A Multi-Layer Approach to the Derivation of Schema Components of Ontologies from German Text

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***Abstract*—We describe an on-going work on the semi-automatic derivation of ontological structures from text. Hereby, we first apply on plain text pattern-based linguistic heuristics, for identifying relevant segments out of which candidate ontology classes and relations can be derived. The second step proposes a consolidation of those candidates on the basis of a partial linguistic and semantic analysis of the textual context of the segments. The last step is dealing with the extension of the derived ontology structures. We use for this a constituency and dependency analysis of the textual segments selected in steps 1 and 2. We show how these three steps support in different but related ways the derivation of ontology components from text.**

Keywords – knowledge acquisition; text-based knowledge

I. Introduction

We describe a semi-automatic incremental multi-layer rule-based methodology for the derivation of ontology schema components from a corpus consisting of the 1992 edition of the German newspaper "Wirtschaftswoche". We use this somehow older corpus, since it has been manually annotated with various types of information. The corpus comprises 200107 words, 11583 sentences and 121331 phrases. By *Derivation of Ontology Schema Components* we mean the acquisition from text of possible concepts and relations between these concepts for the semi-automatic ontology building. By *Ontology Schema* we mean a construct similar to the T-Box of an ontology [23]. Our work is addressing the intensional part of ontologies and can be considered as contributing to the ontology learning field at large. Ontology learning is the process of semi-automatic support in ontology development (see [1]).

We are dealing in our work primarily with German text. In this concrete case, we consider compound nouns and their paraphrases in the corpus as the basic segments in text that can serve for the detection of candidate ontology classes and relations. Compounding is a very rich word formation process in German (and other related Germanic languages), also with well-established construction patterns corresponding to semantic types, which makes them good candidates for the derivation of ontology schema components. We use paraphrases of nominal compounds in the corpus for fixing their status as candidates for classes and for specifying the relations existing between those classes. Paraphrases of compounds are defined as a text segment containing the elements of the compound nouns separated by a limited number of other word forms.

In a second step, we apply morphological, Part-of-Speech (PoS) and lexical-semantic analysis to the text segments described in step1. This helps further filtering out and further specifying the previously derived candidates, avoiding redundancies in the derivation of classes (limiting the names of class labels to lemmas, and joining labels that are synonyms, etc.)

In the last step, we extend the extracted classes and relations on the basis of deeper linguistic processing, more precisely analyzing the constituency and dependency structures of the context of the detected textual segments. Our approach results in a set of generic patterns (in machine learning language we would call them seeds) for deriving a stable structure of conceptual relations from the combined shallow and linguistic analysis of specific textual segments.

The paper is structured as follows. Section 2 gives an overview on related work. Section 3 describes the pattern-based processing of text for detecting segments containing candidates for ontology derivation. Section 4 presents the ontology derivation potential from the textual context of the segments, annotated with PoS, morphology, and lexical semantics. Section 5 deals with the refinement of the ontology derived so far, using constituency and dependency information. Section 6 describes some evaluation work and Section 7 concludes and names some issues for further work.

II. Related Work

There are purely linguistic approaches to Ontology Learning ([3][4][5]), linguistic approaches making use of machine learning for generalization ([6]) and machine learning approaches that use linguistic information ([2][7]). Those approaches have in common that they concentrate on discovering new relations, although some approaches are dealing with the discovery of new concepts ([2][6][8]) too.

The purely linguistic approaches ([3][4][5]) perform ontology learning on the basis of deep linguistic analysis, by activating a graphical interface controlled by the user for entering the extracted knowledge into the ontology.

The method proposed in this paper is based on linguistic patterns, combining shallow and deep linguistic analysis, in an unsupervised way, and thus not involving authoring tools.

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Our work resembles most the one presented by [6], but our combination from shallow and deep linguistic analysis allows covering a wider range of phenomena for the derivation of schema components of ontologies.

III. PATTERN-BASED TEXT ANALYSIS

Although pattern-based linguistic heuristics alone is not enough to acquire extended and complex ontological knowledge, a pre-processing of the plain text is very important when it comes to define an anchor (text segment) from which to start the computationally more expensive process of ontology learning.

