in a semantically interoperable way, using Linked data principles.

The representation of WordNet resources in lemon depends on a straightforward conversion of the WordNet data model, but importantly we introduce the use of URIs to uniquely and formally define structure and content of this WordNet based language resource. URIs are adopted from existing Linked Data resources, thereby further enhancing semantic interoperability. We further integrate a notion of domains into this representation in order to enable domain-specific definition of polarity for each lexical item.

The lemon model allows for the representation of all aspects of lexical information, including lexical sense (word meaning) and polarity, but also morphosyntactic features such as part-of-speech, inflection, etc. This kind of information is not provided by WordNet Affect but will be available from other language resources, including those available at EuroSentiment partners that can be easily integrated with the WordNet Affect information using lemon.

The representation of sentiment polarity uses concepts from Marl.

2 Motivation

Sentiment analysis is now an established field of research and a growing industry (Po et al. 2008). However, language resources for sentiment analysis are being developed by individual companies or research organisations and are normally not shared, with the exception of a few publicly available resources such as WordNet Affect and SentiWordNet. Domain-specific resources for multiple languages are potentially valuable but not shared, sometimes due to IP and licence considerations, but often because of technical reasons, including interoperability.

In the EuroSentiment project we envision instead a pool of semantically interoperable language resources for sentiment analysis, including domain-specific lexicons and annotated corpora. Sentiment analysis applications will be able to: access domain-specific polarity scores for individual lexical items in the context of semantically defined sentiment lexicons and corpora, or access and integrate complete language resources. Access may be restricted according to commercial considerations, with payment schedules in place, or may be partially free. A semantic service access layer will be put in place for this purpose.

3 The lemon Model

The lexicon model for ontologies (lemon) builds on previous work on standards for the representation of lexical resources, i.e., the Lexical Markup Framework (LMF[2]) but extends the underlying formal model and provides a native integration of lexica with domain ontologies. The lemon model is

[1] http://wndomains.fbk.eu/wnaffect.html

[2] http://www.lexicalmarkupframework.org/

described in detail in the lemon cookbook (McCrae et al. 2010). Here we provide a summary of its most prominent features, starting with the lemon core, which is organized around a core path as follows:

- *Ontology Entity*: URI of an ontology element to which a Lexical Form points, providing a possible linguistic realisation for that Ontology Entity
- *Lexical Sense*: functional object that links a Lexical Entry to an Ontology Entity, providing a sense-disambiguated interpretation of that Lexical Entry
- *Lexical Entry*: morpho-syntactic normalisation of one or more Lexical Form
- *Lexical Form*: morpho-syntactic variant of a Lexical Entry, including inflection, declination and syntactic variation
- *Representation*: standard written or phonetic representation for a Lexical Form

In addition, lemon has a number of modules that allow for further modelling. Currently defined modules are: linguistic description, phrase structure, morphology, syntax and mapping, variation.

The linguistic description module is concerned with the use of ISOcat data categories for describing lemon elements. Although lemon itself is a meta-model and therefore agnostic as regards the specific data category set used, we use a specific set of data categories in particular instances of the lemon model, such as LexInfo (Cimiano et al. 2011).

The phrase structure module is concerned with the modelling of lexical entries that are syntactically complex, such as phrases and clauses. The module provides tokenisation and phrase structure analysis to enable representation of the syntactic structure of such lexical entries.

The morphology module is concerned with the analysis and representation of inflectional and agglutinative morphology. The module allows the specification of regular inflections of words by use of Perl-like regular expressions, which greatly simplifies the creation of lexical entries for highly synthetic and inflectional languages.

The syntax and mapping module is concerned with a description of lexical 'predicates' (subcategorisation frames with syntactic arguments) and semantic predicates (properties with subject/object) on the ontology side and the mapping between them. The module allows a mapping to be specified as a one-to-one correspondence.

