DEER - RDF Data Extraction and Enrichment Framework.

Abstract:
Over the last years, the Linked Data principles have been used across academia and industry to publish and consume structured data. Thanks to the fourth Linked Data principle, many of the RDF datasets used within these applications contain implicit and explicit references to more data. For example, music datasets such as Jamendo include references to locations of record labels, places where artists were born or have been, etc. Datasets such as Drugbank contain references to drugs from DBpedia, were verbal description of the drugs and their usage is explicitly available. The goal of mapping component, dubbed DEER, is to retrieve this information, make it explicit and integrate it into data sources according to the specifications of the user. To this end, DEER relies on a simple yet powerful pipeline system that consists of two main components: modules and operators.

Modules implement functionality for processing the content of a dataset (e.g., applying named entity recognition to a particular property). Thus, they take a dataset as input and return a dataset as output. Operators work at a higher level of granularity and combine datasets. Thus, they take sets of datasets as input and return sets of datasets. DEER was implemented in Java, is open-source and can be accessed at `https://github.com/GeoKnow/DEER/`.

Contents

1 Introduction

Manifold RDF data contain implicit references to geographic data. For example, music datasets such as *Jamendo* include references to locations of record labels, places where artists were born or have been, etc. The aim of the spatial mapping component, dubbed DEER, is to retrieve this information and make it explicit. In the following, we begin by presenting the basic assumptions that influence the development of the first component of DEER. Then, we present the technical approach behind DEER. Finally, we present the detailed developers' manual of DEER.

2 Assumptions

Enriched information can be mentioned in three different ways within Linked Data:

1. *Through dereferencing*: Several datasets contain links to datasets with explicit information such as *DBpedia* or *LinkedGeoData*. For example, in a music dataset, one might find information such as
   `http://example.org/Leipzig`
   `owl:sameAs`
   `http://dbpedia.org/resource/Leipzig`.

   We call this type of reference *explicit*. We can now use the semantics of RDF to fetch additional information from DBpedia and attach it to the resource in the other ontology as `http://example.org/Leipzig` and `http://dbpedia.org/resource/Leipzig` refer to the same real-world object.

2. *Through linking*: It is known that the Web of Data contains an insufficient number of links. The latest approximations suggest that the Linked Open Data Cloud alone consists of 31+ billion triples but only contains approximately 0.5 billion links (i.e., less than 2% of the triples are links between knowledge bases). The second intuition behind our approach is thus to use link discovery to map resources in an input knowledge base to resources in a knowledge that contains explicit enrichment information. For example, given a resource `http://example.org/Athen`, DEER should aim to find a resource such as `http://dbpedia.org/resource/Athen` to map it with. Once having established the link between the two resources, DEER can then resolve to the approach defined above.

3. *Through Natural Language Processing*: In some cases, the geographic information is hidden in the objects of data type properties. For example, some datasets contain biographies, textual abstracts describing resources, comments from users, etc. The idea here is to use this information by extracting Named Entities and keywords using automated Information Extraction techniques. Semantic Web Frameworks such as FOX[1] have the main advantage of providing URIs for the keywords and entities that they detect. These URIs can finally be linked with the resources to which the datatype properties were attached. Finally, the additional information can be dereferenced and attached to the resources whose datatype properties were analyzed.

The idea behind DEER is to provide a generic architecture that contains means to exploit these three characteristics of Linked Data. In the following, we present the technical approach underlying DEER.

3 Technical Approach

3.1 Architecture

DEER was designed to be a modular tool which can be easily extended and re-purposed. In its first version, it provides two main types of artifacts:

1. *Modules*: These artifacts are in charge of generating enrichment data based on RDF data. To this aim, they implement the three intuitions presented above. The input for such a module is an RDF dataset (in Java, a *Jena Model*). The output is also an RDF dataset enriched with additional information (in Java, an enriched *Jena Model*). Formally, a module can thus be regarded as a function $\mu : \mathcal{R} \to \mathcal{R}$, where $\mathcal{R}$ is the set of all RDF datasets.

2. *Operators*: The idea behind operators is to enable users to define a workflow for processing their input dataset. Thus, in case a user knows the type of enrichment that is to be carried out (using linking and then links for example), he can define the sequence of modules that must be used to process his dataset. Note that the format of the input and output of modules is identical. Thus, the user is empowered to create workflows of arbitrary complexity by simply connecting modules. Formally, an operator can be regarded as a function $\varphi : \mathcal{R} \cup \mathcal{R}^2 \to \mathcal{R} \cup \mathcal{R}^2$.

[1] `http://fox.aksw.org`

The corresponding architecture is shown in Figure 1. The input layer allows reading RDF in different serializations. The enrichment modules are in the second layer and allow adding information to RDF datasets by different means. The operators (which will be implemented in the future version of DEER) will combine the enrichment modules and allow defining a workflow for processing information. The output layer serializes the results in different format. The enrichment procedure will be monitored by implementing a controller, which will be added in the future version of DEER.

