UNIVERSITÄT PADERBORN

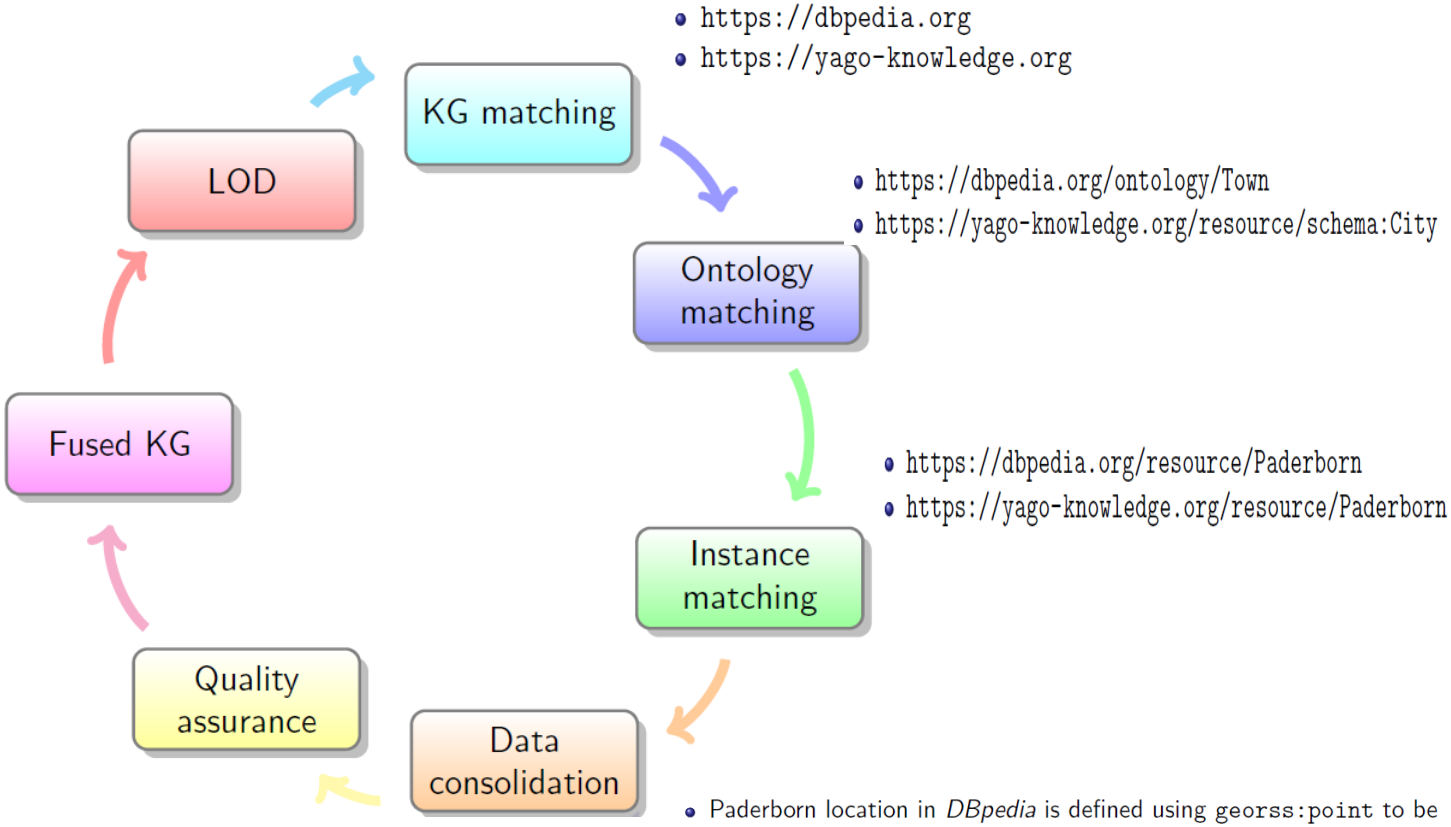
DICE GROUP

KNOWLEDGE GRAPH FUSION

ADVISOR : DR. RER. NAT. MOHAMED SHERIF

UNIVERSITÄT PADERBORN

What is KG Fusion?



