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\textbf{UIMA2LOD: Integrating UIMA Text Annotations into the Linked Open Data Cloud}

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Answers for life.
Agenda

1. Problem of Texts as Unused Resources in LOD Resources
2. UIMA Pipeline for Creating and Integrating Semantic Text Annotations
3. Conceptual Representation of Semantic Text Annotations
4. Case Study on Integrating Annotations into the Model for Clinical Information (MCI)
5. Comparison of Approach with Existing Gold Standard
Problem of Texts as Unused Resources in LOD Resources

- About 80% of all information is encapsulated in unstructured format
- Content enclosed in unstructured texts is not available for structured analysis
- Employ Natural Language Processing (NLP) methods for the extraction of textual information
- Goal of this work to deliver a framework and pipeline for automatically extracting structured information from texts as linked entities, integrated with the LOD cloud, thus extending the LOD cloud with information from textual sources

Enlarged axillary lymph node with diameter 1.5 cm.
Overview of Integration Process: From Semantic Annotation to RDF-Transformation

Integration of Text into LOD

Semantic Data Model

(Unstructured) Texts

Domain Ontology

Model Transformation

Linguistic Annotation → Information Extraction → Semantic Annotation → Structural Annotation → Triplification

Machine Processable, Semantic Data Model

Semantic Enrichment of Text with LOD information

Linguistic Annotation

UIMA-based Information Extraction pipeline operating on recognized linguistically meaningful units

Semantic Annotation

Alignment of text with semantic resources and additional identification of domain-specific concepts

Structural Annotation

Internal representation of textual annotations using defined semantic structures
Information Extraction (IE) framework: High-Level UIMA Component Architecture from Source to Sink

Characteristics
- Unstructured information management architecture
- Former IBM project matured to Apache project
- Architectural framework (incl. tools, annotators) to manage and facilitate analysis of unstructured content
- Helps enriching texts with metadata (so called annotations)

Advantages of UIMA for the medical annotation process
- Modularity of components
- UIMA ships with a list of implemented standard components (FileSystemReader, ConceptMapper, LuceneIndexConsumer, etc.)
- Numerous medical text analysis systems that are built on UIMA
- Exchangeability and reuse of existing (external) components
- Implementation support enables focus on functional requirements rather than technical

Source: http://uima.apache.org/d/uimaj-2.4.2/overview_and_setup.html
Overview of Integration Process:
From Semantic Annotation to RDF-Transformation

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(Uunstructured) Texts
Domain Ontology

Model Transformation

Linguistic Annotation
Information Extraction
Semantic Annotation
Structural Annotation
Triplification

Public Cloud (LOD cloud)
Private Cloud (e.g. MCI)

Semantic Enrichment of Text with LOD information

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Machine Processable, Semantic Data Model

Model Transformation

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Information Extraction

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Structural Annotation

Triplification

(Linguistic) Texts

Domain Ontology

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Semantic Enrichment of Text with LOD information

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**Structural Annotation**

Internal representation of textual annotations using defined semantic structures
Linguistic Annotation

- Three linguistic annotators creating the annotations that reflect the basic linguistic units in the texts:
  1. sentence splitting, (2) tokenization and (3) compound splitting
- NLP Interchange Format (NIF) ontology for representation of resulting linguistic annotations and their relations
- We are able to support adaptation of already existing UIMA annotators – no need for annotators designed specifically for this task
- Requirement for distinct representation of linguistic information in text
Axillary lymph node with diameter 1.5 cm.