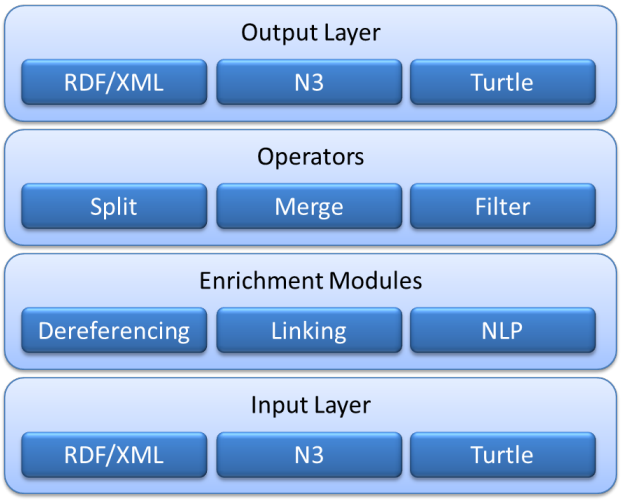


Figure 1: Architecture of DEER

In the following, we present the implementation of the three intuitions presented above in DEER.

3.2 Using Dereferencing

For datasets which contain `owl:sameAs` links, we dereference all links from the dataset to other datasets by using a content negotiation on HTTP as shown in Figure 2. This returns a set of triples that needs to be filtered for relevant information. Here, we use a predefined list of attributes that links to requested information. Amongst others, we look for `geo:lat`, `geo:long`, `geo:lat_long`, `geo:line` and `geo:polygon`. The list of retrieved property values can be configured.

3.3 Using Linking

As pointed out before, links to resources do not occur in several knowledge bases. Here, we rely on the metrics implemented in the LIMES frame-

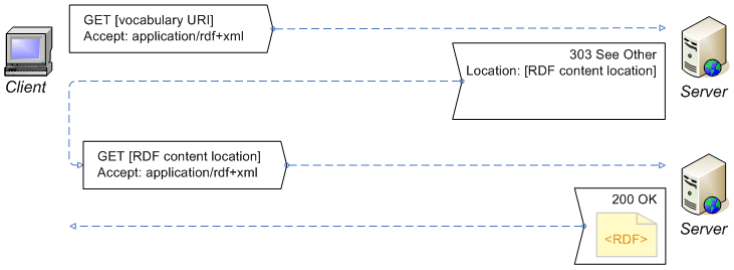


Figure 2: Content Negotiation as used by DEER (courtesy of W3C)

work[2] [5, 4, 6] to link the resources in the input dataset with other datasets. LIMES, the **Li**nk Discovery Framework for **Me**tric **S**paces, is a framework for discovering links between entities contained in Linked Data sources. LIMES is a hybrid framework [4] that combines the mathematical characteristics of metric spaces as well prefix-, suffix- and position filtering to compute pessimistic approximations of the similarity of instances. These approximations are then used to filter out a large amount of those instance pairs that do not suffice the mapping conditions. By these means, LIMES can reduce the number of comparisons needed during the mapping process by several orders of magnitude and complexity without loosing a single link. The architecture of LIMES is shown in Figure 3

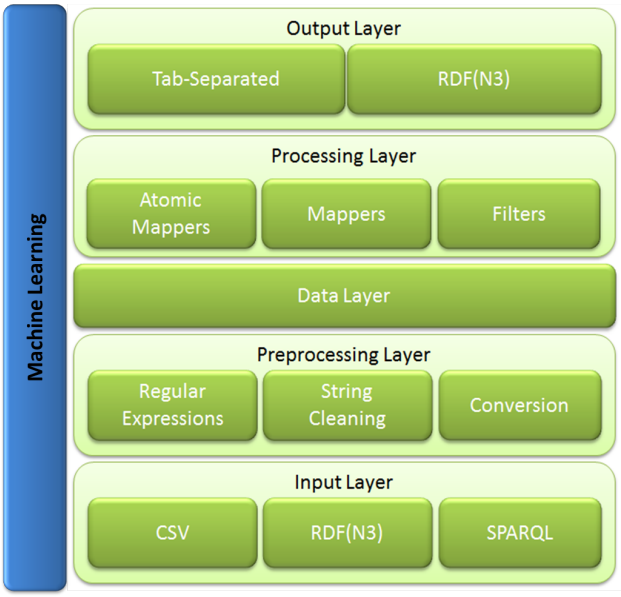


Figure 3: Architecture of LIMES

[2] `http://\limes.sf.net`

Linking using LIMES [4, 3] can be achieved in three ways:

1. *Manually*, by the means of a link specification [4], which is an XML-description of (1) the resource in the input and target datasets that are to be linked and (2) of the similarity measure that is to employed to link these datasets.

2. *Semi-automatically* based on active learning [7, 8, 9]. Here, the idea is that if the user is not an expert and thus unable to create a link specification, he can simply provide the framework with positive and negative examples iteratively. Based on these examples, LIMES can compute links for mapping resources with high accuracy.

3. *Automatically* based on unsupervised machine learning. Here, the user can simply specify the sets of resources that are to be linked with each other. LIMES implements both a deterministic and non-deterministic machine-learning approaches that optimize a pseudo-F-measure to create a one-to-one mapping.

The techniques implemented by LIMES can be accessed via the SAIM user interface[3], of which a screenshot is shown in Figure 4.