UNIVERSITÄT PADERBORN

Overview

- KG Matching
- Ontology Matching
- Instance Matching
- Data Consolidation
- Summary

UNIVERSITÄT PADERBORN

Overview

- **KG Matching**
  - CHAITALI SUHAS BAGWE, RAVITEJA KANAGARLA
- **Ontology Matching**
- **Instance Matching**
- **Data Consolidation**
- **Summary**

UNIVERSITÄT PADERBORN

Goals

- **Find out the similar Knowledge Bases**
  - Using LIMES for Linked Open Data Metadata for link matching
  - Using various document matching techniques for datasets in Hobbit
- **Create a KG Matching operator using DEER**
- **Give output to the next group i.e., Ontology Matching**

UNIVERSITÄT PADERBORN

Steps to match KGs using LIMES

- Collect the metadata from Linked Open Data
- Identify the metadata to be used for KG matching

```
{
  "wiktionary-dbpedia-org": {
    "_id": "wiktionary-dbpedia-org",
    "identifier": "wiktionary-dbpedia-org",
    "doi": "",
    "image": "",
    "links": [
      {
        "target": "dbpedia",
        "value": "25155"
      }
    ],
    "keywords": [
      "crossdomain",
      "linguistics",
      "lodcloud diagram-2014-08-30"
    ],
```

```
"babelnet": {
    "_id": "babelnet",
    "identifier": "babelnet",
    "doi": "",
    "image": "",
    "keywords": [
      "access-web",
      "format-rdf",
      "ldl-2014",
      "lemon",
      "lexical-resources",
      "lexico",
      "linguistics",
      "llod",
      "void-sparql-endpoint"
    ],
    "links": [
      {
        "target": "dbpedia",
        "value": "27585374"
      },
```

UNIVERSITÄT PADERBORN

Steps to match KGs using LIMES

LIMES
Link Discovery Framework for Metric Spaces

- Create a DEER Operator
- Pass the collected metadata to LIMES framework via DEER Operator

```
public Configuration createLimeConfigurationFile(List<Model> models) throws IllegalArgumentException {
  // Creating Limes configuration Object
  Configuration conf = new Configuration();
  // adding prefix
  conf.addPrefix("ns1", "https://example.com/test#");
  conf.addPrefix("owl", "http://www.w3.org/2002/07/owl#");
  conf.addPrefix("rdfs", "http://www.w3.org/2000/01/rdf-schema#");

  KBInfo src = new KBInfo();
  src.setId("sourceId");
  src.setEndpoint("jsontordfoutput.ttl");
  //src.setEndpoint(String.valueOf(models.get(0)));
  src.setVar("?o");
  src.setPageSize(1000);
  src.setType("TURTLE");
  src.setRestrictions(new ArrayList<String>(Arr
  src.setProperties(Arrays.asList(new String[]{
  //src.setProperties(Arrays.asList(new String[]
```

- Store the matched KGs in a RDF model

UNIVERSITÄT PADERBORN

Limes Output

```
<http://wiktionary.dbpedia.org/sparql>
        <http://example.com/test#matches>
                <http://publications.europa.eu/webapi/rdf/sparql> , <http://wordnet.okfn.gr:8890/sparql/> , <
                http://wordnet.rkbexplorer.com/sparql/> , <http://babelnet.org/sparql/> , <http://demo.spraakdata.gu.se/
                ltlod/test/> , <http://linked-data.org/sparql> , <http://mlode.nlp2rdf.org/sparql> , <http://zhishi.me/
                sparql> , <http://ld.panlex.org/sparql> .

<http://www.linklion.org:8890/sparql>
        <http://example.com/test#matches>
                <http://minsky.gsi.dit.upm.es/semanticwiki/index.php/Special:SPARQLEndpoint> , <
                http://ecs.rkbexplorer.com/sparql> , <http://purl.org/twc/hub/sparql> , <
                http://vocabulary.semantic-web.at/PoolParty/sparql/AustrianSkiTeam> , <http://meducator.open.ac.uk/
```

UNIVERSITÄT PADERBORN

HOBBIT

Steps to match KGs using Document Similarity

- **Pre-processing hobbit datasets**
  - Find and split all literals in the dataset into 1-gram token
  - Remove all stopwords, spaces, numbers and special characters
  - Count the frequency of each token
  - Sort the tokens according to their frequency and store them in a list
- **Apply Document Similarities**
  - Matching each datasets against all datasets present
  - Creating RDF model to store the matched similarities

