Training Neural Language Models with SPARQL queries for Semi-Automatic Semantic Mapping

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** Synapta Srl

SEMANTiCS
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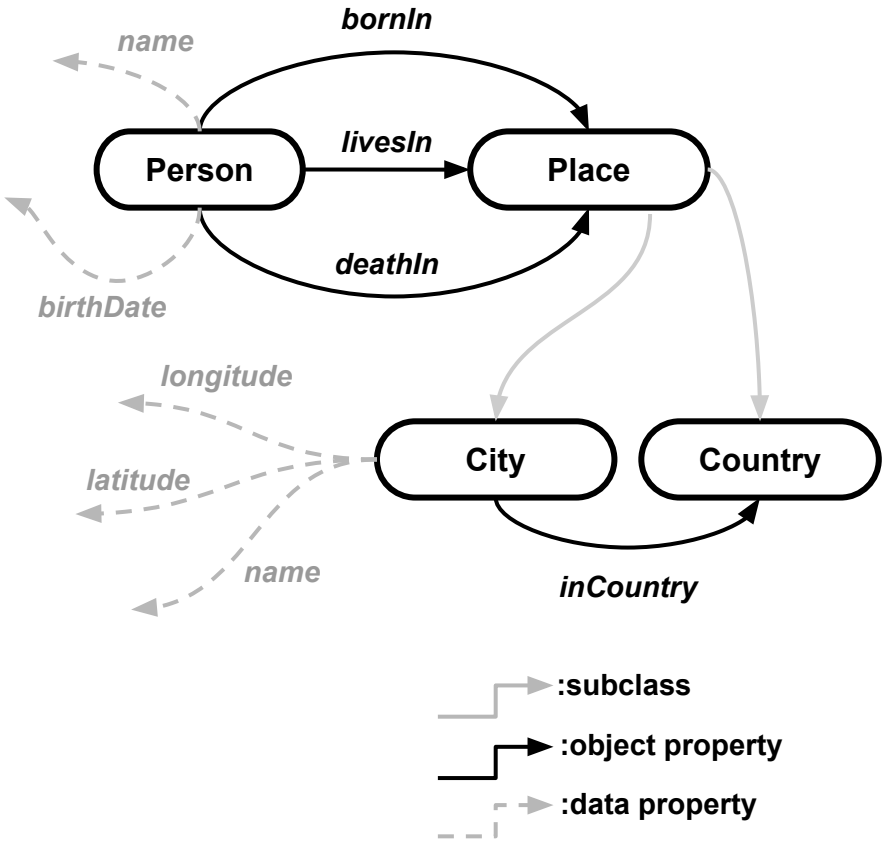
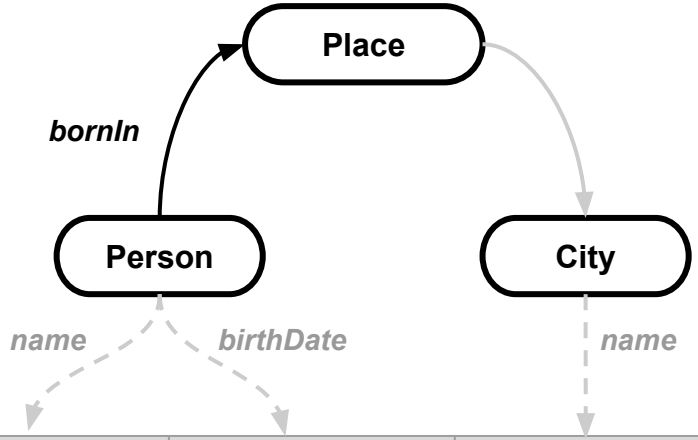
Outline