The variation module is concerned with a description of the relationships between the elements of a lemon lexicon, which are split into three classes: sense relations, lexical variations, form variations. Sense relations require a semantic context, such as translation. Lexical variations require a morphosyntactic context, such as plural. Form variations are all other variations, such as homographs.

An interesting aspect of lemon-based ontology lexicalisation is the use of URIs for uniquely identifying all objects defined by the lemon model (lexicons, lexical entries, words, phrases, forms, variants, senses, references, etc.), which can be linked and maintained in a flexible, modular and distributed way. The lemon model can therefore contribute significantly to the development of Lexical Linked Data (McCrae et al. 2011, Nuzzolese et al. 2011, McCrae et al. 2012), which in turn will greatly enhance distributed development, exchange, maintenance and use of lexical resources as well as of ontologies as they will be increasingly tightly integrated with lexical knowledge.

In the context of the EuroSentiment project we will exploit the lemon model exactly for this purpose: representing language resources for sentiment analysis in a Linked Data conform way (RDF-native form), enabling leverage of existing Semantic Web technologies (SPARQL, OWL, RIF etc.).

4 The Marl Sentiment Ontology

Marl is an ontology for annotating sentiment expressions, which will be used by the EuroSentiment service layer to describe the output of sentiment analysis services as well as by the resource layer to describe the sentiment properties of lexical entries. For this latter purpose in particular, the Marl ontology is used in combination with lemon as illustrated above.

The Marl ontology is a vocabulary designed for annotation and description of subjective opinions expressed in text. The goals of the Marl ontology are to:

- enable publishing raw data about opinions and the sentiments expressed in them
- deliver schema that will allow to compare opinions coming from different systems (polarity, topics and features)

- interconnect opinions by linking them to contextual information expressed from other popular ontologies or specialised domain ontologies.

The Marl ontology has been extended according to the needs of the EuroSentiment project. In particular, the main extension has been its alignment with the PROV-O Ontology (Lebo, 2013) in order to support provenance modelling. The PROV-O ontology is part of the PROV Family (Groth, 2012; Gil, 2012) that provides support for modelling and interchange of provenance on the Web and Information Systems.

Provenance is information about entities, activities and people involved in producing a piece of data or thing, which can be used to form assessment about its quality, reliability and trustworthiness. The main concepts of PROV are entities, activities and agents. Entities are physical or digital assets, such as web pages, spell checkers or, in our case, dictionaries or analysis services. Provenance records describe the provenance of entities, and an entity's provenance can refer to other entities. For example, a dictionary is an entity whose provenance refers to other entities such as lexical entries. Activities are how entities come into existence. For example, starting from a web page, a sentiment analysis activity creates an opinion entity describing the extracted opinions from that web page. Finally, agents are responsible for the activities and can be a person, a piece of software, an organisation or other entities. The Marl ontology has been aligned with the PROV ontology so that provenance of language resources can be tracked and shared.

Sentiment Analysis is an Activity that analyses a Source text according to an algorithm and produces an opinion about the entities described in the source text. The main features of the extracted opinion are the polarity (positive, neutral or negative), the polarity value or strength whose range is defined between a min and max value, and the described entity and feature of that opinion. Opinions can also be aggregated opinions of a set of users.

For a better understanding of the ontology itself, we present below the main classes and properties that form the ontology:

- *Opinion*: a subclass of the Provenance Entity that represents the results of a Sentiment Analysis process. Among its classes we find:
- *describesObject*: property that points to the object the opinion refers to.
- *describesObjectPart*: optional property, used whenever the opinion specifies the part of the object it refers to, not only the general object.
- *describesObjectFeature*: aspect of the object or part that the user is giving an opinion of.
- *hasPolarity*: polarity of the opinion itself, to be chosen from the available Opinion individuals.
- *polarityValue*: degree of the polarity. In other words, it represents how strong the opinion (independently of the polarity) is.
- *algorithmConfidence*: rating the analysis algorithm has given to this particular result. Can be interpreted as the accuracy or trustworthiness of the information
- *extractedFrom*: original source text or resource from which the opinion was extracted.
- *opinionText*: part of the source that was used in the sentiment analysis. That is, the part of the source that contained sentiment information.
- *domain*: context domain of the result. The same source can be analysed in different domains, which would lead to different results.
- *AggregatedOpinion*: when several opinions are equivalent, we can opt to aggregate them into an “AggregatedOpinion”, which in addition to the properties we already covered, it presents these properties:
- *opinionCount*: the number of individual opinions this AggregatedOpinion represents.
- *Polarity*: base class to represent the polarity of the opinion. In every opinion, we will use an instance of this class. The base Marl ontology comes with three instances: Positive, Negative, Neutral
- *SentimentAnalysis*: in Marl, the process of sentiment analysis is also represented semantically, which allows us to understand the opinion data, trace it and keep several results by different algorithms, linking all of them to the process that created them. The main properties of each SentimentAnalysis class are: minPolarityValue: lower limit for polarity values in the opinions extracted via this analysis activity; maxPolarityValue: upper limit for polarity values in the opinions extracted via this analysis activity.
- *Algorithm*: algorithm that was used in the analysis. Useful to group opinions by extraction algorithm and compare them.
- *source*: site or source from which the opinion was extracted. There are two reasons behind this property: grouping by opinion source (e.g. opin-

ions from IMDB) and treating and interpreting opinions from the same source in the same manner.

An example application of the Marl ontology for a sentiment analysis service is shown in the Appendix. It is split in two: a view of the representation of the analysis (Fig 1), and a representation of the result (Fig 2).

5 Representation of WordNet Affect

In this section we describe how language resources based on the Princeton WordNet model (Miller 1995) such as WordNet Affect can be represented using lemon.

WordNet Affect is an extension of the WordNet database, including a subset of synsets suitable to represent affective concepts. Similarly to the extension related to domain labels, one or more affective labels (a-labels) are assigned to a number of WordNet synsets. In particular, the affective concepts representing emotional state are individuated by synsets marked with the a-label ‘emotion’. The emotional categories are hierarchically organized in order to specialize synsets with a-label emotion and to distinguish synsets according to emotional valence. There are also other a-labels for concepts representing moods, situations eliciting emotions, or emotional responses[3].

Unique and independently established URIs for WordNet synsets allow for a distributed representation that enable Semantic Web based linking between and integration of WordNet based as well as other language resources. We illustrate this here with an example from WordNet Affect, using English based WordNet 3.0 URIs as defined by the Europeana project.

Consider the following example for the English noun ‘fear’ in WordNet and equivalent Italian synonyms taken from the Italian WordNet (i.e. this holds for any English aligned Wordnet) in WordNet Affect:

Princeton WordNet:

n#05590260 12 n 03 fear 0 fearfulness 0 fright 0 017 @ 05560878 n 0000 ! 05595229 n 0101 = 00080744 a 0000 = 00084648 a 0000 ~ 05590744 n 0000 ~ 05590900 n 0000 ~ 05591021 n 0000 ~ 05591212 n 0000 ~ 05591290 n 0000 ~ 05591377 n 0000 ~ 05591481 n 0000 ~ 05591591 n 0000 ~ 05591681 n 0000 ~ 05591792 n 0000 ~ 05592739 n 0000 ~ 05593389 n 0000 %p 10337259 n 0000 | an emotion experienced in anticipation of some specific pain or danger (usually accompanied by a desire to flee or fight)

WordNet Affect:

n#05590260 fifa paura spavento terrore timore |
"una emozione che si prova prima di qualche specifico dolore o pericolo"
n#05590260 affective-label="negative-fear"
n#05590260 domain-label="Psychological_Features"

***lemon* transformation & integration:**

Using lemon we can represent and integrate information on the Italian synonyms, their links to the English based synset using Princeton WordNet URIs, and sentiment properties using Marl. Domain properties will be based on WordNet Domains[4]. The example illustrates the positive polarity of ‘fear’ in English (and ‘fifa, paura, spavento, terrore’ in Italian) in the context of ‘horror movies’ and negative polarity in the context of ‘children movies’.