UNIVERSITÄT PADERBORN

Document Similarities Algorithms

- Jaccard Similarity
- Weighted Jaccard Similarity
- Dice Similarity
- TF-IDF with Cosine Similarity
- Bert Similarity

UNIVERSITÄT PADERBORN

Output – Bert Similarity

```
<agrovoc_uniroma2_it.nt>
        <BertSimilarityOutput=0.3667376935482025>
                <data_nobelprize_org.nt> ;
        <BertSimilarityOutput=0.3763076663017273>
                <dbtune_org_bbc_peel_sparql.nt> ;
        <BertSimilarityOutput=0.5186800360679626>
                <dbtune_org_magnatune_sparql.nt> ;
        <BertSimilarityOutput=0.5870665907859802>
                <www_imagesnippets_com_sparql.nt> ;
        <BertSimilarityOutput=0.596704363822937>
                <data_ox_ac_uk_sparql.nt> ;
        <BertSimilarityOutput=0.5990902185440063>
                <dbtune_org_jamendo_sparql.nt> ;
        <BertSimilarityOutput=0.599832296371460>
                <www_orpha_net.nt> ;
        <BertSimilarityOutput=0.6346958875656128>
                <ldf_fi_ww1lod.nt> ;
        <BertSimilarityOutput=0.6368116140365601>
                <cdrewu_eagle-i_net_sparqler.nt> ;
        <BertSimilarityOutput=0.6752213835716248>
                <semanticweb_cs_vu_nl_verrijktkoninkrijk_sparql.nt> ;
        <BertSimilarityOutput=0.6857293844223022>
                <dbmi-icode-01_dbmi_pitt_edu.nt> ;
        <BertSimilarityOutput=0.6954165101051331>
                <onto_fel_cvut_cz_rdf4j-server_repositories.nt> ;
        <BertSimilarityOutput=0.6978609561920166>
```

UNIVERSITÄT PADERBORN

Benchmarking

Dataset Pairs	A1	A2	A3	A4	A5	Mutual Agreement
(dbtune_org_jamendo, data_nobel)	✓	✓	✓	✗	✓	✓
(dbtune_org_jamendo, data_ox_ac)	✓	✓	✓	✓	✓	✓
(cdrewu_eagle, imagesnippets)	✓	✗	✓	✓	✓	✓
(cdrewu_eagle, dbtune_org_magna)	✓	✓	✗	✗	✓	✓

A1, A5 – Software Engineers
A2 – Mechanical Engineer
A3 – Civil Engineer
A4 – Electrical Engineer

UNIVERSITÄT PADERBORN

Benchmarking

Algorithms	Precision Score	Recall Score	F1 Score
Tf-idf with Cosine Similarity	0.94	0.85	0.892
Jaccard Similarity	0.94	0.80	0.863
Weighted Jaccard Similarity	0.97	0.87	0.884
Dice Similarity	0.97	0.69	0.804
Bert Similarity	0.97	0.80	0.874
LIMES Framework	100	0.73	0.843

UNIVERSITÄT PADERBORN

Future works

- More Document Similarities can be added
- Trying the approaches on bigger datasets (> 1GB)
- Using dedicated Knowledge Graph matching approach like Tapioca

UNIVERSITÄT PADERBORN

Overview

- KG Matching
- Ontology Matching
  - SOWMYA KAMARTH RAMESH, KRISHNA MADHAV
- Instance Matching
- Data Consolidation
- Summary

UNIVERSITÄT PADERBORN

Goals

- Integrating with DEER framework
- Implementation of another matching system (FCA)
- Benchmarking our Operator