A. Detection of Candidate Concepts and Relations

A first intuition guiding our investigation is the fact that German nominal compounds are good indicators for the expression of relations between concepts expressed by the elements of the compounds. According to [9], the German determinative compounds (determinative compounds are those in which one element is subordinated to the other element of the other, more precisely, one element determines/specifies the other element [10]) consist mostly of two elements, whereas the first one usually specifies the second. From this observation one can heuristically derive a hyponymy relation between the whole compound and its second element: *Konzernchef* (*chief of corporation*) is a specific type of a C*hef (chief).*

Although German uses also copulative compounds, we do not expand on those in the actual paper, in which we concentrate on binary determinative noun-noun compounds (copulative compounds are compounds were the elements are considered semantically coequal and which do not have a main element which specifies or determines the other element in the compound. This type of compounding is more seldom in German [11]). We implemented a quite straightforward pattern-based algorithm for the detection of this type of compounds: we first search for nouns in the corpus (for German, a string starting with a capital letter between blanks or between a blank and a punctuation sign). If, in a second search round, we can detect that such a noun item appears as sub-string in a larger noun, then we considered that we have found a compound. While this approach works quite well for finding the nouns acting as the prefix of a compound (since it starts with a capital letter), we need to access a lexicon for deciding if the suffix of the compound is also a noun (we use for this the lexicon listed in [24].)

We include in our patterns the German joint elements (Fugeelement) which may appear in compounds (such as "*s*" in *Wohnungsbau* (*house building*), in order to get the right string, when the word is used in isolation. But with our very simple approach we do miss the nouns that undergo morphology changes when they are used in a compound.

We consider the two elements of a nominal compound as acting as potential ontology classes, and the remaining task is then to specify the possible relations between these two nouns, or candidate ontology classes.

B. Deriving Candidate Ontology Classes and Relations from Nominal Compounds

On the basis of the detection of compounds, and assuming that elements of compounds act as possible ontology classes, we suggest two rules for deriving potential elements for the schema of an ontology: the structural type represented by the *subClassOf* relation (rendering the relation between the whole compound and its second element) and a relation denoting an *objectProperty* (rendering the relation between the two elements of the compound). We are using here the OWL-DL terminology for the property name.

The first rule states that between a compound as a whole and its second noun there is a subClassOf relation. This decision is motivated by the definition of the determinative compounds which introduces hyponymy between the compound and its second noun.

For example, from the compound *Bankenvertreter* we derive the relation: *subClassOf(Bankenvertreter, Vertreter),* which translated into English means that a *representative of a bank* is a *subClassOf* a *representative*.

Our intuition - sustained by the already existing analyses of the German compound ([11][12][13]) - was that there exists also an additional relationship between the elements of a compound, which we consider of being of type *objectProperty*. Applying the corresponding rule to the already mentioned compound *Bankvertreter* we derive a *objectProperty(Bank, Vertreter)* relation between the class *Bank (bank)* and the class *Vetreter (representative).*

Obviously, the (naïve) processing strategy presented above is very general and the very generic *objectProperty* relation we can derive is not really satisfying. In order to improve this state, we try to find expressions in the text that are containing paraphrases of the compounds, expecting to find more semantic information for allowing the further specification of the (generic) object property relation we established between the elements of a compound.

C. Patterns for the Recognition of Paraphrases of Compounds

After splitting the compound back into *noun1* + *noun2* we automatically search for paraphrases (in our context a paraphrase consists of a test window that contains the elements of a compound separately) of all found compounds in our corpus. Our decision to look for the paraphrases of compounds is motivated by the fact, that while we assume that the elements of a compound are semantically related to each other, analyzing the paraphrases will allow specifying more precisely this relation [9]. Compounds without a paraphrase are no longer considered for ontology derivation. For now the search space for detecting paraphrases is our corpus, but this will be extended to other corpora.

Our assumption is also sustained by [11] and [13]. Although they have two different methods for approaching this issue, the main idea is the same: the elements of a compound are semantically related to each other and this relation becomes visible in the paraphrase.

We find in the corpus two kinds of paraphrases, in which the elements of the original compounds are linguistically related: either by a genitive article as *Vertreter der Bank (representative of the bank)* or by a preposition as *Chef im Konzern (chief of corporation).* The finding of a paraphrase for a compound validates the *subClassOf* relation, whereas the use of lexical semantics on the elements of a paraphrase allows specifying the *objectProperty*.