- Context
- Approach and Implementation
- Results
- Conclusion and Future Works

Context

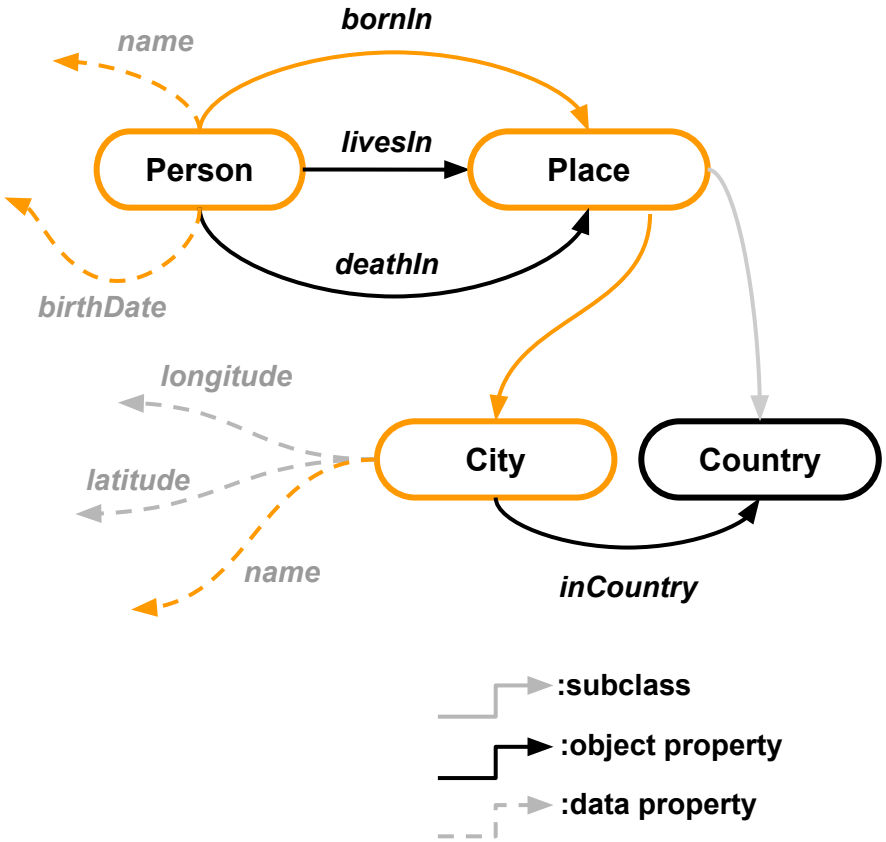
Semantic Mapping

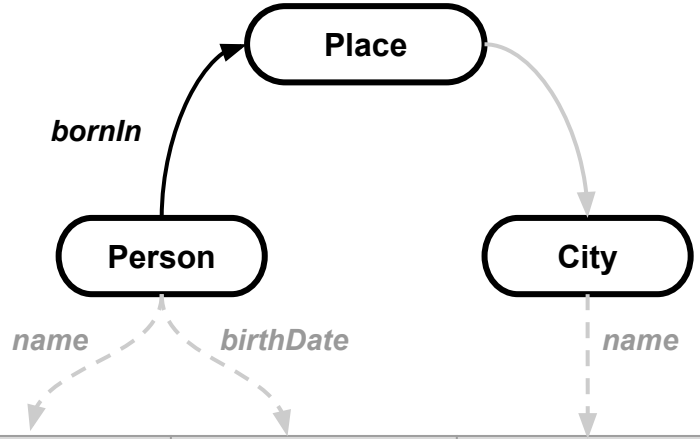




people	birth dates	birth places
Alessandro Manzoni	1860-06-08	Milan
Walter Scott	1771-08-15	Edinburgh
Wolfgang Goethe	1749-08-28	Frankfurt

Semantic Mapping





people	birth dates	birth places
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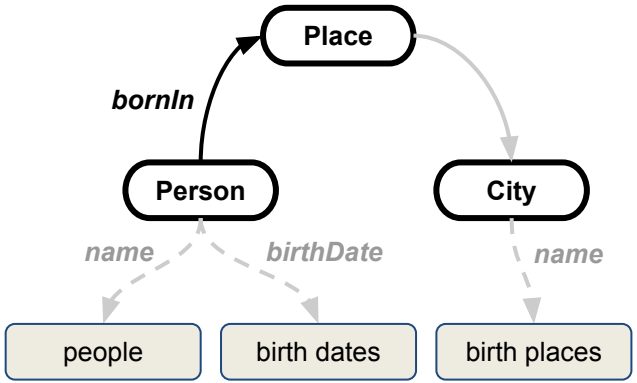
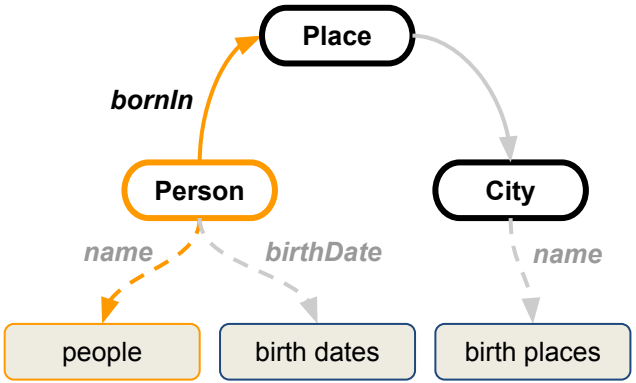
Semantic Mapping (RML)

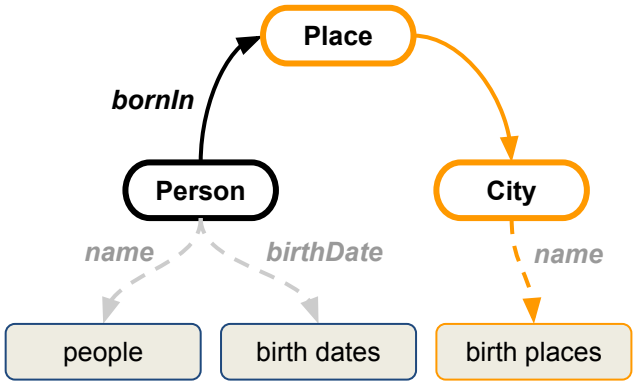


Semantic Mapping (RML)