Linguistic Annotations
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Semantic Data Model

Machine Processable, Semantic Data Model

(Machine Processable, Semantic Data Model)

Model Transformation

Linguistic Annotation → Information Extraction → Semantic Annotation

Semantic Annotation

Structural Annotation

Triplification

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Semantic Enrichment of Text with LOD Information

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Semantic Annotation
Alignment of text with semantic resources and additional identification of domain-specific concepts

Structural Annotation
Internal representation of textual annotations using defined semantic structures
Information Extraction (IE)

• Semantic Annotations that represent useful information of the target domain
• Domain defines annotators necessary – multitude of NLP algorithms can be integrated (including regular expressions, entity lists, and other more sophisticated algorithms)

• Annotations specific to the use case tackled
e.g. medical measurements describing the organs’ size status
  • *Representation specific to the use case*

```xml
@prefix ex: <http://example.org/stuff/1.0/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema/> .

<http://example.org/stuff/1.0/MeasurementAnnotation124112>
  ex:begin 20; ex:end 26;
  ex:text "1.5 cm"^^xsd:string;
  ex:measures 1.5;
  ex:unit "cm"^^xsd:string .
```
Axillary lymph node with diameter 1.5 cm.  
IE-based Annotations
Overview of Integration Process: From Semantic Annotation to RDF-Transformation

Integration of Text into LOD

Semantic Data Model
(Unstructured) Texts
Domain Ontology

Machine Processable, Semantic Data Model

Model Transformation

Linguistic Annotation
Information Extraction
Semantic Annotation
Structural Annotation
Triplification

Public Cloud (LOD cloud)
Private Cloud (e.g. MCI)

Semantic Enrichment of Text with LOD information

Linguistic Annotation
UIMA-based Information Extraction pipeline operating on recognized linguistically meaningful units

Semantic Annotation
Alignment of text with semantic resources and additional identification of domain-specific concepts

Structural Annotation
Internal representation of textual annotations using defined semantic structures
Semantic Annotation

- Semantic Annotations that represent useful information of the target domain
- Created using vocabulary from domain ontologies
- Two possible application scenarios:
  1. Identify domain-specific semantically classified concepts + interconnect ontology’s knowledge to the textual information
  2. Link to other existing LOD datasets

- Implementation based on UIMA Concept Mapper
- Requires transformation of ontology vocabulary into defined XML structure

```xml
<token RID="RID1301" URI="http://www.owl-ontologies.com/Ontology1392225293.owl#RID1301"
  pn="lung" semanticClass="anatomical">
  <variant base="lung"/>
  <variant base="Lunge"/>
  <variant base="pulmo"/>
</token>
```

- Annotations are created by mapping stemmed UIMA variants from the XML dictionary to the text’s tokens
Axillary lymph node with diameter 1.5 cm.

Semantic Annotations
Overview of Integration Process: From Semantic Annotation to RDF-Transformation

Integration of Text into LOD

- Semantic Data Model
- Machine Processable, Semantic Data Model
- Model Transformation
  - Linguistic Annotation
  - Information Extraction
  - Semantic Annotation
    - Structural Annotation
    - Triplification

Semantic Enrichment of Text with LOD information

**Linguistic Annotation**
- UIMA-based Information Extraction pipeline operating on recognized linguistically meaningful units

**Semantic Annotation**
- Alignment of text with semantic resources and additional identification of domain-specific concepts

**Structural Annotation**
- Internal representation of textual annotations using defined semantic structures
Open Annotation (OA) Structures

- Structural annotations that interconnect the linguistic and the semantic world of the text annotations
- Show how semantics is mapped to linguistic annotation using semantic annotations
- Generic approach by employing basic elements
  - *annotation* – annotation element
  - *target* – linguistic annotation
  - *body* – reference to ontology concept

Single-Target = One Token annotated

Multiple Targets = Multiple Tokens annotated
Axillary lymph node with diameter 1.5 cm.
Structural Annotations
Overview of Integration Process: From Semantic Annotation to RDF-Transformation

Integration of Text into LOD

Semantic Data Model

Unstructured Texts

Domain Ontology

Model Transformation

Linguistic Annotation

Information Extraction

Semantic Annotation

Structural Annotation

Triplification

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Private Cloud (e.g. MCI)