IV. SHALLOW LINGUISTIC ANALYSIS

The addition of PoS and morphology annotation to the paraphrases helps in solving the redundancy problem of the ontology classes: by using lemmas for generating names of classes we avoid generating as many classes as this lemma has morphological variations in the text. Lexical semantics allows reducing the number of classes by grouping lemmas to more general "words" (like the synsets of GermaNet (GN) [14]) and at the same time specifying the derived generic relation *objectProperty* according to the semantics (therefore we use GN's semantic fields for nouns: artifact, attribute, shape, feeling, body, cognition, communication, motive, food, object, phenomenon, plant, substance, time, animal, state, act, process, person, group, possession, relation, attribute, event, quantity, location) of these lemmas and of other word forms present in the paraphrase.

A. Specifying Relations with Lexical Semantics

Analyzing the paraphrases annotated with GN's semantic information we discovered the following six relations between the already detected classes:

- *hasPosition,*
- *disposesOver,*
- *hasDimension,*
- *hasAttribute,*
- *hasEvent,*
- *hasLocation.*

For example, for the compound *Aktiengesellschaft (stock company)* we found the reformulation *Aktien der Gesellschaft (shares of the company)*, where *Aktien* was semantically classified as belonging to GN's semantic class *possession* and *Gesellschaft* has been classified as belonging to GN's semantic class *group* enabling the structural integration of the discovered classes and relations into a more sophisticated ontology structure. The heuristics for the derivation of the relation between the two concepts *Aktien (shares*) and *Gesellschaft (company)* proposes the verbalization of the more generic class to which the first noun in the paraphrase belongs. This way the verbalized *possession* was transformed into *disposesOver* generating *disposesOver(Gesellschaft, Aktien).*

Applying morphology and lexical semantics to the second type of paraphrase patterns, those involving prepositions, we notice that the generic *objectProperty* can be further specialized depending on the lexical semantics of the used prepositions.

Prepositions are semantically ambiguous, but the ambiguity can be reduced on the base of the lexical semantics of the associated nouns. Analyzing this type of paraphrases we discovered, based on the same heuristics as for genitive phrases, a set of six rules for the derivation of ontological relations. From this six relations, five were already discovered during the analysis of genitive phrases: *disposesOver, hasDimension, hasAttribute, hasEvent,* and *hasLocation.* Only one relation is new: the *hasAffiliation* relation.

B. Analyzing Modification Phenomena

In the process of detecting paraphrases we observed that many of the paraphrases contain modifiers. In order to determine the type of ontological relation that can be extracted from the structure modifier(s)-nominal head (such as *multinationale Gesellschaft* (*multinational corporation*)), some components of the structure had to be viewed from a lexical semantic point of view. We concentrate here on adjectives and adverbs, and apply to them various language specific classification schemes.

For adjectives we used the classification by [15] and for adverbs the classification by [16] (we use for modifiers this semantic classification because they are more fine-grained than GermaNet's classification and we can easily add new adjectives and adverbs to it). As for nouns, the semantic classes to which the adjectives and adverbs belong are introduced as ontology classes.

Based on this classification we introduce new relations between the modifiers and the noun they modify. Having for example the paraphrase *Aktien der deutschen Gesellschaft* (*shares of the German corporation*), the derivation rule will return the following relation: *hasNationality(Gesellschaft, Nationality).* Here *hasNationality* is a subproperty of *hasAffiliation.*

Many of the nouns appearing in paraphrases are modified by just one modifier. But there are cases in the corpus in which a noun is preceded by more than one modifier. For multiple premodifiers which are not separated by any punctuation sign or conjunction to each other, we speak of an aggregation of adjectives. For example for *großen deutschen Konzern* (*large German concern*), linguistically the first premodifier in the token chain modifies the remaining phrase [17]. From this kind of linguistic constructions we extract *hasNationality(Konzern, Nationality)* and *hasDimension(Konzern, Dimension).*

A different linguistic principle applies for modifiers connected by punctuation signs or/and conjunctions: each pre-modifier introduces a relation between itself and the noun it modifies [17]. From *kleinen, krisengeplagten Firmen* (*small firms, affected by the crisis*) we extract *hasDimension(Firma, Dimension)* and *hasMode(Firma, Mode)*. As one can see, we cannot model directly the two different ways plural modification is linguistically working in the ontology.