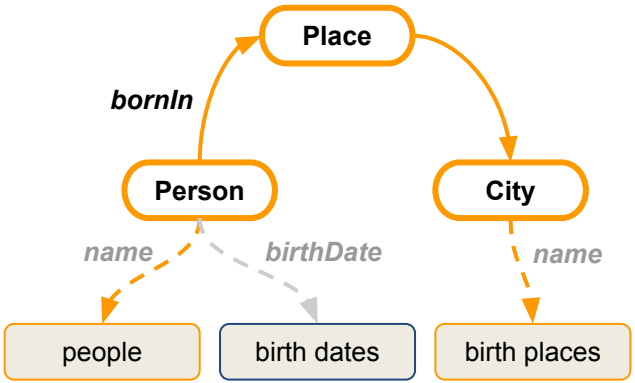

```
<#Writers>
   rml:logicalSource [
      rml:source “authors.csv”
      rml:referenceFormulation ql:CSV
   ];
   rr:subjectMap [
      rr:template
   “http://ex.com/writers/{people}”
      rr:class myontology:Person
   ];
   rr:predicateObjectMap [
      rr:predicate myontology:name
      rr:objectMap [
         rml:reference “people”;
      ]
   ];
   rr: predicateObjectMap [
      rr: predicate myontology:bornIn;
      rr:objectMap [
         rr:parentTriplesMap <#Place>;
      ]
   ] .
```

Semantic Mapping (RML)




```
<#Place>
   rml:logicalSource [
      rml:source “authors.csv”
      rml:referenceFormulation ql:CSV
   ];
   rr:subjectMap [
      rr:template
   “http://ex.com/cities/{birth places}”
      rr:class myontology:City
   ];
   rr:predicateObjectMap [
      rr:predicate myontology:name
      rr:objectMap [
         rml:reference “birth places”;
      ]
   ].
```

Semantic Mapping (RML)




```
<#Writers>
   rml:logicalSource [
      rml:source “authors.csv”
      rml:referenceFormulation ql:CSV
   ];
   rr:subjectMap [
      rr:template
   “http://ex.com/writers/{people}”
      rr:class myontology:Person
   ];
   rr:predicateObjectMap [
      rr:predicate myontology:name
      rr:objectMap [
         rml:reference “people”;
      ]
   ];
   rr: predicateObjectMap [
      rr: predicate myontology:bornIn;
      rr:objectMap [
         rr:parentTriplesMap <#Place>;
      ]
   ] .
```

```
<#Place>
   rml:logicalSource [
      rml:source “authors.csv”
      rml:referenceFormulation ql:CSV
   ];
   rr:subjectMap [
      rr:template
   “http://ex.com/cities/{birth places}”
      rr:class myontology:City
   ];
   rr:predicateObjectMap [
      rr:predicate myontology:name
      rr:objectMap [
         rml:reference “birth places”;
      ]
   ].
```

Semantic Mapping Issues

- Manual generation of semantic mappings requires a significant effort and expertise

- The automation of this task is currently a challenging problem
  - Semantic Types Detection
  - Semantic Relations Discovery

Name Conflicts

- Schemas and ontologies use different conventions to name their artifacts (modeling the same domain)
  - Short identifiers vs long-speaking names
  - Plural vs singular names
  - Different tokenization techniques

