Flexible Ontology Population from Text: The OwlExporter

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Abstract
Ontology population from text is becoming increasingly important for NLP applications. Ontologies in OWL format provide for a standardized means of modeling, querying, and reasoning over large knowledge bases. Populated from natural language texts, they offer significant advantages over traditional export formats, such as plain XML. The development of text analysis systems has been greatly facilitated by modern NLP frameworks, such as the General Architecture for Text Engineering (GATE). However, ontology population is not currently supported by a standard component. We developed a GATE resource called the OwlExporter that allows to easily map existing NLP analysis pipelines to OWL ontologies, thereby allowing language engineers to create ontology population systems without requiring extensive knowledge of ontology APIs. A particular feature of our approach is the concurrent population and linking of a domain- and NLP-ontology, including NLP-specific features such as safe reasoning over coreference chains.

1. Introduction
Ontologies have become a major tool for developing semantically rich applications. Ontology models are capable of representing a large amount of information using a small number of axioms (individuals and relationships). The semantically rich models provide users with a high level conceptualization of the information, while at the same time enabling them to focus on specific parts of the model. Web ontologies developed in the OWL-DL (W3C, 2004) language also provide a standardized means for querying, linking, and reasoning about knowledge.

As a majority of the world’s knowledge is encoded in natural language text, automating the population of these ontologies using results obtained from NLP analysis of documents (Cimiano, 2006) has recently become a major challenge for NLP applications (Figure 1).

![Figure 1: Populating Ontologies from Text](image)

NLP application development has been greatly facilitated by integrated frameworks such as GATE (Bontcheva et al., 2004) or UIMA (Ferrucci and Lally, 2004). Standard tasks such as tokenization, POS tagging, or chunking are supported by a large number of existing components that can be easily assembled into more complex application pipelines. However, exporting the results of these NLP analyses into an ontology (ontology population) still requires large manual efforts on part of the language engineer.

We have implemented a GATE processing resource called the OwlExporter that allows to largely automate ontology population from text for an existing application pipeline. In addition to domain-specific concepts, it provides a number of novel features that address the particularities of NLP processing, such as exporting sentences, noun and verb phrase chunks, and integrating reasoning support for coreference chains. The component, as well as supporting resources, is available under an open source license.¹

2. Motivation
The GATE NLP framework (Bontcheva et al., 2004) already provides means for working with ontologies using an integrated ontology layer. However, our component significantly enhances the state of the art by four important aspects:

- **Support for OWL-DL.** GATE’s ontology layer is based on OWLIM (Kiryakov et al., 2005), which only supports the less semantically rich OWL-Lite language. Our component enables populating OWL-DL ontologies, which is important for users that need to create more expressive models, and benefit from the inferences created by a description logic reasoner such as Racer (Haarslev and Möller, 2001), Pellet (Siri et al., 2007), or FaCT++ (Tsarkov and Horrocks, 2006).

- **Automated Ontology Export.** While a standard task, populating ontologies is not supported through a standard component. Population of ontologies needs to be performed using GATE’s ontology API by writing additional custom code in Java. Language engineers need to have a good knowledge of the OWL formalism, such as how to model semantically rich axioms to create usable ontologies. In contrast, our OwlExporter is a component that provides a separation of concerns, where ontology population is largely automated and can easily be added by a language engineer without requiring extensive knowledge of programming or ontology languages.

- **NLP Ontology Population.** NLP pipelines typically build annotations during processing that are not directly related to the application domain, but can provide important information during subsequent analysis. For example, a bio-NLP pipeline would discover information about organisms,

¹OwlExporter, http://www.semanticsoftware.info/owlexporter
drugs, proteins, etc., but also create structural information like sentences, noun phrase chunks, or coreference chains. We provide automated support for integrating these information into the populated ontology and create the necessary relations for safe reasoning on them.

Addressing these three factors enables the OwlExporter to provide an automated, portable and simplified means of representing the knowledge found in text as instances and relationships within an ontology.

3. Related Work

We are unaware of any components designed to run within GATE that provide generic ontology population support for existing NLP pipelines. The efforts of (Chiarcos et al., 2008) aims at 1) finding a common ground between annotations and features created by different NLP tools 2) developing a generic XML schema to represent the annotations 3) store the marked up information in a database, and finally 2) use a linguistic ontology to represent the POS and GLOSS annotations. The tool however is fully automated with limited control from the user over what gets processed. Since the information found in text is completely arbitrary, introducing a fully automated tool to process such information will prove expensive. The OwlExporter gives the user full control over what domain specific and NLP information from the corpus get exported into the ontology.

The efforts of (Java et al., 2007) were geared towards creating OWL models from an existing “NLP-Oriented” (Java et al., 2007) ontology called OntoSem using an extension called OntoSem2OWL. Because OntoSem2OWL is tied to a single source, the validity of the OWL models produced by OntoSem2OWL rely solely on OntoSem.