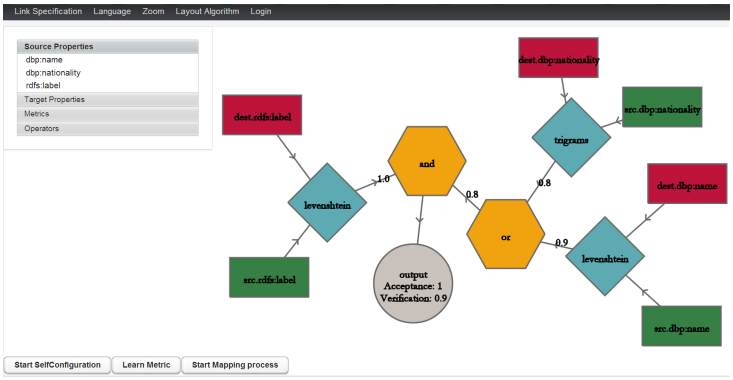


Figure 4: Screenshot of SAIM

3.4 Using Named Entity Recognition

The enrichment information hidden in datatype properties is retrieved by using Named Entity Recognition. In the first version of DEER, we rely on the FOX framework. The FOX framework is a stateless and extensible framework that encompasses keyword extraction and named entity recognition. Its architecture consists of three layers as shown in Figure 5.

[3] `http://saim.aksw.org`

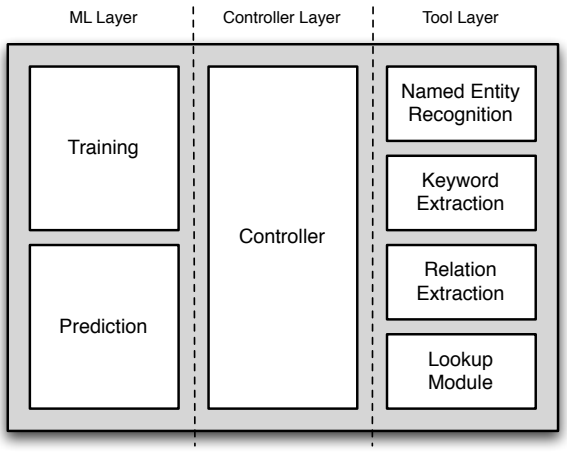


Figure 5: Architecture of the FOX framework.

FOX takes text or HTML as input. Here we use the objects of datatype properties, i.e., plain text. This data is sent to the *controller layer*, which implements the functionality necessary to clean the data, i.e., remove HTML and XML tags as well as further noise. Once the data has been cleaned, the controller layer begins with the orchestration of the tools in the *tool layer*. Each of the tools is assigned a thread from a thread pool, so as to maximize usage of multi-core CPUs. Every thread runs its tool and generates an event once it has completed its computation. In the event that a tool does not complete after a set time, the corresponding thread is terminated. So far, FOX integrates tools for KE, NER and RE. The KE is realized by tools such as KEA[4] and the Yahoo Term Extraction service[5]. In addition, FOX integrates the Stanford Named Entity Recognizer[6] [2], the Illinois Named Entity Tagger[7] [10] and Alchemy[8] for NER.

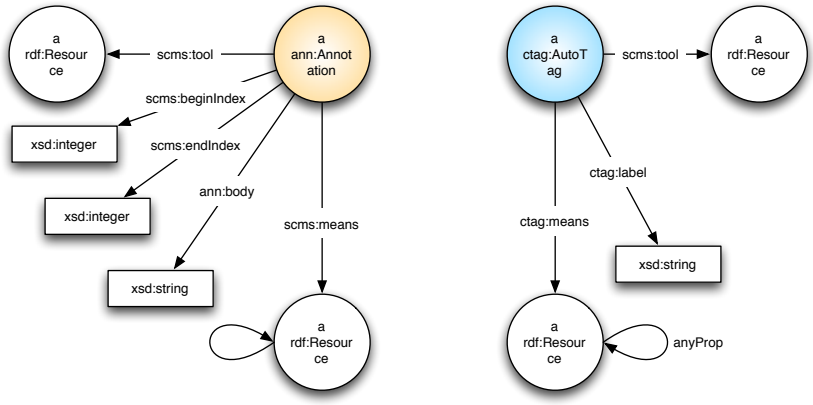
The results from the tool layer are forwarded to the *prediction module* of the *machine-learning layer*. The role of the prediction module is to generate FOX's output based on the output the tools in FOX's backend. For this purpose, it implements several ensemble learning techniques [1] with which it can combine the output of several tools. Currently, the prediction module carries out this combination by using a feed-forward neural network. The neural network inserted in FOX was trained by using 117 news articles. It reached 89.21% F-Score in an evaluation based on a ten-fold-cross-validation

[4] `http://www.nzdl.org/Kea/`
[5] `http://developer.yahoo.com/search/content/V1/termExtraction.html`
[6] `http://nlp.stanford.edu/software/CRF-NER.shtml`
[7] `http://cogcomp.cs.illinois.edu/page/software_view/4`
[8] `http://www.alchemyapi.com`

on NER, therewith outperforming even commercial systems such as Alchemy.