Declaration of namespaces used – *wn* declares WordNet 3.0 synsets, *lemon* declares the core lemon lexicon model, *lexinfo* declares specific properties for part-of-speech etc., *wd* declares domain categories, *marl* declares sentiment properties:

```
@prefix wn: <http://semanticweb.cs.vu.nl/europeana/lod/purl/vocabularies/princeton/wn30/> .
@prefix lemon: <http://www.monnet-project.eu/lemon#> .
@prefix lexinfo: <http://www.lexinfo.net/ontology/2.0/lexinfo#> .
@prefix wd: <http://www.eurosentiment.eu/wndomains/> .
@prefix marl: <http://purl.org/marl/ns#> .
```

Declaration of lexicon identifier, language and lexical entries:

```
:lexicon a lemon:Lexicon ;
   lemon:language "it" ;
   lemon:entry     :fifa,
                   :paura,
                   :spavento,
                   :terrore.
```

[3] A SKOS version of WordNet Affect is available from http://gsi.dit.upm.es/ontologies/wnaffect/

[4] http://wndomains.fbk.eu/

Declaration of lemma, sense (link to synset in WordNet 3.0, polarity and domain context) and part-of-speech of ‘fifa’:

```
:fifa a lemon:Lexicalentry ;
  lemon:canonicalForm [ lemon:writtenRep
"fifa"@it ] ;
  lemon:sense [ lemon:reference wn:synset-fear-noun-1;
          marl:polarityValue 0.375 ;
          marl:hasPolarity marl:positive ;
          lemon:context wd:horror_movies ] ;
  lemon:sense [ lemon:reference wn:synset-fear-noun-1;
          marl:polarityValue 0.375 ;
          marl:hasPolarity marl:negative ;
          lemon:context wd:children_movies ];
  lexinfo:partOfSpeech lexinfo:noun .
```

Declarations of lemma and part-of-speech of ‘paura, spavento, terrore, timore’:

```
:paura a lemon:Lexicalentry ;
   lemon:canonicalForm [ lemon:writtenRep
          "paura"@it ] ;
   lexinfo:partOfSpeech lexinfo:noun .

:spavento a lemon:Lexicalentry ;
   lemon:canonicalForm [ lemon:writtenRep
          "spavento"@it ] ;
   lexinfo:partOfSpeech lexinfo:noun .

:terrore a lemon:Lexicalentry ;
   lemon:canonicalForm [ lemon:writtenRep
          "terrore"@it ] ;
   lexinfo:partOfSpeech lexinfo:noun .

:timore a lemon:Lexicalentry ;
   lemon:canonicalForm [ lemon:writtenRep
          "timore"@it ] ;
   lexinfo:partOfSpeech lexinfo:noun .
```

Declarations of sense equivalence (synonymy) of ‘paura, spavento, terrore, timore’ with ‘fifa’:

```
:paura a lemon:LexicalSense ;
          lemon:equivalent :fifa.

:spavento a lemon:LexicalSense ;
          lemon:equivalent :fifa.

:terrore a lemon:LexicalSense ;
          lemon:equivalent :fifa.

:timore a lemon:LexicalSense ;
          lemon:equivalent :fifa..
```

6 Representation of Lexical and Sentiment Features

The examples discussed in the previous section showed the representation of WordNet based language resources with lemon. However also many other types of language resources exist, including sentiment dictionaries maintained by the EuroSentiment use case partners that define domain words with their polarity scores as well as inflectional variants, part-of-speech, etc. We can also represent such language resources using lemon combined with Marl, thereby making them interoperable with the lemon version of WordNet Affect as well as other lemon based language resources.