Semantic Enrichment of Text with LOD information

Linguistic Annotation
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Semantic Annotation
Alignment of text with semantic resources and additional identification of domain-specific concepts

Structural Annotation
Internal representation of textual annotations using defined semantic structures
Triplification

• Correct representation of the text annotations created by the NLP pipeline into RDF graph
• Gold Standard: UIMA RDF Consumer
  • 5 limitations with respect to triplification of
    1. Data Properties
    2. Plain Literals
    3. Ambiguities in Unique IDs
    4. Object Properties
    5. Non-Functional Properties
Triplification –
(1) Declarative Modeling of Data Properties

• Each annotation feature is represented using three triples
• Our approach: Lean and intuitive representation of data properties
Triplification – (1) Declarative Modeling of Data Properties

- Each annotation feature is represented using three triples
- Our approach: Lean and intuitive representation of data properties
Triplification –
(2) Typed instead of Plain Literals

- Plain literals cannot be interpreted with their correct data type
- Our approach: Use the information from the UIMA type system and assign correct data type
- Enable automated analysis of the values
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Triplification –
(3) Resolution of Ambiguities with Unique IDs

- Incorrect calculation of identifiers for resources leads to ambiguities in assignment of `featureName` and `featureValue`
- Our approach: Hash code representing all features (names and values)
- Combined into URL as unique identifier for resource
Triplification –
(3) Resolution of Ambiguities with Unique IDs

- Incorrect calculation of identifiers for resources leads to ambiguities in assignment of `featureName` and `featureValue`.
- Our approach: Hash code representing all features (names and values).
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**Hashcode**

```
:meas1

measures  →  unit

„1.5“^^xs  discontinuity
  d:int
  „cm“^^xs  unit
  xsd:StringLength
```

**UIMA RDF Consumer**

```
:meas1

↓

:feature456

↓

:feature456
```
Resolution of Ambiguities with Unique IDs

- Incorrect calculation of identifiers for resources leads to ambiguities in assignment of `featureName` and `featureValue`.
- Our approach: Hash code representing all features (names and values).
- Combined into URL as unique identifier for resource.

**Hashcode**

- `:meas1`
  - `measures`
    - "1.5"^^xsd:float
      - `d:int`
      - `xsd:string`
  - `unit`
    - "cm"^^xsd:string

**UIMA RDF Consumer**

- `:meas1`
  - `:feature456`
    - `featureName`
    - `featureValue`
Triplification –
(4) Triplification of Object Properties

- Linked resources are only triplified to their string representation
- Entities are isolated and links are missing
- Our approach: Deep triplification (recursion) of referenced resources with their features
- Reoccurring resources are identified by their unique id and referenced accordingly
Triplification –
(4) Triplification of Object Properties

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**Complex Triplification**

```
:sentence1  :lymph Node1

contains   hasProperty

:meas1      :meas1
```

**UIMA RDF Consumer**

```
:meas1       :sentence1
contains     contains

„Meas1 [...]“ „Meas1 [...]“

:lymph Node1

hasProperty
```

Claudia Bretschneider/ UIMA2LOD
Triplification –
(5) Triplification of Non-Functional Properties

• All multi-value features should be triplified to non-functional properties, however the used string representation masks the existing values (for both data and object properties)
• Our approach: Identification of value dimension and consideration of multi-value features by deep triplification (recursion) of referenced values
Triplification –

(5) Triplification of Non-Functional Properties

- All multi-value features should be triplified to non-functional properties, however the used string representation masks the existing values (for both data and object properties)
- Our approach: Identification of value dimension and consideration of multi-value features by deep triplification (recursion) of referenced values

Multi-value Features

UIMA RDF Consumer

```
Multi-value Features

:meas1
  measures
    "1.5"^^xsd:int
    "3"^^xsd:int
    "2.7"^^xsd:int

UIMA RDF Consumer

:meas1
  :feature2
    measures
    "FSArray"
```
Qualitative Comparison of Approach with Existing Gold Standard