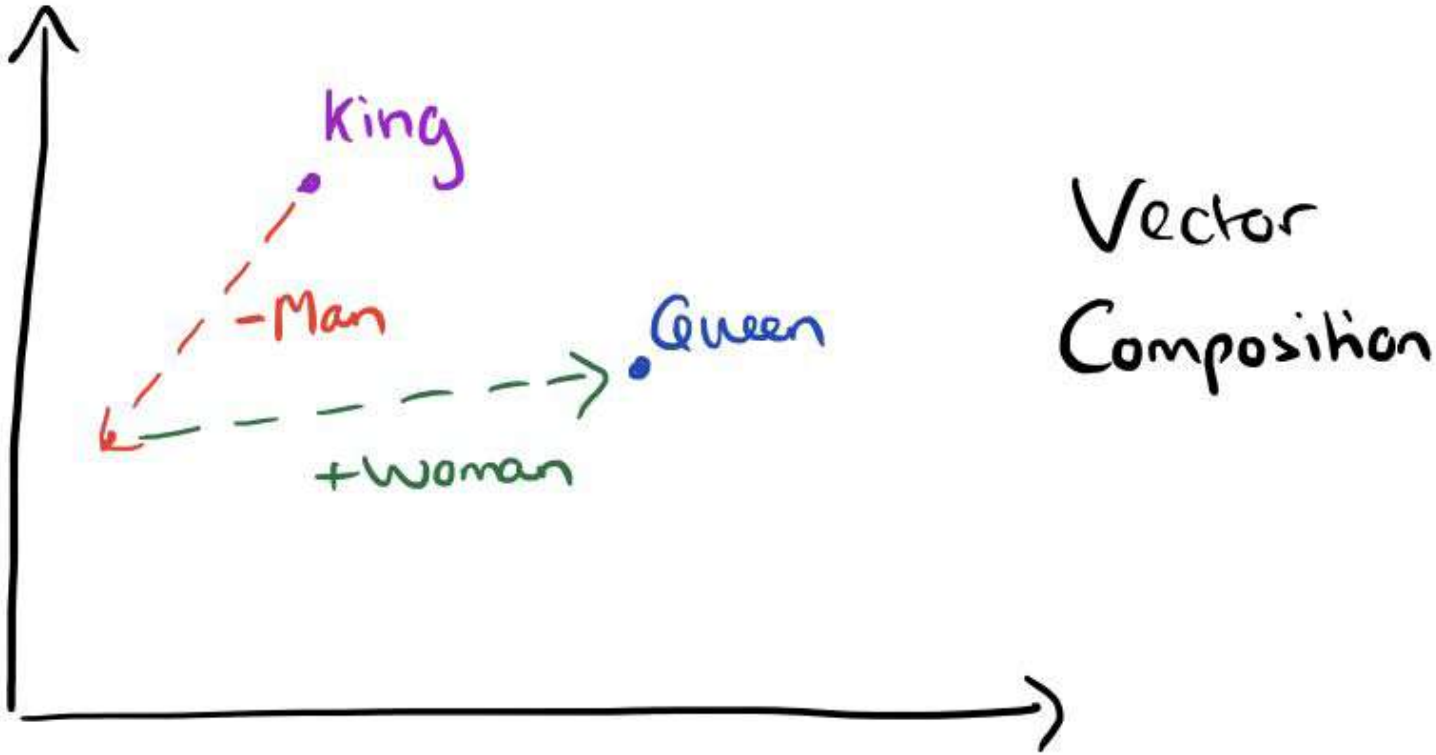
Approach

A semi-automatic approach for the construction of semantic mappings based on the training of **Word2Vec** with **SPARQL queries**

Word2Vec as Language Model

- The goal of a Language Model (LM) is to learn the joint probability function of sequences of words

- Word2Vec is a LM based on a two-layered neural network to learn *word embeddings*
  - Dense and low-dimensional vectors that convey syntactic and semantic information of words


king
-Man
Queen
+woman
Vector
Composition

SPARQL queries as sequence of words that incorporate semantic information expressed through domain ontologies

SPARQL Queries

```
?person dbo:birthPlace ?birthPlace .
?birthPlace dbp:latitude ?lat .
?birthPlace dbp:longitude ?long .

?person dbo:birthPlace ?bp .
?bp dbp:latitude?lat .
?bp dbp:longitude ?long .
```

SPARQL Variables

?person dbo:birthPlace **?birthPlaces** .
?birthPlaces dbp:latitude ?lat .
?birthPlaces dbp:longitude ?long .

?person dbo:birthPlace **?bp** .
?bp dbp:latitude ?lat .
?bp dbp:longitude ?long .

SPARQL Variables

?person dbo:birthPlace **?birthPlaces** .

?birthPlaces dbp:latitude ?lat .

?birthPlaces dbp:longitude ?long .

?person dbo:birthPlace **?bp** .

?bp dbp:latitude ?lat .

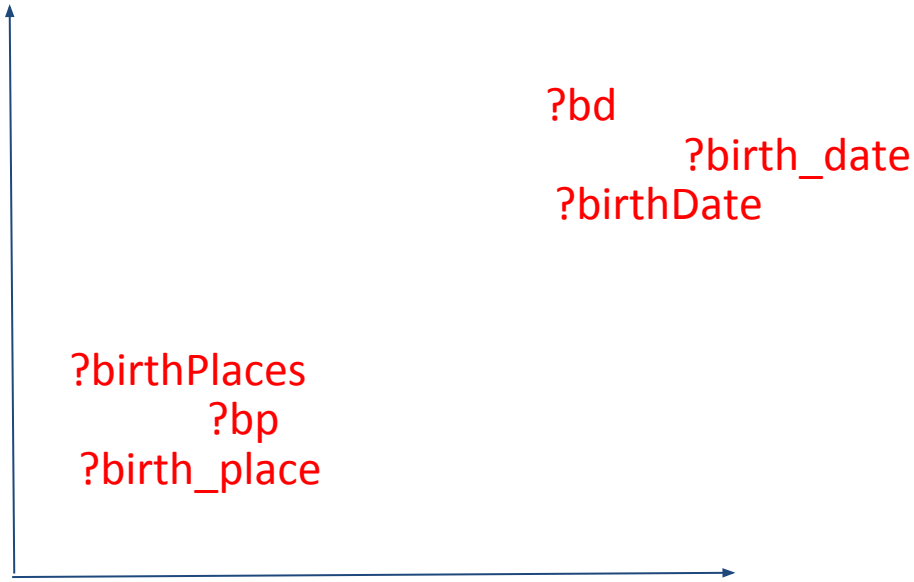
?bp dbp:longitude ?long .