A more specific case is represented by the modification of adjectives by adverbs such in *sehr großes Gehalt* (*very big salary*). In this case the adverb *sehr* modifies the adjective *großes* and not the whole phrase [10] *großes Gehalt.* We extract then the relations: *hasAspect(Dimension, Aspect)* and *hasDimension(Gehalt, Dimension).*

Since modification is a very powerful linguistic phenomenon with a high coverage in the corpus, the three extraction rules discussed above cover 26 relations, depending on the semantic class of the modifier.

V. PHRASE STRUCTURE AND SYNTACTIC INFORMATION

Although, many extraction rules were generated with the shallow linguistic analysis, we are aware that the sentential level is an additional resource for the extraction of ontological information. We decided to first analyze predicate-argument structures in all sentences containing a paraphrase, since those contain in our sense already enough hints for possible ontology classes and relations. The analysis of the extracted sentences has shown that there is potential for extracting additional ontology schema components. In this case we also have to take into account additional PoS tags and morphological information (for example for the verbs). As a lexical-semantic resource for the verb, we use both the classification by [18] and GN.

A. Extraction of Ontology Schema Components from Grammatical Functions

With the help of grammatical functions (for example the subject-object relation in a sentence) we developed a set of rules for extracting the arguments of specific verbs in the corpus. This allows extracting relations such as

- *earn,*
- *appliesFor,*
- *estimate,*
- *hasPossession,*
- *partOf,*
- *subClassOf,*
- *etc.*

Let us consider the following sentence: *Die Papierherstellung ist zu einer extrem kapitalintensiven Branche geworden* (*Paper production evolved to a very capital-intensive branch*). In this example, the verb *sein* (*be*) connects the subject *Papierherstellung* (*paper production*) and the *kapitalintensiven Branche* (*capital-intensive branch*) of the sentence.

In fact, the rule states that only the nominal heads of the phrases identified as subject and object enter the ontology and therefore we extract *subClassOf(Papierherstellung, Branche*). Additionally, for each of the two nouns we use GN's information about synonyms, antonyms, hyponyms and meronyms. In a next step, we include then also the information that *Branche* can have the property *kapitalintensiv*.

VI. EVALUATION

The evaluation of the method for extracting ontology schema components was performed on a manually annotated test suite. The test suite consists of 200 randomly selected sentences (out of over 11000) which were annotated by a student of business informatics. We plan to ask another person to annotate the same corpus. This was till now not possible for time reasons.

We applied our method and the corresponding tools on this test corpus. The quantitative evaluation was performed in two stages, and after each stage we measured the performance of our method. We compared the results of our method with the manual annotation by calculating the F-measure.

TABLE 1. PRECISION AND RECALL SCORES

Phenomenon	Prec.	Recall	1st run	2nd run
Compound (*subClassOf*)	1	1	1	1
Modification	1	0,52	0,68	1
(Para)phrase	1	0,23	0,37	0,76
Gramm Funct.	0.5	0,30	0,38	0,80

From the results in Table 1 we notice that we have the best results when it comes to extract the *subClassOf* relation, which is extracted mainly from compounds. It seems that our compound filtering process is really helping in getting a high number of correct answers. But it seems also that the 200 manually annotated sentences contain only determinative compounds, and we would have to test our method on copulative compounds too.

The *subClassOf* relation is extracted not only from compounds but is introduced into the ontology from GN (using the more abstract “words” in the synsets). In this case the left-hand side argument of the *subClassOf* relation differs from the one chosen by the manual annotator.

We consider still our method to be valid, since we found it totally normal that a human being annotates semantically different than GN (the student didn't have GN as a resource to consult for his annotation). Both assignments by GN and by the student are correct, but we notice that the manual annotator has chosen a more specific class than the one our method uses.

The results from the modification phenomena show that we have a very good precision. This means that we either find a true relation or we do not find it at all. This corresponds to the methodology applied: if a modifier is in our modifier lexicon it produces a true relation, if not it does not produce anything and these we can read from the recall score.

For the relations extracted from phrases we achieve the lowest scores concerning the recall. This low score is due to three factors: there is no rule for extracting a relation, the implemented rule does not work properly and the rule exists but it does not fire because of lack of semantic information. We can influence on the first two factors by writing new rules or improving the implementation of the existing rules.

In fact the GN lookup fails because certain nouns in our analysis do not have a stem and the GN lookup is based on stems. This is an issue that we can solve in a next stage of our work.