Consider the following example for the German noun ‘Einschlag’ (‘impact’) with lexical features (inflection, part-of-speech) and polarity score:

```
Einschlag    Einschlag NN negative -/-0.0048/- L
Einschlages Einschlag NN negative -/-0.0048/- L
Einschlags   Einschlag NN negative -/-0.0048/- L
Einschläge   Einschlag NN negative -/-0.0048/- L
Einschlägen Einschlag NN negative -/-0.0048/- L
```

Using lemon and Marl we can represent this and integrate it with additional information as follows:

Declaration of namespaces used – *wn* declares WordNet 3.0 synsets, *lemon* declares the core lemon lexicon model, *isocat* declares specific properties for part-of-speech etc. (*isocat* is part of the *lexinfo* model used in the previous example), *marl* declares sentiment properties:

```
@prefix wn:
<http://semanticweb.cs.vu.nl/europeana/lod/purl/vo-
cabularies/princeton/wn30/> .
@prefix lemon: <http://www.monnet-
project.eu/lemon#> .
@prefix isocat: <https://catalog.clarin.eu/isocat/inter-
face/index.html> .
@prefix marl:
<http://gsi.dit.upm.es/ontologies/marl/ns#> .
```

Declaration of lexicon identifier, language and lexical entry:

```
:lexicon a lemon:Lexicon ;
   lemon:language "de" ;
   lemon:entry :Einschlag.
```

Declaration of lemma, sense (link to synset in WordNet 3.0, polarity), alternate forms (inflectional variants with features), part-of-speech and sentiment polarity:

```
:Einschlag
```

```
lemon:canonicalForm [
  lemon:writtenRep "Einschlag"@de ;
       isocat:DC-1297 isocat:DC-1883 ;
       # gender=masculine
       isocat:DC-1298 isocat:DC-1387 ;
       # number=singular
       isocat:DC-2720 isocat:DC-1331 ] ;
       # case=nominative
  lemon:sense [ lemon:reference
       wn:synset-impact-noun-1;
       marl:polarityValue 0.0048;
        marl:hasPolarity marl:negative ] ;
  lemon:altForm
    [ lemon:writtenRep "Einschlages"@de ;
       isocat:DC-1297 isocat:DC-1883 ;
       # gender=masculine
       isocat:DC-1298 isocat:DC-1387 ;
       # number=singular
       isocat:DC-2720 isocat:DC-1293 ] ;
       # case=genitive
    [ lemon:writtenRep "Einschlags"@de ;
       isocat:DC-1297 isocat:DC-1883 ;
       # gender=masculine
       isocat:DC-1298 isocat:DC-1387 ;
       # number=singular
       isocat:DC-2720 isocat:DC-1293 ] ;
       # case=genitive
    [ lemon:writtenRep "Einschläge"@de ;
       isocat:DC-1297 isocat:DC-1883 ;
       # gender=masculine
       isocat:DC-1298 isocat:DC-1354 ;
       # number=plural
       isocat:DC-2720 isocat:DC-1331 ] ;
       # case=nominative
    [ lemon:writtenRep "Einschlägen"@de ;
       isocat:DC-1297 isocat:DC-1883 ;
       # gender=masculine
       isocat:DC-1298 isocat:DC-1354 ;
       # number=plural
       isocat:DC-2720 isocat:DC-1265 ] ;
       # case=dative
isocat:DC-1345 isocat:DC-1333.
# partOfSpeech=noun.
```

7 Ongoing and Future Work

Sentiment Analysis aims at determining the attitude of the writer to some topic (positive, negative, neutral). Emotion analysis goes one step further and aims at determining the emotional or affective state of the writer when writing. In EuroSentiment, we have defined two vocabularies for annotating sentiment and emotion expressions, called Marl and Onyx, respectively. In this paper we focused on the representation of sentiment annotations with Marl. The definition and representation of emotion expressions with Onyx is ongoing work, with the objective of covering different theoretical models of emotions (Sánchez-Rada et al., 2013). Onyx will support the representation and use of several emotion taxonomies such as WordNet Affect or EmotionML