Once the neural network has combined the output of the tool and generated a better prediction of the named entities, the output of FOX is generated by using the vocabularies shown in Figure 6. These vocabularies extend the two broadly used vocabularies Annotea[9] and Autotag [10]. In particular, we added the constructs explicated in the following:

- `scms:beginIndex` denotes the index in a literal value string at which a particular annotation or keyphrase begins;
- `scms:endIndex` stands for the index in a literal value string at which a particular annotation or keyphrase ends;
- `scms:means` marks the URI assigned to a named entity identified for an annotation;
- `scms:source` denotes the provenance of the annotation, i. e., the URI of the tool which computed the annotation or even the system ID of the person who curated or created the annotation and
- `scmsann` is the namespace for the annotation classes, i.e, location, person, organization and miscellaneous.



(a) Named Entity Annotation (b) Keyword Annotation

Figure 6: Vocabularies used by FOX for representing named entities (a) and keywords (b)

[9] `http://www.w3.org/2000/10/annotation-ns#`
[10] `http://commontag.org/ns#`

4 Developers' Manual

4.1 DEER packages

DEER contains five basic *Java* packages:

1. `IO package` which deals with input/output operations using:
   - `Reader` class which handles all RDF reading process from file/URL/End-Point.
   - `Writer` class which handles all the RDF writing process.
2. `Modules package` contains the `GeoLiftModule` interface which is implemented by all modules' classes. All modules can be created using the `ModuleFactory` class calling its `createModule()` method with the desired module's name as parameter. Also, the `getImplementations()` method returns all implemented modules. Currently, five modules are implemented:
   - `DereferencingModule` class which handles dereferencing additional information extending process.
   - `LinkingModule` class which handles linking information extending processes.
   - `NLPModule` class which handles named entity extraction process.
   - `AuthorityConformationModule` class which handles the subject authority conformation process.
   - `PredicateConformationModule` class which handles the predicates conformation process.
   - `FilterModule` class which handles filter process.
3. `Operators package` contains the `GeoLiftOperator` interface which is implemented by all operators' classes. All operators can be created using the `OperatorFactory` class calling its `createOperator()` method with the desired operator's name as parameter.
   - `CloneOperator` class to generate from 1 input dataset a set of $n \geq 2$ clone output datasets.
   - `MergeOperator` class to generate one merged output dataset out of $n \geq 2$ input datasets.
4. `Helper package` containing helper classes used by DEER such as vocabularies classes.

5. `Workflow package` containing classes responsible for DEER overall execution process.

4.2 DEER Modules

By *Modules* we mean these artifacts in charge of generating enrichment data based on RDF data. The input for such a module is an RDF dataset. The output is also an RDF dataset enriched with enriched information. Formally, a module can thus be regarded as a function $\mu : \mathcal{R} \rightarrow \mathcal{R}$, where $\mathcal{R}$ is the set of all RDF datasets. Currently, DEER implements six modules: dereferencing, linking, NLP, authority conformation, predicate conformation and filter.

All modules implement the `GeoLiftModule` interface methods

- Model process() method takes as input a *Jena* model and a Map of different parameters in form of `("parameterName", "parameterValue")`, and as output all DEER module generates a Jena model also, this organization ease the usage of the modules in different workflows.
- getParameters(), returns list of all available module parameters.
- getNecessaryParameters(), returns list of all necessary module parameters that have no default values.
- selfConfig(Model source, Model target), returns a map of parameters learned from the inputs (currently in progress).

Adding new modules to DEER is possible by implementing the `GeoLiftModule`.

4.2.1 Dereferencing Module

For datasets which contain similarity proprieties links (e.g. `owl:sameAs`), we deference all links from the dataset to other datasets by using a content negotiation on HTTP as shown in Figure 2. This returns a set of triples that needs to be filtered for relevant information. Here, we use a predefined list of attributes that links to additional information. Amongst others, we look for `geo:lat`, `geo:long`, `geo:lat_long`, `geo:line` and `geo:polygon`. The list of retrieved property values can be configured.

In this module, a *Java Jena* model and a list of interested predicates are given as inputs. This is done by iterating over the model's resources (dubbed as original resources) and for each of the original resource an extraction of the predicates' values (objects) that are in the form of URI is performed. These URIs (dubbed as dereferenced resources) are more filtered to be the resources used in *DBpedia*. The dereferenced resources are handled by a

Table 1: Dereferencing module parameters

Parameter Key	Parameter value
`inputProperty<n>`	List of interesting predicates to enrich the model, and their Objects' values. e.g.⟨"inputProperty1","`http://www.w3.org/2003/01/geo/wgs84_pos#lat`"⟩. **Mandatory parameter**
`outputProperty<n>`	The enriched output property. By default this parameter is set to `http://geoknow.org/ontology/relatedTo`
`useBlankNodes`	Use blank node in output dataset. By default, this parameter is set to `false`.

dereference operation in order to find the interested predicates list for them. Such predicates and their objects' values are fetched and added to the the original resource to extend its information. Listing 1 provides a sample code showing how to use the `DereferencingModule` module:

4.2.2 Linking Module

Links to other resources do not occur in several knowledge bases. Here, we rely on the metrics implemented in the LIMES framework[11] [5, 4, 6] to link the resources in the input dataset with other datasets.