Technologies

- JAVA
- DEER

UNIVERSITÄT PADERBORN

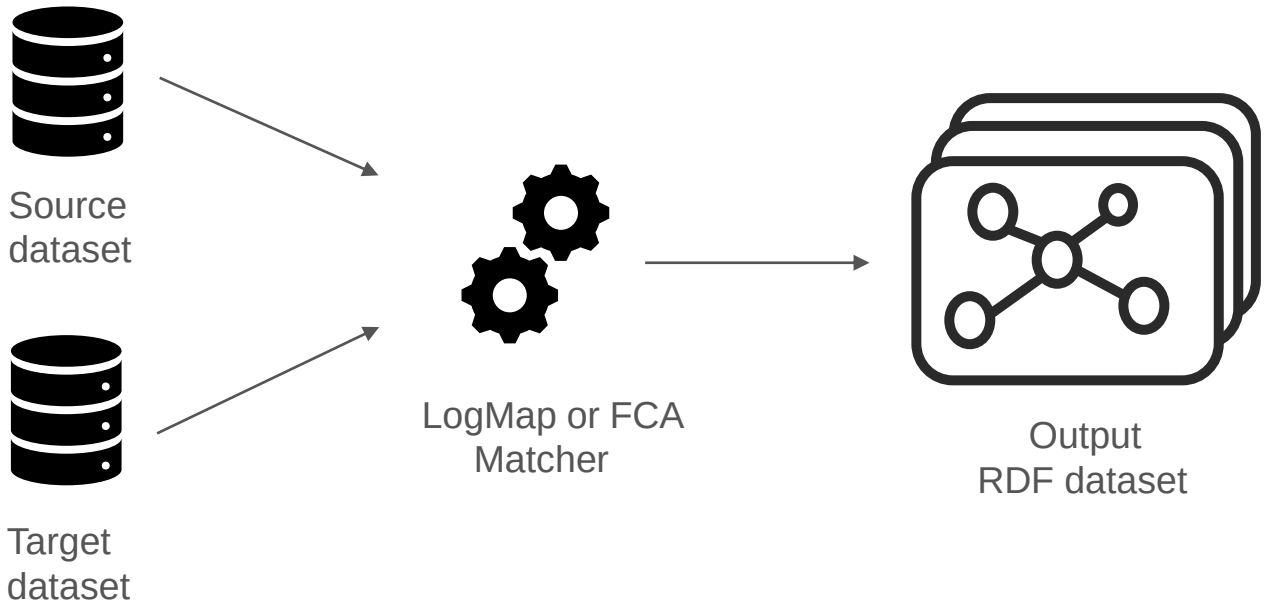
Configuration File

```
:ontologyMatcher
 a deer:OntologyMatchingOperator ;
 deer:typeOfMap "Classes ";
 deer:matching_Library "FCA";
 fcage:hasInput :kgmatcher ;
.
```

```
:ontologyMatcher
 a deer:OntologyMatchingOperator ;
 deer:typeOfMap "Classes and ObjectProperty";
 deer:matching_Library "LOGMAP";
 fcage:hasInput :kgmatcher ;
.
```

UNIVERSITÄT PADERBORN

Overview of our Operator



UNIVERSITÄT PADERBORN

Ontology Matching Operator

- Dynamically fetching RDF datasets
- Accessing SPARQL endpoints
- Storing Ontologies in local file
- Generating Matched Mappings
- Reificated Output

UNIVERSITÄT PADERBORN

Output

```
@prefix deer:  <https://w3id.org/deer/> .

deer:Match_1  deer:found  [ a       <http://www.w3.org/1999/02/22-rdf-syntax-ns#Statement> ;
                            <http://www.w3.org/1999/02/22-rdf-syntax-ns#object>
                                    <http://eagle-i.org/ont/repo/1.0/Person> ;
                            <http://www.w3.org/1999/02/22-rdf-syntax-ns#predicate>
                                    deer:matchesWith ;
                            <http://www.w3.org/1999/02/22-rdf-syntax-ns#subject>
                                    <http://eagle-i.org/ont/app/1.0/Person> ;
                            deer:ObjectEndPoint   <http://tsu.eagle-i.net/sparqler/sparql> ;
                            deer:SubjectEndPoint  <http://utep.eagle-i.net/sparqler/sparql> ;
                            deer:confidenceValue  "0.6"
                          ].
```

UNIVERSITÄT PADERBORN

Benchmarking

Dataset Pairs	A1	A2	A3	Mutual Agreement
NCI_overlapping_fma.owl, FMA_overlapping_nci.owl	✓	✓	✓	✓
SNOMED_overlapping_fma.owl, FMA_overlapping_snomed.owl	✓	✓	✓	✓
Conference.owl, Ekaw.owl	✓	✓	✗	✓

A1, A2 – Software Engineers
A3 – Mechanical Engineer

UNIVERSITÄT PADERBORN

Benchmarking

Dataset Pairs	Matcher	Precision	Recall	F1
NCI_overlapping_fma.owl, FMA_overlapping_nci.owl	LogMap Matcher	0.94	0.92	0.93
	FCA Matcher	0.91	0.93	0.92
SNOMED_overlapping_fma.owl, FMA_overlapping_snomed.owl	LogMap Matcher	0.92	0.91	0.91
	FCA Matcher	0.93	0.86	0.89
Conference.owl, Ekaw.owl	LogMap Matcher	0.94	0.87	0.90
	FCA Matcher	0.92	0.87	0.89