SPARQL Variables and Data Attributes

- Syntactic similarities between attributes of a data source and SPARQL query variables

- Name conflicts between traditional data sources and ontologies are mitigated:
  - Short names also in SPARQL variables
  - Plural instead of singular expressions

SPARQL Query Variables



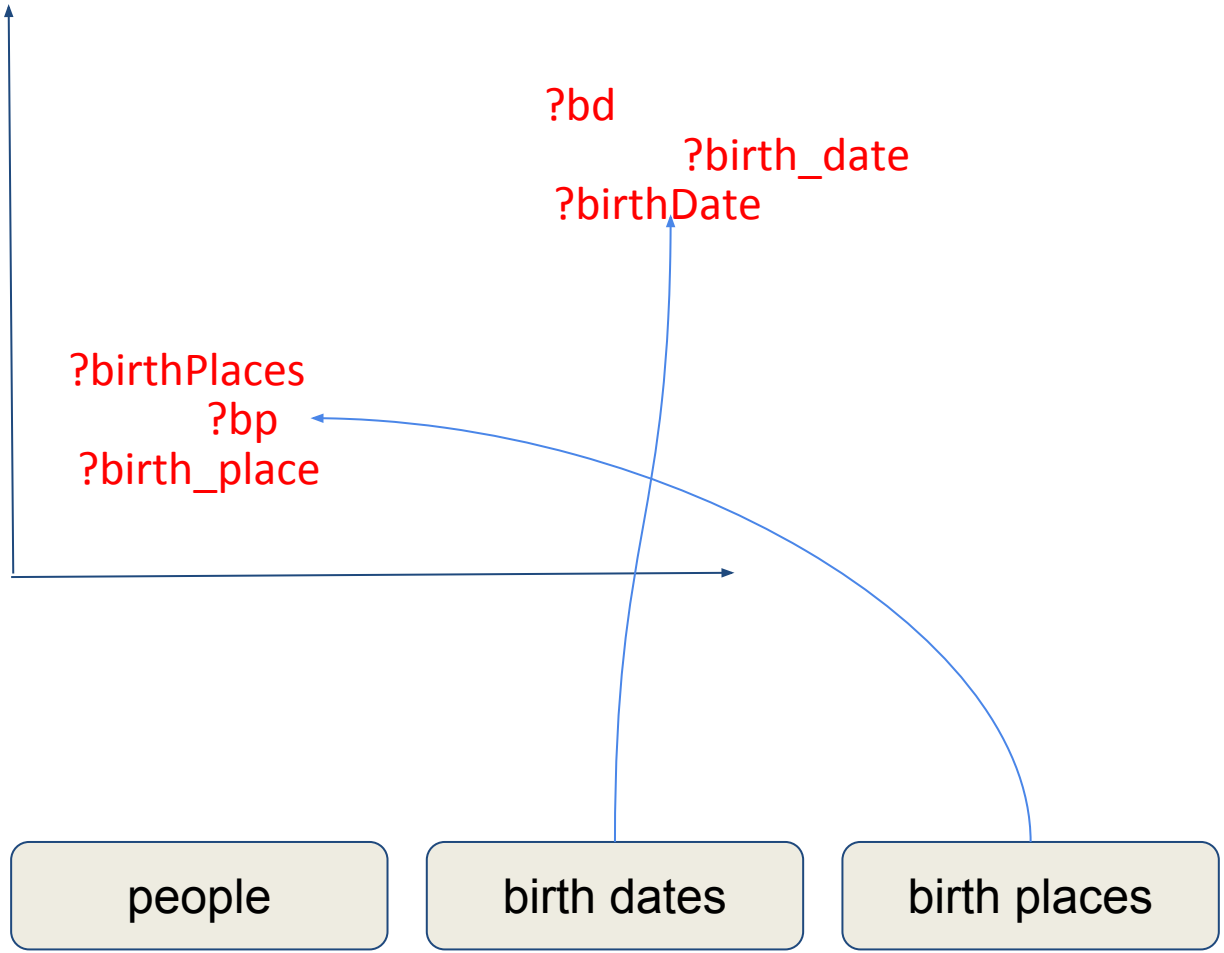
Data Attributes

people

birth dates

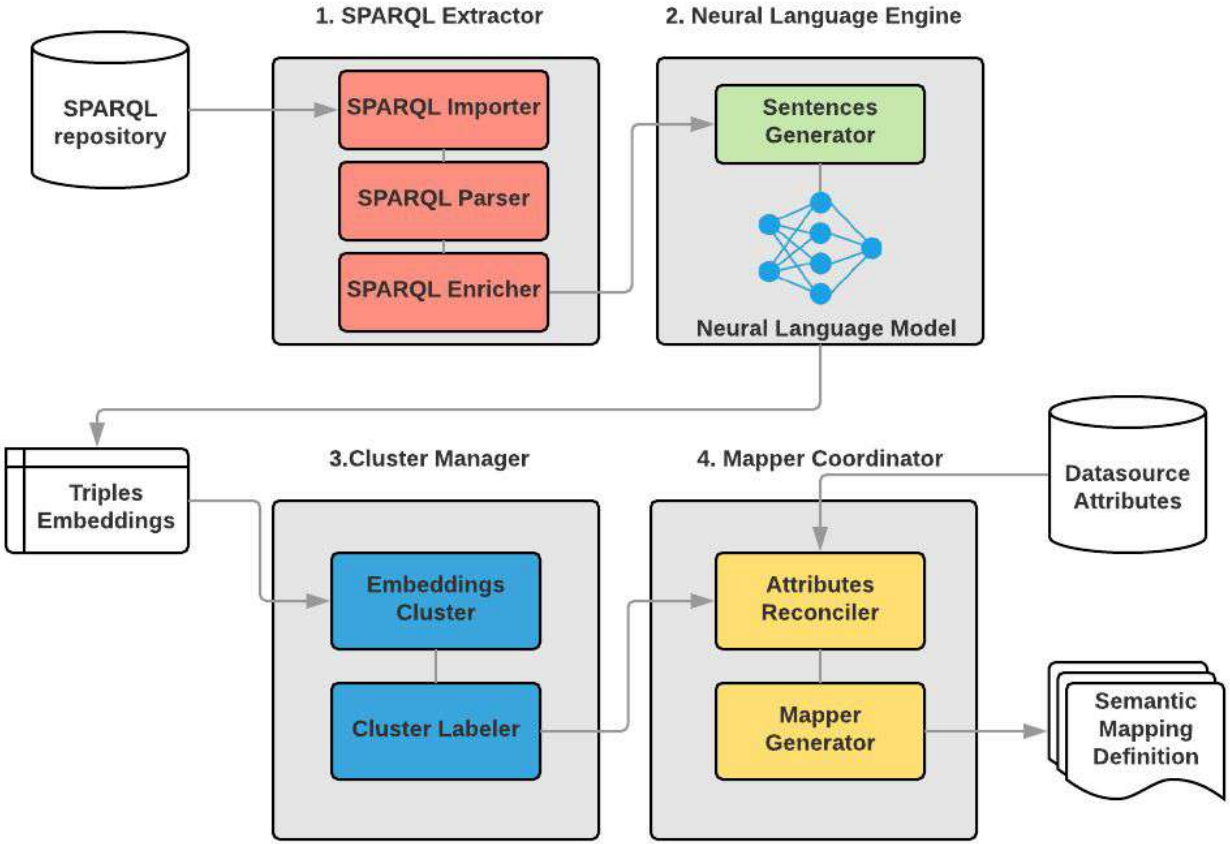
birth places

SPARQL Query Variables



Data Attributes

Implementation


1. SPARQL Extractor
2. Neural Language Engine
SPARQL repository
SPARQL Importer
SPARQL Parser
SPARQL Enricher
Sentences Generator
Neural Language Model
Triples Embeddings
3.Cluster Manager
4. Mapper Coordinator
Datasource Attributes
Embeddings Cluster
Cluster Labeler
Attributes Reconciler
Mapper Generator
Semantic Mapping Definition

SPARQL Extractor

It conducts a pre-processing stage, in order to prepare a set of SPARQL queries as input of the Neural Language Model

- **SPARQL Importer**: it downloads SPARQL queries of LSQ project (AKSW Group)
- **SPARQL Parser**: it extracts triples patterns of SPARQL queries (427.186 triple patterns)
- **SPARQL Enricher**: it harmonizes the context of SPARQL queries that express the same semantics

SPARQL Enricher Details

dbpedia:Alessandro_Manzoni dbo:birthPlace ?birthPlace .

dbpedia:Walter_Scott dbo:birthPlace ?birthPlace .

?person dbo:birthPlace ?bp .

SPARQL Enricher Details

dbpedia:Alessandro_Manzoni dbo:birthPlace ?birthPlace .
dbpedia:Walter_Scott dbo:birthPlace ?birthPlace .
?person dbo:birthPlace ?bp .

DBpedia Class: http://dbpedia.org/ontology/person
DBpedia Label: person

SPARQL Enricher Details

dbpedia:Alessandro_Manzoni dbo:birthPlace ?birthPlace .

dbpedia:Walter_Scott dbo:birthPlace ?birthPlace .

?person dbo:birthPlace ?bp .

?person dbo:birthPlace ?birthPlace .

?person dbo:birthPlace ?birthPlace .