`LinkingModule` have two inputs: an input model and list of parameters (see table 2 for parameters details). The linking process starts by generating links between the input dataset model and another dataset as second partner. As said before, the linking process is done using LIMES. LIMES linking specification file is given as parameter. The output model of the `LinkingModule` is generated as the input model plus the generated links added with their original resources in the input model using some linking property such as `owl:samAs`. Listing 2 provides a sample code showing how to use the Linking module.

4.2.3 NLP Module

The enrichment information hidden in datatype properties is retrieved by using Named Entity Recognition (NER). DEER- as an expandable modeller framework - can inject any NER framework to implement the *NLP module*. In the current version of DEER, we rely on the FOX framework.

[11] `http://limes.sf.net`

Listing 1: Code fragment to call the `DereferencingModule` class.

```
// Define DereferencingModule object
DereferencingModule u =
    ModuleFactory.createModule("dereferencing");
// Define parameters Map
Map<String, String> parameters = new HashMap<String, String>();
// Set parameters
parameters.put("predicate1", predicate1Value);
parameters.put("predicate2", predicate2Value);
// read input Model
Model model = Reader.readModel(datasetSource);
// Enrich the Model
Model resultedModel = u.process(model, parameters);
// Use the enriched model
Writer.writeModel(enrichedModel, "TTL", System.out);
```

Table 2: Linking module parameters

Parameter key	**Parameter value**
`specFile`	The path to specification file used for linking process, the original dataset to be enriched must be on the source dataset , e.g. `linkingModuleData/linking/spec.xml`.
`linksFile`	The path to links file resulted from the linking process. This file's path is the same as the one specified in LIME's specifications file as output file, e.g. `linkingModuleData/linking/links.nt`.
`linksPart`	Represents the original model's URI position as source/left or target/right in the linking specifications. Its value is either 'source' or 'target'.

Listing 2: Code fragment to call the `Linking` class.

```
// Define Linking object
Linking l = ModuleFactory.createModule("linking");
// Define parameters Map
Map<String, String> parameters = new HashMap<String, String>();
// Set parameters
parameters.put("datasetSource",datasetSourceValue);
parameters.put("specFilePath",specFilePathValue);
parameters.put("linksFilePath",linksPathValue);
parameters.put("linksPart",linksPartValue);
// read input Model
Model model = Reader.readModel(parameters.get("datasetSource"));
// Enrich the Model
model = l.process(model, parameters);
// Use the enriched model
Writer.writeModel(enrichedModel, "TTL", System.out);
```

Table 3 provides details about the `NLPModule`'s parameters. A sample code demonstrating the `NLPModule` class is provided introduced in Listing 3.

4.2.4 Authority Conformation Module

Change a specified source URI authority to a specified target URI authority. For example, using source URI authority of `http://dbpedia.org` and target URI authority of `http://deer.org` changes a resource like `http://dbpedia.org/Berlin` to `http://deer.org/Berlin`. As an example, listing 4 introduces a code segment to manipulate the `AuthorityConformationModule` to change the source authority from `http://dbpedia.org` to the target authority `http://deer.org/Berlin`. Table 4 provides a full list of the authority conformation module parameters.

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4.2.5 Predicate Conformation Module

The `PredicateConformationModule` can be used to change a specific source properties to specific target properties. As an example, listing 5 introduces a code segment to manipulate the `PredicateConformationModule` that changes all occurrences of `RDF:label` to `SKOS:prefLabel`. Table 5 provides a full list of the predicate conformation module parameters.

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Table 3: NLP module parameters

Parameter key	**Parameter value**
`literalProperty`	Literal property used by FOX for NER. If not set, the top ranked literal property will be pecked automatically by `LiteralPropertyRanker` sub-module, which ranks the lateral properties of a model according to the average size of each literal property divided by the number of instances of such property.
`addedGeoProperty`	property added to the input model with additional knowledge through NLP. By default, this parameter is set to *gn:relatedTo*[11]
`useFoxLight`	An implemented NER class name, either: • `org.aksw.fox.nertools.NEROpenNLP` • `org.aksw.fox.nertools.NERIllinoisExtended` • `org.aksw.fox.nertools.NERIllinoisExtended` • `org.aksw.fox.nertools.NERBalie` • `org.aksw.fox.nertools.NERStanford` By default this parameter is set to `OFF` in which all NER classes runs in parallel and a combined result will be returned, if this parameter is given with a wrong value, `org.aksw.fox.nertools.NERStanford` will be used.
`NERType`	Force FOX to look for a specific NE's types only. Available types are: `location` (default value), `person`,`organization`, and `all` to retrieve the all the previous three types.
`askEndPoint`	Ask the *DBpedia* endpoint for each location returned by FOX (setting it generates slower execution time but more accurate results). By default this parameter is set to *false*

Table 4: Conformation module parameters

Parameter key	**Parameter value**
`sourceSubjectAuthority`	Source URI to be replaced.
`targetSubjectAuthority`	Target URI to replace the sourceURI.