- Irregular triplifications of the UIMA RDF Consumer leads to
  - Irreversible loss of object properties and non-functional properties
  - Unavailability of linking between object properties not available
- Incomplete RDF graph with high lacks in information is replaced by full and correct representation of the text annotations for further analysis in Semantic Web-based applications

<table>
<thead>
<tr>
<th></th>
<th>CAS2RDF</th>
<th>UIMA2LOD</th>
</tr>
</thead>
<tbody>
<tr>
<td># NIF Annotations</td>
<td>1,506,029</td>
<td></td>
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<tr>
<td># Semantic Annotations</td>
<td>416,251</td>
<td></td>
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<td># OA Annotations</td>
<td>486,425</td>
<td></td>
</tr>
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<td># Triples</td>
<td>144,215,917</td>
<td>47,700,368</td>
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<tr>
<td># Triples with wrong</td>
<td></td>
<td></td>
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<tr>
<td>serialization of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Functional Properties</td>
<td>681,745</td>
<td>–</td>
</tr>
<tr>
<td>Object Properties</td>
<td>8,302,645</td>
<td>–</td>
</tr>
<tr>
<td>Runtime of Annotation Pipeline</td>
<td>24h</td>
<td>9 min</td>
</tr>
<tr>
<td></td>
<td>for 180 docs</td>
<td>for all 2713 docs</td>
</tr>
</tbody>
</table>
Conclusion and Future Work

• Pipeline to automatically triplify the text annotations created in a UIMA pipeline and integrate the text annotations into the LOD cloud
• Consumer fully applicable for any pipeline
• Some annotators have to be exchanged by existing or new implementations to adapt for the texts' domains

• Future Work
  • Automated process to transform a semantic model into the UIMA-internal representation of the type system
  • Extract information from Big Data corpus (10,000 patients from examinations over a period of up to 30 years)
Model Transformation

- Alignment of Semantic Model and UIMA type system
- Annotations are stored in UIMA’s CAS in addition to their predefined type systems (structure of annotations)
- Annotator uses type system to instantiate created text annotations
- Annotations are assigned features of different types and their triplification equivalences
  - **Primitive data types**
    - $\rightarrow$ owl:DataProperty
  - **Complex data types** (i.e. Referencing other annotation types)
    - $\rightarrow$ owl:ObjectProperty
  - **Features with multiple instances**
    - $\rightarrow$ not
      - owl:FunctionalProperty
For the resulting RDF graph to be a valid LOD dataset the requirements imposed by Berners-Lee have been taken into account:

1. **Use URIs as names for things**
2. **Use HTTP URIs so that people can look up those names**
   During the Triplication step each annotation instance gets assigned a unique ID represented as HTTP URI, so that the first two requirements are fulfilled.
3. **When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL)**
   For extraction of useful information we included a number of steps (Linguistic Preprocessing, Information Extraction, Open Annotation (OA) Creation), which at the same time support the envisioned conceptual representation. Again here, for the correct structural representation of the resulting triples, the Triplication step is implemented to use the defined standards.
4. **Include links to other URIs, so that they can discover more things.**
   Finally, to enhance the LOD cloud with additional information entities that are also interconnected with existing datasets, we included the Named Entity Recognition step.
Case Study on Integrating RDF Annotations into the Model for Clinical Information (MCI)
Case Study on Integrating RDF Annotations into the Model for Clinical Information (MCI)

• Resources:
  – Corpus of 2,713 German medical radiology reports
  – RadLex ontology v3.12 containing 74,875 terms for NER
  – Model for Clinical Information (MCI)

• Transformation process for text annotation RDF graph to MCI
  1. Transformation of RDF Graph into MCI Schema
  2. Transformation and Normalization of Measurement Annotations
  3. Disambiguation of Anatomical Entities
  4. Inference