Hayashi (Hayashi, 2007) proposed a taxonomic classification of the various processing and language resources within GATE. The works however does not attempt to implement an automated means of populating the taxonomy. Klein and Potter (Klein and Potter, 2004) also attempted an ontology for NLP services, however; their work did not include “detailed taxonomies” as described in (Hayashi, 2007).

4. Design and Implementation

GATE applications are assembled from individual components, which all add information to the documents in a corpus. For example, part-of-speech tags, noun phrase chunks, or named entities are all recorded in individual annotations attached to a document.

The core idea of our OwlExporter is to take the annotations generated by an NLP pipeline and provide for a simple means of establishing a mapping between NLP and domain annotations on one hand and the concepts and relations of an existing NLP and domain-specific ontology on the other hand. The former can then be automatically exported to the ontology in form of individuals and the latter as datatype or object properties (Figure 2).

The resulting, populated ontology can then be used within any ontology-enabled tool for further querying, reasoning, visualization, or other processing (Figure 4).

The OwlExporter is able to populate already existing domain specific ontologies in any OWL format, as well as NLP ontologies like the GOLD Ontology (Farrar and Langendoen, 2003) that model commonly used concepts in the language engineering domain (Figure 3).
4.1. Mapping NLP Annotations to OWL Concepts

The language engineer only needs to add two simple grammar rules to allow ontology population from an existing application. In essence, two new annotations need to be created that declare the mapping between the NLP annotations (created during processing) and the external NLP and domain ontologies (created by an ontology engineer):

OwlExportClass: This annotation records which document annotations need to be exported, and to which ontology class. For example, an NE system might recognize entities such as a “Person” or “Company.” The OwlExportClass annotation could then specify to export Person → Person and Company → Organization, i.e., each detected person will become an instance of the ontology class Person and each company NE an instance of Organization.

OwlExportRelation: This annotation defines the export of relations between entities, which are recorded using OWL object properties. For example, an IE system might additionally detect that a certain person works_for a certain company. To export this as an ontology relation between the Person and Organization instances, each such relation is mapped using an OwlExportRelation annotation.

For entities in a text corpus that need to be exported as datatype relationships, an additional feature is required in the OwlExportClass annotation that matches the name of the property within the ontology (for example, hasGender=Male). Our OwlExporter handles subsumption required for attribute export; For example, consider the following KB: Person, Male ⊑ Person, Female ⊑ Person, hasName(Person,xsd:string). If we attempt to export a Female name, the OwlExporter is able to process this expression, knowing that hasName (Person, xsd:string) also applies to sub-concepts of Person.

These rules can be easily written in GATE’s JAPE language (Cunningham et al., 2000). In Figure 5 we show an example of a JAPE grammar that accepts the Mention annotation as input, and creates the new annotation OwlExportClass with the list of features such as kind, className and corefchain.

4.2. Domain and NLP Ontologies

As discussed above, the OwlExporter uses two ontologies for populating a text corpus. The first ontology is a domain specific ontology that models concepts and relationships that are relevant to the given domain (e.g., biology, architecture, software engineering); and the second ontology is a domain independent NLP ontology that contains concepts commonly used in language engineering. The NLP ontology can contain concepts such as Document, Sentence, NP and VP and the OwlExporter automatically populates the NLP ontology with relationships such as hasEntity or containsSentence that associate the individuals from the domain ontology to the individuals of the NLP ontology, as shown in Figure 6. This provides for advanced queries and reasoning on the populated ontology, e.g., finding all entities of a certain concept that appear in the same sentence as another object, or which NPs exist in a given sentence.

4.3. Coreference Chain Export and Reasoning

The OwlExporter also support modelling entities that reappear in different parts of a corpus, and that are linked together using coreference chains. For example, an NE corefencer such as the one in ANNIE (Cunningham et al., 2002) can identify the nominal and pronominal coreferences between entities and create chains that link them together. Our OwlExporter can use the identified coreferences to semantically enrich the populated ontology, so that a reasoner will be aware of them.

When the coreferencer identifies entities of a corpus as being part of the same referent or representative an annotation (for example, NP Chain) is created that contains a list of entities that make up a coreference chain. The OwlExporter’s OwlExportClass annotation accepts a corefChain feature that contains the ID of the coreference chain annotation. With the simple inclusion of the corefChain feature (a run-time option) the OwlExporter:

Creates the corefSentenceWithId relationship: The corefSentenceWithId relationship associates the
referent in a chain with the sentences containing the occurrences of the coreferences.

**Creates the corefStringWithId relationship:** The corefStringWithId relationship ties the referent to it the multiple occurrences of its coreferences.

**Creates the sameAs relationship:** The OwlExporter establishes the links between the individuals in the ontology using the symmetric owl:sameAs property (Franz Baader et al., 2007). This allows the related individuals to be classified by an OWL reasoner as being equivalent.