Listing 3: Code fragment to call the `NLPModule` class.

```
// Define NLPModule object
NLPModule geoEnricher= ModuleFactory.createModule("nlp");
// Define parameters Map
Map<String, String> parameters = new HashMap<String, String>();
// Set parameters
parameters.put("useFoxLight", "OFF");
parameters.put("askEndPoint", "false");
// read input Model
Model inputModel = Reader.readModel(inputFileValue);
// Enrich the Model
Model enrichedModel = geoEnricher.process(inputModel,
    parameters);
// Use the enriched model
Writer.writeModel(enrichedModel, "TTL", System.out);
```

Table 5: Conformation module parameters

`sourceProperty<i>`	i^{th} source property to be replaced by the i^{th} target property.
`targetProperty<i>`	i^{th} target property to replace the i^{th} source property.

Listing 4: Code fragment to call the `AuthorityConformationModule` class.

```
// Define NLPModule object
AuthorityConformationModule geoEnricher =
    ModuleFactory.createModule("authorityconformation");
// Define parameters Map
Map<String, String> parameters = new HashMap<String, String>();
// Set parameters
parameters.put("sourceSubjectAuthority", "http://dbpedia.org");
parameters.put("targetSubjectAuthority", "http://deer.org");
// read input Model
Model inputModel = Reader.readModel(inputFileValue);
// Enrich the Model
Model enrichedModel = geoEnricher.process(inputModel,
    parameters);
// Use the enriched model
Writer.writeModel(enrichedModel, "TTL", System.out);
```

Listing 5: Code fragment to call the `PredicateConformationModule` class.

```
// Define NLPModule object
PredicateConformationModule geoEnricher =
    ModuleFactory.createModule("predicateconformation");
// Define parameters Map
Map<String, String> parameters = new HashMap<String, String>();
// Set parameters
parameters.put("sourceProperty1",
    "http://www.w3.org/1999/02/22-rdf-syntax-ns#label");
parameters.put("targetProperty1",
    "http://www.w3.org/2004/02/skos/core#prefLabel");
// read input Model
Model inputModel = Reader.readModel(inputFileValue);
// Enrich the Model
Model enrichedModel = geoEnricher.process(inputModel,
    parameters);
// Use the enriched model
Writer.writeModel(enrichedModel, "TTL", System.out);
```

Table 6: Filter module parameters

Parameter key	**Parameter value**
`triplesPattern`	Set of triple pattern to run against the input model of the filter module. By default, this parameter is set to `?s ?p ?o.` which generate the whole input model as output, changing the values of `?s`, `?p` and/or `?o` will restrict the output model.

4.2.6 Filter Module

Runs a set of triples patterns' against an input model to filter some triples out of it and export them to an output model. For example running triple pattern `"?s <http://dbpedia.org/ontology/abstract> ?o"` against an input model containing "`http://dbpedia.org/resource/Berlin`" will generate output model containing only Berlin's abstracts of *DBpedia*. Listing 6 demonstrate the filter module usage. table 6 provides a full list of the filter module parameters.

Listing 6: Code fragment to call the `FilterModule` class.

```
// Define NLPModule object
FilterModule geoEnricher= ModuleFactory.createModule("filter");
// Define parameters Map
Map<String, String> parameters = new HashMap<String, String>();
// Set parameters
parameters.put("triplesPattern ", "?s
    <http://dbpedia.org/ontology/abstract> ?o");
parameters.put("askEndPoint", "false");
// read input Model
Model inputModel = Reader.readModel(inputFileValue);
// Enrich the Model
Model enrichedModel = geoEnricher.process(inputModel,
    parameters);
// Use the enriched model
Writer.writeModel(enrichedModel, "TTL", System.out);
```

4.3 DEER Operators

The idea behind operators is to enable users to define a workflow for processing their input dataset. DEER operators combine the enrichment modules and allow defining a workflow for processing information. Note that the format of the input and output of operator is identical. Thus, the user is empowered to create workflows of arbitrary complexity by simply connecting modules and/or operators. Formally, an operator can be regarded as a function $\varphi : \mathcal{R}^* \rightarrow \mathcal{R}^*$.

All operators classes implement the `GeoLiftOperator` interface's two methods `getParameters()` and `process()`, where the `getParameters()` method returns a list of its module input parameters, and the `process()` method takes as input a list of *Jena* models and a *Map* of different parameters in form of `("parameterName", "parameterValue")`. Each of the DEER operators outputs a list of Jena models. This organization ease the usage of the operators in different workflows. Adding new operators to DEER is possible by implementing the `GeoLiftOperator`.

4.3.1 Clone Operator

The idea behind the clone operator is to enable parallel execution of different modules in the same dataset. The clone operator takes one dataset as input and produces $n \geq 2$ output datasets, which are all identical to the

input dataset. Each of the output datasets of the clone operator has its own workflow (as to be input to any other module or operator). Thus, DEER is able to execute all workflows of output datasets in parallel.

4.3.2 Merge Operator

The idea behind the merge operator is to enable combining datasets. The merge operator takes a set of $n \geq 2$ input datasets and merges them into one output dataset containing all the input datasets' triples. As in case of clone operator, the merged output dataset has its own workflow (as to be input to any other module or operator).