Neural Language Engine

It assigns an embedding representation to variables included in triples retrieved by the SPARQL Extractor

- **Sentence Generator**: it transforms triples in sentences
- **Neural Language Model**: it exploits Word2Vec to assign embeddings to SPARQL variables

Cluster Manager

It assigns an RML template to clusters built on the embedding representation of SPARQL variables (semi-automatic)

- **Embedding Cluster**: it aggregates in clusters SPARQL variables vectors located in a close proximity (DBScan + K-means)
- **Cluster Labeler**: it provides a console through which the user can assign the RML templates to each of the cluster

```
<#Writers>
   rml:logicalSource [
      rml:source “authors.csv”
      rml:referenceFormulation ql:CSV
   ];
   rr:subjectMap [
      rr:template
   “http://ex.com/writers/{$P}”
      rr:class myontology:Person
   ];
   rr:predicateObjectMap [
      rr:predicate myontology:name
      rr:objectMap [
         rml:reference “$P”;
      ]
      sm:variables ?person, ?p, ?people
   ];
   rr: predicateObjectMap [
      rr: predicate myontology:bornIn;
      rr:objectMap [
         rr:parentTriplesMap <#Place>;
      ]
   ] .
```

```
<#Place>
   rml:logicalSource [
      rml:source “authors.csv”
      rml:referenceFormulation ql:CSV
   ];
   rr:subjectMap [
      rr:template
   “http://ex.com/cities/{$C}”
      rr:class myontology:City
   ];
   sm:variables ?birthplace, ?birthPlace,
?bp, ?birth_place;
   rr:predicateObjectMap [
      rr:predicate myontology:name
      rr:objectMap [
         rml:reference “$C”;
      ]
   ].
```

Mapper Coordinator

It generates the semantic mapping between the data source and the domain ontology

- **Attributes Reconciler**: it takes as input the RML template + the data source
  - Goal: reconciling variables mentioned in the RML template and the attribute of the data source (Normalized Levenshtein)
- **Mapper Generator**: it produces the final output, that consists in a RML file

```
<#Writers>
   rml:logicalSource [
      rml:source “authors.csv”
      rml:referenceFormulation ql:CSV
   ];
   rr:subjectMap [
      rr:template
   “http://ex.com/writers/{people}”
      rr:class myontology:Person
   ];
   rr:predicateObjectMap [
      rr:predicate myontology:name
      rr:objectMap [
         rml:reference “people”;
      ]
      sm:variables ?person, ?p, ?people
      sm:score 0.89
   ];
   rr: predicateObjectMap [
      rr: predicate myontology:bornIn;
      rr:objectMap [
         rr:parentTriplesMap <#Place>;
      ]
   ].
```

```
<#Place>
   rml:logicalSource [
      rml:source “authors.csv”
      rml:referenceFormulation ql:CSV
   ];
   rr:subjectMap [
      rr:template
   “http://ex.com/cities/{birth places}”
      rr:class myontology:City
   ];
   sm:variables ?birthplace, ?birthPlace,
?bp, ?birth_place;
   sm:score 0.93
   rr:predicateObjectMap [
      rr:predicate myontology:name
      rr:objectMap [
         rml:reference “birth places”;
      ]
   ].
```

Results

Datasets test + Evaluation

1. The Wikipedia infobox template for a person
2. Web tables of the Famous Birthdays website
3. Web tables of the Biography.com website

Wikipedia	Famous Birthdays.com	Biography.com
name	NONE	name
birth_date	birthday	birth date
birth_place	birthplace	place of birth
death_date	death date	death date
death_place	NONE	place of death

Evaluation Approach + Results

$$precision = \frac{triples(DSM) \bigcap triples(SSM)}{triples(DSM)}$$

1. The Wikipedia infobox template → **Precision: 1**
2. Web tables of the Famous Birthdays → **Precision: 0.3**
3. Web tables of the Biography.com website → **Precision: 0.6**

Discussion

1. **Wikipedia**: there is a complete overlap between the RML triples generated by the system and the domain experts

2. **FamousBirthdays.com**: the name of the subject is not directly reported in the Web table, but it is reported in another section of the Web page

3. **Biography.com**: “place of birth” and “place of death” strings are never used as variables in our SPARQL training set

Conclusions

- A semi-automatic approach for the construction of **semantic mappings** based on the training of **Word2Vec** with **SPARQL queries**

- Exploiting the potential **syntactic closeness between SPARQL variables and attributes of a data source**, we reconstruct the semantics of the data source

Future Works

- We plan to extend SPARQL variables using lexical databases like Wordnet
- We want to empower our approach using also the attribute values
- We desire to explore approaches to directly train neural networks with semantic models

Thank you!