The scores for ontology extraction from grammatical functions show one characteristic common to all other phenomena: the relation is either not found but if it is found than it is correct. The precision and recall (and consequently the F-measure) scores are influenced not necessary by our rules, but by the assignment of grammatical functions by the parser. Because we cannot influence the ambiguity of the grammatical function assignment, in the second evaluation round we manually corrected the ambiguities provided by the parser.

In the second evaluation round we concentrated also on relations from phrases and modification. We improved the scripts implementing the rules for ontology extraction from phrases and enlarged our lexicons for ontology extraction from modification phenomena. We also have to notice here, that the disambiguation of the grammatical function assignment provided a considerably improvement of the measured scores.

Also part of the evaluation, in a broader sense, is the integration of the ontological knowledge extracted here into a bigger ontology. We suggest for this purpose The Suggested Upper Merged Ontology (SUMO) [25]. SUMO is in a large freely available ontology. Another important characteristic of SUMO is the fact that it has been mapped to the whole lexicon of WordNet. From this perspective, SUMO is the ontology which fits our approach, when it comes to integrate our work into a broader ontology. It is true, that there is no direct mapping between GN and SUMO. This situation can besolved by first mapping from GN to WordNet and then to SUMO. The direct mapping between GN and WordNet is possible since both have the same general structure concerning the semantic tree.

VII. Conclusion and Further Work

Our aim was to present a multi-layer, rule-based approach for the extraction of ontology schema components and to show that a significant amount of ontological knowledge can be derived without using exclusively deeper linguistic information.

While applying our method on German language, we saw that this approach can be extended to all Germanic languages making use of compounding. Swedish is a good example, and [22], for example discusses the potential of compound for building a FrameNet resource for Swedish.

We also experimented with other language families, more specifically French. Different from the German compounds, the French compounds are not always conflated to a single word. The cumulated form of compounds such as *sociolinguistique (sociolinguistic)* is in French the exception. The majority of compounds in French consist either of two components connected by a hyphen such as *timbre-poste (stamp)* or are just two or more words which appear in a lexical chain such as *dessin animé (animated cartoon)* or *séance marathon (marathon session)*. The most productive of the latter compounds are the compounds constructed with prepositions such as *mesure de sécurité (safety measure)*. Noun-noun compounds are in French less frequent than in German or English [21]. We applied our method on compounds consisting of nouns, of an adjective and a noun and prepositional compounds. Assuming the appropriate linguistic tools, our method can be applied to French text.

It seems thus that only the first step of our work would need a complete re-implementation when applying our strategy to other language (families).

The phenomena which we consider in this work are compounding, nominalization, premodification, postmodification, phrase-structure combined with lexical semantics. From the purely linguistic point of view we do not take into consideration the peculiarities of relative clauses. We also do not cope now with the semantic and linguistic properties of the negation particle or with coreference. These phenomena are not treated here because of a more pragmatical and practical reason: the linguistic tools we have at hand do not annotate these kinds of phenomena. Experiments on the instantiation were also performed, achieving promising results. To integrate these phenomena into the approach presented here remains an issue for future work.

Beside these points, we are now working on modeling our findings about the relations between natural language expressions and ontology schema components in an appropriate way. This is done within the context of a running European R&D project, the Monnet project [26]. In this project, a model, called “lemon” [27], for representing lexicons in ontologies, has been implemented. While this model has been primarily designed for the ontological representation of natural language expressions used in labels of ontologies, we see a big opportunity for using this model for the representation of language data we have been dealing with in the context of knowledge acquisition from text. First steps are dealing with abstracting over the lexical material we found in text, and confining ourselves with the use of linguistic categories, that are related to specific ontology schema components. The work is thus going toward a declarative description of linguistic patterns that should be used in ontology engineering.

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References

[1] P. Buitelaar, P. Cimiano, and B. Magnini, “Ontology learning from text: An overview,” in Ontology Learning from Text: Methods, Evaluation and Applications. Frontiers in Artificial Intelligence and Applications, IOS Press, vol. 123, pp. 3-12, 2005.

[2] M. A. Hearst, “Automatic acquisition of hyponyms from large text corpora,” in Proceedings of 14th International Conference on Computational Linguistics (COLING-92), pp. 539-545, Nantes, France, 2002.

[3] P. Cimiano, A. Hotho, and S. Staab, “Learning concept hierarchies from text corpora using formal concept analysis,” Journal of Artificial Intelligence Research, vol. 24, pp. 462-471, 2005.