UNIVERSITÄT PADERBORN

Future Work

- Improving timeout for SPARQL query execution
- Working with dataset having triples pointing to invalid OWL files
- Handling bigger dataset

UNIVERSITÄT PADERBORN

Overview

- KG Matching
- Ontology Matching
- Instance Matching
  - KHALID KHAN, KHALID BIN HUDA
- Data Consolidation
- Summary

UNIVERSITÄT PADERBORN

GOAL

- Implement a technique for Instance Matching
- Creating a DEER Operator

Technologies

- JAVA
- DEER
- LIMES

UNIVERSITÄT PADERBORN

Instance Matching Operator

- **Named: InstanceMatchingOperator**
- **Highlights:**
  - Creating prefixes dynamically
  - Calculate coverage of the properties
  - Dynamically creating LIMES configuration
  - Use Wombat simple algorithm
  - Introducing Type-driven wombat simple

UNIVERSITÄT PADERBORN

Configuration File

```
15
16  :matcher   #add source and target and restriction(read from output of ontology matching group)
17   a deer:InstanceMatchingOperator ;
18   deer:coverage "0.70" ;          #Coverage of a Property     #propteryCount/TotalInstanceCount #Default=90%
19   deer:maxLimit "10";             #Maximum number of Properties #Default=3
20   deer:type "file";               #It can be "file" or "endpoint"
21   deer:source "data_nobelprize_org.nt";
22   deer:target "eu_dbpedia_org.nt";
23
24   deer:sourceRestriction [ deer:restrictionURI owl:class ;];
25   deer:targetRestriction [ deer:restrictionURI foaf:Person ;];
26
27   deer:tabuSourceProperty [ deer:propertyURI foaf:id ;];
28
29   fcage:hasInput :reader ;
30  .
31
```

UNIVERSITÄT PADERBORN

Example

Data File source: dbmi-icode-01_dbmi_pitt_edu.nt

Source Restrictions: "?s rdf:type owl:Class"

Properties matched:

puob156:IAO_0000115
gefor191:hasOBONamespace
gefor335:id
w3200488:label

Data File target: agrovoc_uniroma2_it.nt

Target Restrictions: "?t rdf:type skos:Concept"

Properties matched:

w3200541:prefLabel
pudc237:created
pudc20:modified
w3200302:altLabel

wombat simple

OUTPUT:

<http://purl.obolibrary.org/obo/CHEBI_75958> <http://aims.fao.org/aos/agrovoc/c_28563> 0.6153846153846154

UNIVERSITÄT PADERBORN

Benchmarking

- For benchmarking we slightly modified simple wombat
- Added a step to classify properties based on data type
- Use this classification while matching
- For example:

Vector Measure = [euclidean, manhattan]

String Measures = [jaccard, qgrams]

Temporal Measure = [tmp_predecessor, tmp_successor]

Product Name	Price	Manufacturing Date
Floppy disk	223	11-02-1997
Mouse	250	10-05-1998

String Vector Temporal

Label	Retail Price	Production Date
Disk	250	12-05-2000
Screen	500	19-01-2020

UNIVERSITÄT PADERBORN

Benchmarking Result

Dataset	Execution Time Wombat Simple (ms)	Execution Time Type-Driven Wombat Simple (ms)	F-Measure Wombat Simple	F-Measure Type-Driven Wombat Simple	Accuracy Wombat Simple	Accuracy Type-Driven Wombat Simple
Amazon and Google	27821	16006	0.415	0.423	0.999	0.999
Abt-Buy	3969	2693	0.104	0.028	0.987	0.986
DBLP-ACM	64038	53567	0.889	0.900	0.999	0.999
Person 1	6985	6181	0.803	0.805	0.997	0.997
Restaurants	8944	8053	0.447	0.467	0.999	0.999

UNIVERSITÄT PADERBORN

Future Work

- Implementing a more sophisticated Data type classifier. Use this classification while matching
- For a better performance use parallel programming

UNIVERSITÄT PADERBORN

Overview

- KG Matching
- Ontology Matching
- Instance Matching
- Data Consolidation
  - PHILIP COUTINHO DE SOUSA
- Summary