5 DEER RDF Specification Paradigm

In the current version of DEER we introduce our new RDF based specification paradigm. The main idea behind this new paradigm is to enable the processing execution of specifications in an efficient way. To this end, we first decided to use RDF as language for the specification. This has the main advantage of allowing for creating specification repositories which can be queried easily with the aim of retrieving accurate specifications for the use cases at hand. Moreover, extensions of the specification language do not require a change of the specification language due to the intrinsic extensibility of ontologies. The third reason for choosing RDF as language for specifications is that we can easily check the specification for correctness by using a reasoner, as the specification ontology allows for specifying the restrictions that specifications must abide by.

introduces an example of RDF specification file presented in turtle serialization, which will be used as a guiding example through the next subsections. For the sake of clarity, we represent the configuration file in form of graph in figure 7.

5.1 DEER Execution Workflow

First of all, DEER determines the set of output datasets $D = \{d_1, \ldots, d_n\}$, i.e. datasets which are included as output of some modules/operators but not as input to any other modules/operators. In our example it is only d_8. Then, for each dataset d_i in D, DEER tries to find d_i either trivially from file/URI/endpoint or recursively by solving for modules/operators that generate d_i as output.

Going back to our example, DEER first tries to read d_8 trivially but it fail as there is no direct way to read it. Then, DEER recursively goes

for solving the `Conformation module` as it generates d_8 as output. This recursive procedure continues until DEER reads the dataset d_1 from the endpoint. Afterwards, going back in the recursion stack DEER produces the triples of d_8.

5.1.1 RDF Specification Resources

DEER RDF specification file may contain four main resource types (dataset, module, operator and parameter). in the following we will describe each of them along with our example shown in listing 7.

- **Dataset Resource** As its name implies, a Dataset resource represents a dataset. For an example see listing 7 (lines 4:6), in which the RDF specification represents a dataset with URI `http://dbpedia.org/resource/Berlin` and endpoint `http://dbpedia.org/sparql`. DEER extracts the CBD of the *Berlin* resource from *DBpedia* endpoint.

  Beside defining a resource as a dataset (e.g. listing listing 7 (lines 4)), a dataset resource may also contain the following predicates:

  - `rdfs:label` setting label for the dataset.
  - `:hasUri` setting URI of the dataset resource, to read resource through content negotiation *(e.g. listing listing 7 (line 5))*.
  - `:fromEndPoint` end point to read the CBD from. *Note: must be used in conjunction with* ***`:hasUri`*** *predicate, otherwise an error will be generated by* DEER*. (e.g. listing 7 (line 6))*.
  - `:inputFile` input file to load the dataset from.
  - `:outputFile` output file to save the dataset to *(e.g. listing 7 (lines 14))*.
  - `:outputFormat` output format to save the dataset in it *(e.g. listing 7 (lines 14))*, Turtle format will be used as default format if this property is not set.

- **Module Resource** Beside defining a resource as a module *(e.g. listing 7 (line 16))*, a Module resource may also contain the following predicates:

  - `rdfs:label` setting label for the module *(e.g. listing 7 (line 17))*.
  - `:hasInput` setting input datasets for the module *(e.g. listing 7 (line 18))*.

Listing 7: Example of RDF configuration file.

```
@prefix : <http://geoknow.org/specsontology/> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix geo: <http://www.w3.org/2003/01/geo/wgs84_pos#> .
:d1             a                 :Dataset ;
                :hasUri           <http://dbpedia.org/resource/Berlin> ;
                :fromEndPoint     <http://dbpedia.org/sparql> .
:d2             a                 :Dataset .
:d3             a                 :Dataset .
:d4             a                 :Dataset .
:d5             a                 :Dataset .
:d6             a                 :Dataset .
:d7             a                 :Dataset .
:d8             a                 :Dataset ;
                :outputFile       "GeoLiftBerlin.ttl" ;
                :outputFormat     "Turtle" .
:deref          a                 :Module, :DereferencingModule ;
                rdfs:label        "Dereferencing module" ;
                :hasInput         :d1 ;
                :hasOutput        :d2 ;
                :hasParameter     :derefParam1 .
:derefParam1    a    :ModuleParameter, :DereferencingModuleParameter ;
                :hasKey           "inputProperty1" ;
                :hasValue         geo:lat  .
:clone          a                 :Operator, :CloneOperator ;
                rdfs:label        "Clone operator" ;
                :hasInput         :d2 ;
                :hasOutput        :d3, :d4 .
:nlp            a                 :Module, :NLPModule ;
                rdfs:label        "NLP module" ;
                :hasInput         :d3 ;
                :hasOutput        :d5 ;
                :hasParameter     :nlpPram1, :nlpPram2 .
:nlpPram1       a                 :ModuleParameter, :NLPModuleParameter ;
                :hasKey           "useFoxLight" ;
                :hasValue         "OFF" .
:nlpPram2       a                 :ModuleParameter, :NLPModuleParameter ;
                :hasKey           "askEndPoint" ;
                :hasValue         false  .
: filter        a                 :Module, :FilterModule  ;
                rdfs:label        "Filter module" ;
                :hasInput         :d4 ;
                :hasOutput        :d6 ;
                :hasParameter     :FilterPram1 .
:filterPram1    a       :ModuleParameter, :NLPModuleParameter ;
            :hasKey     "triplesPattern" ;
            :hasValue "?s <http://dbpedia.org/ontology/abstract> ?o".
:merge          a                 :Operator, :MergeOperator ;
                rdfs:label        "Merge operator" ;
                :hasInput         :d6, :d5 ;
                :hasOutput        :d7 .
:aconform       a         :Module, :AuthorityConformationModule ;
                rdfs:label        "Authority Conformation module" ;
                :hasInput         :d7 ;
                :hasOutput        :d8 ;
                :hasParameter     :aconformPram1, :aconformPram2 .
:aconformPram1 a                  :ModuleParameter, :NLPModuleParameter ;
                :hasKey           "sourceSubjectAuthority" ;
                :hasValue         "http://dbpedia.org" .
:aconformPram2 a                  :ModuleParameter, :NLPModuleParameter ;
                :hasKey           "targetSubjectAuthority" ;
                :hasValue         "http://deer.org" .
```