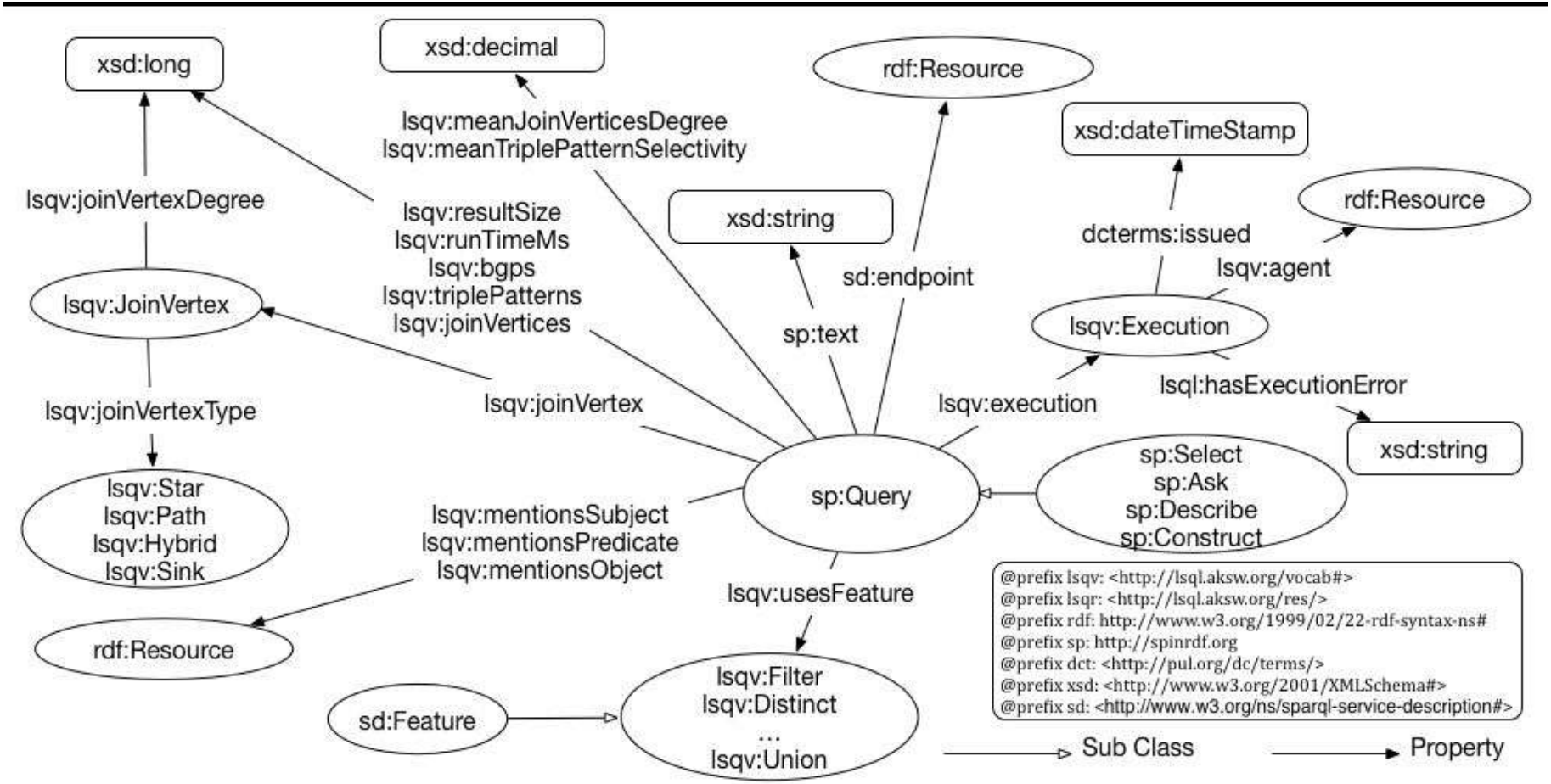
Training Neural Language Models with SPARQL queries for Semi-Automatic Semantic Mapping

Mail: giuseppe.futia@polito.it

Twitter: giuseppe_futia

GitHub: https://github.com/giuseppefutia/

Appendix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rdf:Resource
lsqv:meanJoinVerticesDegree
lsqv:meanTriplePatternSelectivity
xsd:dateTimeStamp
rdf:Resource
lsqv:joinVertexDegree
lsqv:resultSize
lsqv:runTimeMs
lsqv:bgps
lsqv:triplePatterns
lsqv:joinVertices
xsd:string
sd:endpoint
dcterms:issued
lsqv:agent
lsqv:JoinVertex
sp:text
lsqv:Execution
lsqv:joinVertexType
lsqv:joinVertex
lsqv:execution
lsql:hasExecutionError
xsd:string
lsqv:Star
lsqv:Path
lsqv:Hybrid
lsqv:Sink
sp:Query
sp:Select
sp:Ask
sp:Describe
sp:Construct
lsqv:mentionsSubject
lsqv:mentionsPredicate
lsqv:mentionsObject
lsqv:usesFeature
@prefix lsqv: <http://lsql.aksw.org/vocab#>
@prefix lsqr: <http://lsql.aksw.org/res/>
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@prefix xsd: <http://www.w3.org/2001/XMLSchema#>
@prefix sd: <http://www.w3.org/ns/sparql-service-description#>
rdf:Resource
lsqv:Filter
lsqv:Distinct
...
lsqv:Union
sd:Feature
Sub Class
Property