UNIVERSITÄT PADERBORN

Goal

- Merge Data
- Flexible Usage

Technologies

- JAVA
- DEER

UNIVERSITÄT PADERBORN

Consolidation Operator

- **Name: ConsolidationOperator**
- **Idea:**
  - Source sameAs Target
  - MatchableProperties
  - Use FusionStrategies on Properties
- **Highlights**
  - Easily expandable

UNIVERSITÄT PADERBORN

Consolidation Strategies

Strategy	String	Integer	Date	Boolean	Fallback
Standard	Max	Avg	/	And	Take Source
Precise	Min	/	/	And	Take Source
Expertise Source	/	/	/	/	Take Source
Expertise Target	/	/	/	/	Take Target
Min/Max/Average /Union	Min/Max/Avg /Union	Min/Max/Avg / -	Min/Max/Avg / -	And	Take Source
Voting	Max Voting	Max Voting	Max Voting	Max Voting	Take Source

UNIVERSITÄT PADERBORN

Configuration File

```
:consolidation
 a deer:ConsolidationOperator ;
 deer:sameAs "http://www.w3.org/2002/07/owl#sameAs"; # predicate that symbolizes equality
 deer:entityName "http://www.w3.org/1999/02/22-rdf-syntax-ns#type"; #predicate describes the given entitys
 deer:sourceName "https://w3id.org/deer/datasetSource"; # predicate of the data Source
 deer:targetName "https://w3id.org/deer/datasetTarget"; # predicate of the data Target
 deer:addTarget "true"^^xsd:boolean ; # integrate unmatched from the target dataset
 deer:namespaceForIntegration "https://w3id.org/deer/nameprefix/"; # prefix for integration of unmatched from target to
 deer:provenanceProperty "https://w3id.org/deer/provenance";
 deer:globalFusionStrategy "standard"; # standard, precise, expertise, [...]
 deer:outputVariant "ttl"; # output file
 deer:propertyFusion [ # Strategy by Propertys, if not defined use globalFusion
    deer:propertyValue "http://xmlns.com/foaf/0.1/name"; ##property of the source Dataset
    deer:fusionStrategy "expertiseTarget"; ## same as globalstrategy
```

UNIVERSITÄT PADERBORN

Example

```
Source:
<http://data.nobelprize.org/resource/laureate/448> <http://dbpedia.org/property/dateOfBirth> "1943-09-06"^^<http://www.w3.org/2001/XMLSchema#date> .
<http://data.nobelprize.org/resource/laureate/448> <http://dbpedia.org/ontology/birthPlace> <http://data.nobelprize.org/resource/city/Derby> .
<http://data.nobelprize.org/resource/laureate/448> <http://xmlns.com/foaf/0.1/givenName> "Richard J."^^<http://www.w3.org/2001/XMLSchema#string> .
<http://data.nobelprize.org/resource/laureate/448> <http://www.w3.org/2002/07/owl#sameAs> <http://yago-knowledge.org/resource/Richard_J._Roberts> .
<http://data.nobelprize.org/resource/laureate/448> <http://xmlns.com/foaf/0.1/name> "Richard J. Roberts"^^<http://www.w3.org/2001/XMLSchema#string> .

Target:
<http://sparql.cwrc.ca/ontologies/cwrc#26ad3610-a0bb-4e62-8fbc-d6be9ccbbdf6-partof-327d5213ef>
<http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://xmlns.com/foaf/0.1/Person> .
<http://sparql.cwrc.ca/ontologies/cwrc#26ad3610-a0bb-4e62-8fbc-d6be9ccbbdf6-partof-327d5213ef>
<http://xmlns.com/foaf/0.1/name> " Richard J Lane"^^<http://www.w3.org/2001/XMLSchema#string> .
<http://sparql.cwrc.ca/ontologies/cwrc#26ad3610-a0bb-4e62-8fbc-d6be9ccbbdf6-partof-327d5213ef>
<http://purl.org/dc/terms/lastName> "Richard J Lane"^^<http://www.w3.org/2001/XMLSchema#string> .


MatchableProperties:
<http://xmlns.com/foaf/0.1/name> - <http://www.w3.org/2001/XMLSchema#string> .
```

UNIVERSITÄT PADERBORN

Example

<http://data.nobelprize.org/resource/laureate/448> <http://xmlns.com/foaf/0.1/name> "Richard J. Roberts"^^<http://www.w3.org/2001/XMLSchema#string> .