  - `:hasOutput` setting output datasets for the module *(e.g. listing 7 (line 19))*.
  - `:hasParameter` setting parameters for the module *(e.g. listing 7 (line 20))*.

- **Operator Resource** Beside defining a resource as an operator *(e.g. listing 7 (line 24))*, a Module resource may also contain the following predicates:
  - `rdfs:label` setting a label for the operator *(e.g. listing 7 (line 25))*.
  - `:hasInput` setting input datasets for the operator *(e.g. listing 7 (line 26))*.
  - `:hasOutput` setting output datasets for the operator *(e.g. listing 7 (line 27))*.
  - `:hasParameter` setting parameters for the operator.

- **Parameter Resource** Beside defining a resource as a parameter *(e.g. listing 7 (line 21))*, a Module resource may also contain the following predicates:
  - `rdfs:label` setting label for the parameter.
  - `:hasKey` setting the parameter key *(e.g. listing 7 (line 22))*.
  - `:HasValue` setting the parameter value *(e.g. listing 7 (lines 23))*.

  The values of (key, values) pairs are modules/operators dependent.

6 Running DEER From Command-Line

The DEER can be directly executed from command-line using the provided `deer.jar`[12] file. Simply, provide the RDf configuration file as the only one parameter for the DEER jar file.

Example : `deer.jar src/main/resources/workflow/config.ttl`

[12]the `deer.jar` file is in the `jars` folder of the project

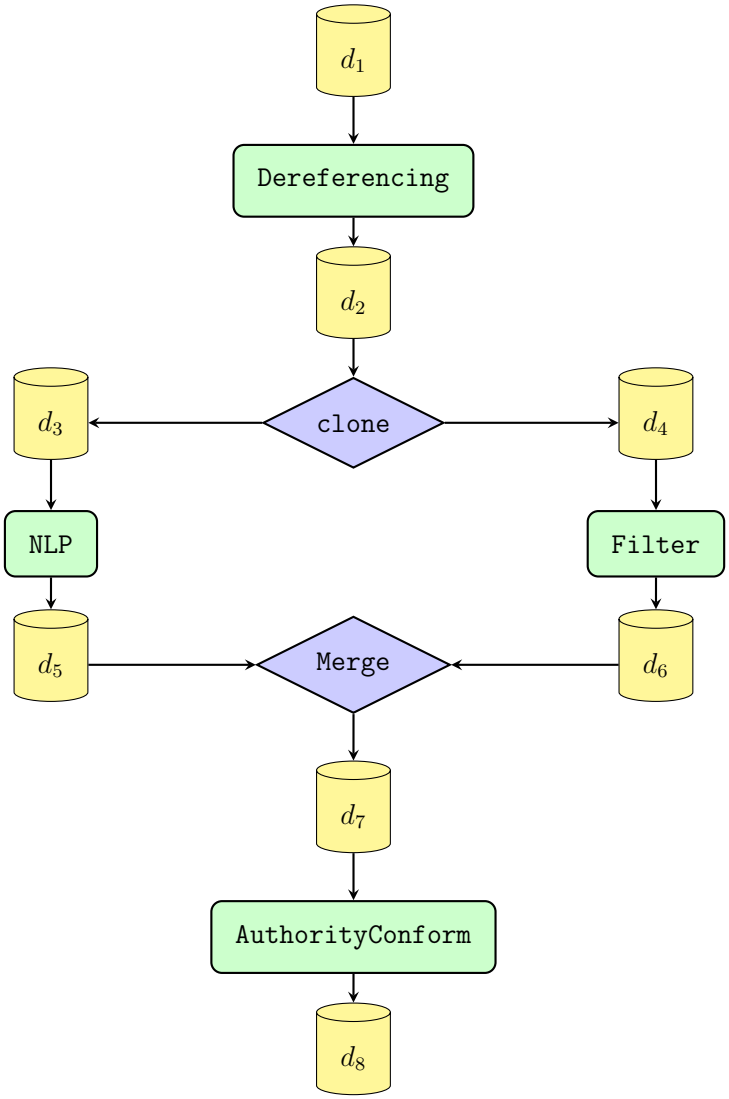

Figure 7: Graph representation of configuration file presented by listing 7

7 Conclusions

In this manual, we presented the DEER component for enriching RDF datasets. In future work, we aim to implement a graphical user interface on top of DEER to enable users to specify their workflows graphically. Moreover, we aim to develop an algorithm for learning the RDF specs of DEER from a small set of positive examples.

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