Our ongoing and future work is concerned also with the definition and implementation of a work flow that will enable the generation of domain-specific semantically interoperable lexica for sentiment analysis. The work flow will use lemon and Marl for the representation and integration of:

- WordNet Domains information on domain(s)
- domain entity information from DBpedia and/or other relevant semantic resources
- WordNet Affect information on synsets (using Onyx)
- morphosyntactic information (part-of-speech, inflection, …) from other language resources in the EuroSentiment Language Resource Pool
- SentiWordNet scores and/or automatically extracted domain sentiment scores

Given a particular sentiment analysis task domain, the approach is based on the analysis of a representative text collection for the purpose of entity identification, synset disambiguation, morphosyntactic analysis, and domain-specific polarity value extraction.

8 Conclusions

We presented a model for the specification, integration and use of language resources for sentiment analysis based on Linked Data principles.

The presented model is based directly on the lemon and Marl ontologies for the representation of Linked Data based lexical resources and sentiment expressions respectively. This work is now being extended so that emotion analysis is also addressed.

In the context of the EuroSentiment project the combined model will be used for the integrated and semantically interoperable representation of sentiment dictionaries and annotations. As a result, EuroSentiment will make available lexical resources based on this interoperable representation with the aim of fostering the development of services using sentiment analysis.

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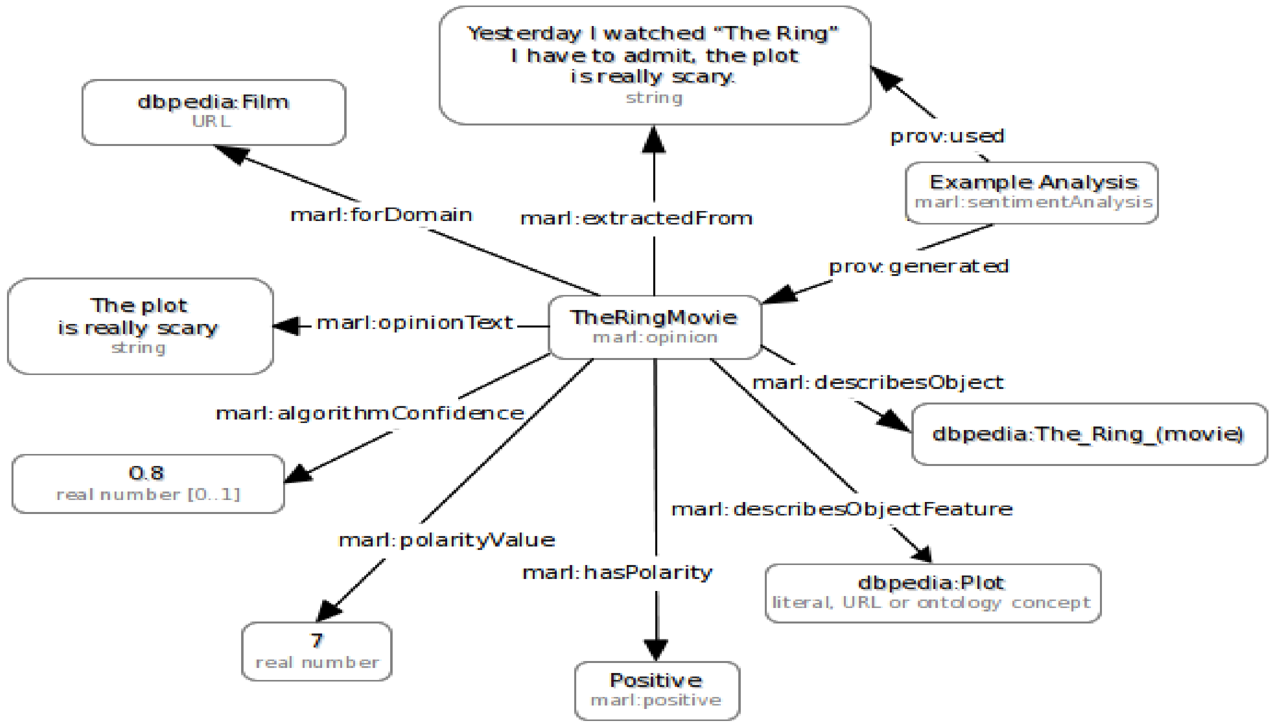