In Figure 7 we show the corefSentenceWithId and corefStringWithId relationships created by the OwlExporter for a coreference chain. Figure 10 shows how the OwlExporter models coreference chains using the owl:sameAs property.

**5. Application and Evaluation**

In this section we briefly illustrate how the OwlExporter is being used within different NLP applications, and benchmark how long it takes the OwlExporter to populate ontologies using corpora of different sizes.

**5.1. General Workflow**

Populating ontologies using the entities in a text corpus and the OwlExporter is achieved by a few simple steps:

1. Creating a new or reusing an existing domain ontology in association with a generic NLP ontology.
2. Using a GATE pipeline with its set of processing resources, and the annotations created by it.
3. Creating the mappings between the pipeline’s existing annotations and the annotations needed by the OwlExporter:
   (a) Map the pipeline’s annotations that are to be exported as instances of the ontology to the OwlExportClass annotation.
   (b) Map the annotations that are to be exported as relationships in an ontology to the OwlExportRelation annotation.
4. (optional) Mapping annotations created by a coreferencer to the OwlExportClass annotation using the name of the coreference chain annotation, and the corefChain feature.

**5.2. Application Examples**

In this section, we show how some existing applications make use of the OwlExporter.

**Information Extraction.** ANNIE is an example information extraction system distributed with the standard GATE distribution (Cunningham et al., 2002). Using our OwlExporter, we can easily extend it into an ontology population system.

Table 1 shows some example annotations created by the ANNIE pipeline, followed by the OwlExportClass annotations needed by the OwlExporter to export individuals to the ontology. In this example, we use an already existing ontology “demo.owl” that models commonly used concepts in GATE such as Person, Place and Organization.

Table 1: Mapping existing ANNIE annotations to OwlExportClass annotation

| Type                | Start | End | Id   | Features                                                                 |
|---------------------|-------|-----|------|---------------------------------------------------------------------------|
| Person              | 0     | 5   | 11   | gender=male, rule=FirstName                                               |
| OwlExportClass      | 0     | 5   | 15   | representationId=11, Kind=Class, className=Person, instanceName="Ninus", hasGender=male |
| Location            | 15    | 23  | 12   | locType=city, rule=Location                                               |

Table 2: Mapping existing relationship annotations to the OwlExportRelation annotation

| Type               | Start | End | Id    | Features                                                                 |
|--------------------|-------|-----|-------|---------------------------------------------------------------------------|
| Class              | 30    | 45  | 7991  | class=Class, kind=Class, instanceName=FeatureRenderer                   |
| Interface          | 52    | 60  | 7992  | class=Class, kind=Class, instanceName=Renderer                           |
| OwlExportRelation  | 3638  | 3651| 11176 | domainId=7991, propertyName=hasSuperClass rangeId=7992, Kind=Relation    |

Figure 7: Coreference Chain Relationships exported into an OWL Ontology

**Implementation.** For implementing the OwlExporter we use the Protégé 4 API for tasks such as creating concepts, individuals, and relationships. We also use the GATE 5.1 API for processes such getting the values of run-time parameters, extracting content from the text corpus and getting the annotation sets.
In Figure 8 we show the list of annotations created by the algorithmic processing resources of the ANNIE pipeline.

The annotation set includes the OwlExportClass and OwlExportClassNLP annotations that are exported to the ontology. Also shown are the features that belong to the OwlExportClassNLP annotation for an NP entity in the corpus.

In Figure 2 we show how entities of a corpus that have been tagged as being Person, and Location are exported to the domain ontology. And finally in Figure 3 we show how the Document, Sentence, and NP entities from a corpus are exported as instances of their related concepts in the NLP ontology.

**Software Engineering.** In a software text mining application (Witte et al., 2007), we detect relationships between domain-specific concepts such as software classes and interfaces. Exporting the NLP-detected relations, extracted from software documentation, into an ontology allows software engineers to run semantically-oriented queries on the populated ontology to obtain information for software maintenance tasks (Witte et al., 2007). In Table 2 we show an example of annotations created by the software miner pipeline, followed by the OwlExportRelation annotation needed by the OwlExporter to export relationships to the ontology.

Figure 9 shows a SPARQL query applied to the populated Software Miner ontology that extracts all the individuals that are of type Class and that are specializations of a given Interface.

In Table 3 we have summarized a set benchmarks that measure how long it takes the OwlExporter to export annotations. We have included the size of the text corpus, the number of created individuals and created relations. As can be seen from the table, a large number of entities can be exported without significant performance penalties.

**5.3. OwlExporter Evaluation**

Within this work, we emphasized on the importance of the Web Ontology Language (OWL) in language engineering. We stressed the need of a simple and efficient solution that enables the population of ontologies within existing NLP frameworks, in particular GATE.

We introduced the OwlExporter processing resource, a tool that is designed to automate the process of ontology export from text. It has already been used for a number of real-world applications in various domains, and is now made generally available under an open source license.
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