[4] G. Aguado de Cea, A. Gomez-Perez, E. Montiel-Ponsoda, and M. del Carmen Su´arez-Figueroa, “Natural language-based approach for helping in the reuse of ontology design patterns,” Proceedings of the EKAW Conference, pp. 32-47, 2008.

[5] N. Aussenac-Gilles and M.-P. Jacques, “Designing and evaluating patterns for relation acquisition from texts with caméléon,” Terminology, vol. 5, nr. 1, pp. 450-473, 2008.

[6] M. Ciaramita, A. Gangemi, E. Ratsch, J. Saric, and I. Rojas, "Unsupervised learning of semantic relations for molecular biology ontologies," in Ontology Learning and Population: Bridging the Gap between Text and Knowledge, IOS Press, pp. 91-107, 2008.

[7] P. Gamallo, M. Gonzalez, A. Agustini, G. Lopes, and V. S. de Lime, "Mapping syntactic dependencies onto semantic relations," in Proceedings of the ECAI Workshop on Machine Learning and Natural Language Processing for Ontology Engineering, pp. 15-22, 2002.

[8] E.de la Clergerie, "Spécifications du service d'extraction supervisée d'ontologies," SCRIBO Project, Tech. Rep., 2009.

[9] J. Erben, "Einführung in die deutsche Wortbildungslehre", 3rd ed. Berlin: Erich Schmidt Verlag GmbH and Co., 1993.

[10] Duden, "Grammatik der deutschen Gegenwartssprache", 4th ed Mannheim/Wien/Zürich, Dudenverlag, 2006.

[11] M. Lohde, "Wortbildung des modernen Deutschen", Tübingen: Francke, 2006.

[12] W. Fleischer and I. Barz, "Wortbildung der deutschen Gegenwartssprache", 2nd ed. Tuebingen, Niemeyer, 1995.

[13] W. Motsch, "Deutsche Wortbildung in Grundzügen", 2nd ed. Berlin, de Gruyter, 2006.

[14] C. Kunze and L. Lemnitzer, "GermaNet – representation, visualization, application," in Proceedings of the LREC, pp.1485-1491, 2002.

[15] S.-M. Lee, "Untersuchungen zur Valenz des Adjektivs in der deutschen Gegenwartssprache", Frankfurt am Main, Germany: Lang, 1994.

[16] A. Lobeck, "Discovering Grammar: An Introduction to English Sentence Structure", Oxford University Press, 2000.

[17] G. Zifonun, L. Hoffmann, and B. Strecke, "Grammatik der deutschen Sprache", Berlin/New York, de Gruyter, 1997, vol. 3.

[18] H. Schumacher, Verben in Feldern, 1st ed. Berlin: de Gruyter, 1986.

[19] M. Vela and T. Declerck,"A Methodology for Ontology Learning: Deriving Ontology Schema Components from Unstructured Text", Proceedings of the Workshop on Semantic Authoring, Annotation and Knowledge Markup, Redondo Beach, California, United States, pp. 22-26,2009.

[20] M. Vela and T. Declerck, "Concept and Relation Extraction in the Finance Domain", Proceedings of the Eighth International Conference on Computational Semantics (IWCS-8), Tilburg, Netherlands, Tilburg University, pp. 346-351, 1/2009.

[21] H. Geckelerand and W. Dietrich, "Einführung in die französische Sprachwissenschaft", Erich Schmidt Verlag, 2007.

[22] L. Borin, D. Dannélls, M. Forsberg, M. Toporowska Gronostaj, and D. Kokkinakis, "The Past Meets the Present in the Swedish FrameNet++" , 14th EURALEX International Congress, pp. 269-281, 2010.

[23] http://wiki.dbpedia.org/Ontology, retrieved October, 2011.

[24] http://wortschatz.uni-leipzig.de, retrieved October, 2011.

[25] http://www.ontologyportal.org/, retrieved October, 2011.

[26] www.monnet-project.eu/, retrieved October, 2011.

[27] J. McCrae, G. Aguado-de-Cea, P. Buitelaar, P. Cimiano, T. Declerck, A. Gomez-Perez, J. Gracia, L. Hollink, E. Montiel-Ponsoda, and D. Spohr, "Interchanging lexical resources on the Semantic Web. Journal for Language Resources and Evaluation", in press.

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