Figure 1: Example of a Sentiment Analysis activity representation

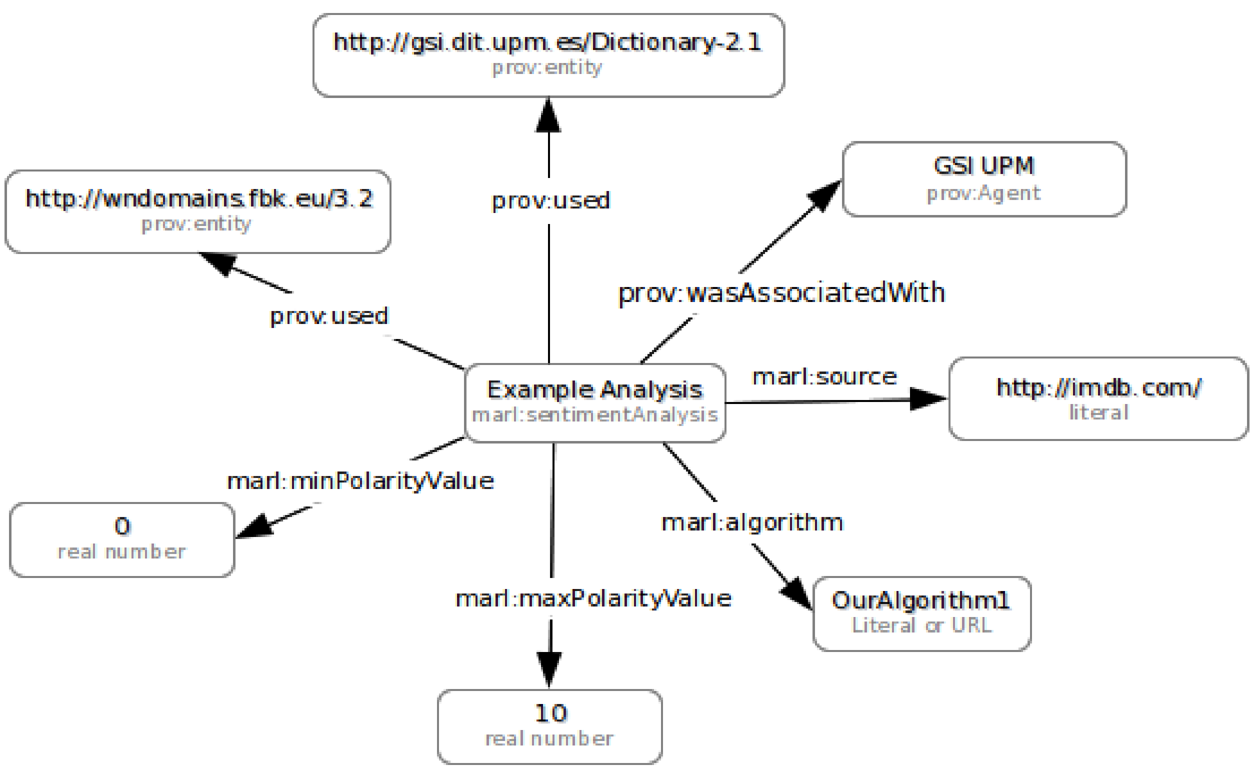

Figure 2: Example Sentiment Analysis result