<http://sparql.cwrc.ca/ontologies/cwrc#26ad3610-a0bb-4e62-8fbc-d6be9ccbbdf6-partof-327d5213ef> <http://xmlns.com/foaf/0.1/name> " Richard J Lane"^^<http://www.w3.org/2001/XMLSchema#string> .

Strategy	Result
Standard	Roberts
Precise	Lane
ExpertiseSource	Roberts
ExpertiseTarget	Lane
Min/Max/Average/Union	Lane/Roberts/ - / RJ Roberts RJ Lane
Voting	Not Applicable -> Source -> Roberts

UNIVERSITÄT PADERBORN

Future Work

- Matchable Properties from Previous Groups
- More Advance Fusion Strategies
- Different Output Formats
- New Output format
- Reification - Configuration

UNIVERSITÄT PADERBORN

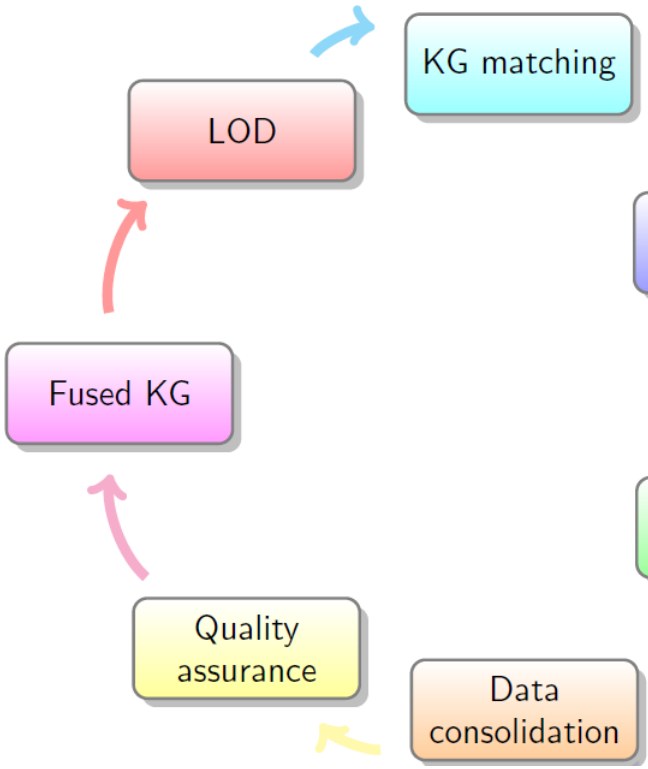
Overview

- KG Matching
- Ontology Matching
- Instance Matching
- Data Consolidation
- Summary

UNIVERSITÄT PADERBORN

Summary

- LIMES Framework
- Document Similarity Algorithms i.e. Bert, Dice, Jaccard, Weighted Jaccard, Tfidf-Cosine.



- LogMap
- FCA-Map
- Type-driven Wombat Simple
- Simple Wombat
- Strategy Dispatchmap

UNIVERSITÄT PADERBORN

THANK YOU FOR LISTENING

QUESTIONS?

UNIVERSITÄT PADERBORN

Summary

KG Matching

```
<http://msm.eagle-i.net/sparqler/sparql>
        <http://example.com/test#matches>
                <http://cau.eagle-i.net/sparqler/sparql>.
```

Ontology Matching

```
<http://vivoweb.org/ontology/core#CoreLaboratory>
    <http://www.w3.org/1999/02/22-rdf-syntax-ns#matchesWith>
        <http://vivoweb.org/ontology/core#Laboratory> .
```

Instance Matching

```
<http://cdrewu.eagle-i.net/i/00000136-0961-ccb9-1a88-e81c80000000>
        <http://www.w3.org/2002/07/owl#sameAs>
        <http://harvard.eagle-i.net/i/0000012e-6cd0-f03d-55da-381e80000000> .
```

Data Consolidation

```
source=[http://data.nobelprize.org/resource/laureate/448, http://xmlns.com/foaf/0.1/name, "Richard J. Roberts"],
target=[http://sparql.cwrc.ca/ontologies/cwrc#26ad3610-a0bb-4e62-8fbc-d6be9ccbbdf6-partof-327d5213ef,
http://xmlns.com/foaf/0.1/name, " Richard J Lane"],
result=Richard J. Roberts
```