Ontology Matching and Evaluation

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INRIA

- Institut National de Recherche en Informatique et en Automatique

EXMO Group: Computer mediated exchange of structured knowledge
- Leader: Jérôme Euzenat
- http://www.inrialpes.fr/exmo/

30 groups of research
~210 researchers
~210 engineers and administratives
~240 docs and post docs (45% étrangers)
Outline

- What is ontology matching
- Matching approaches and strategies
- Ontology Alignment Evaluation Initiative (OAEI)
- SEALS project
- Alignment API
- 10 challenges for ontology matching
Context

- **Ontology**
  - a formal, explicit specification of a shared conceptualization (Gruber, 1993)
  - key role in knowledge based systems

- **Problem**
  - semantic heterogeneity between ontology-based systems

- **Solution**
  - ontology matching
Ontology matching

Traditional application domains:
- Schema integration
- Data warehouse
- Mediator generator

Emergent
- P2P databases
- Agent communication
- Web services integration
Matching process

(Shvaiko and Euzenat [2005])
Correspondence

Definition (Correspondence)

Given two ontologies $o$ and $o'$, a correspondence between $o$ and $o'$ is a 5-tuple $<id, e, e', e, n>$ where

- $id$ is a identifier of the correspondence
- $e$ and $e'$ are entities of $o$ and $o'$
- $r$ is a relation (equivalence, more general, disjointness)
- $n$ is a confidence measure (usually in the $[0,1]$ range)
Alignment

Definition (Alignment)

Given two ontologies \( o \) and \( o' \), an **alignment** between \( o \) and \( o' \) is

- a set of correspondences on \( o \) and \( o' \)
- includes some metadata (multiplicity: 1-1, 1-*: method, data, etc)
Matching approaches

(Euzenat and Shvaiko [2007])
Matching approaches

- Representative categories
  - Syntactic/lexical (string-based similarity)
  - Semantic (WordNet based)
  - Structural (positions of the terms in the ontology hierarchy)
Syntactic and semantic

• Syntactic/lexical matcher (string-based similarity)
  • e = “photo-camera” and e’ = “camera-photo”
    - exactMatch, with strength = matches/max length = 2 / 2 = 1
  
  • e = “science” and e’ = “computer-science”
    - broadMatch, with strength = matches/max length = 1 / 2 = 0.5

• Semantic matcher (WordNet based)
  • e = “personal-computer” and e’ = “pc”
    - exactMatch, with strength = 1, direct synonymous WordNet
Structural matcher

- Structural matcher
  - Based on taxonomy overlap and semantic cotopy (Maedche and Staab, 2002)

\[
TO_n(e_s, e_t, O_s, O_t) = \frac{|\text{Electronic, PersonalComputer} \cap \text{Electronic, PC}|}{|\text{Electronic, PersonalComputer} \cup \text{Electronic, PC}|}
\]

\[
SC(\text{PersonalComputer}, O_e) = \{\text{Electronic, PersonalComputer}\}
\]

\[
SC(\text{PC}, O_e) = \{\text{Electronic, PC}\}
\]

\[
\text{exactMatch} = \frac{2}{2} = 1
\]
Matching strategies

Ontology Matching Strategies

- Manual
- Automatic
- Hybrid

Kind of processing:
- Sequential
- Parallel

Strategies:
- Similarity Aggregation
- Agent-based
- Machine Learning
- Probabilistic
- Argumentation
- Negotiation

(Trojahn, 2008)
Goal of evaluation

- Improve the performance of systems
- Comparison of systems
- Various sets of tests and criterion
- Created the **Ontology Alignment Evaluation Initiative** (OAEI)
OAEI

- Organization of a yearly evaluation event
- Different domains of test data (complexity, size, ...)
- Participants submit their alignments in a standard format
- These are compared with available reference alignments
- Deviation is measured by classical measures, such as precision and recall
- Results are published on the web site and OM Workshop
- http://oaei.ontologymatching.org/
OAEI
OAEI metrics

Definition (Precision and Recall)

Given a reference alignment $R$

- **precision** of some alignment $A$ is given by
  $$P(A, R) = \frac{|R \cap A|}{|A|}$$

- **recall** is given by
  $$R(A, R) = \frac{|R \cap A|}{|R|}.$$ 

When no reference alignment is provided: consensus, task-oriented,..
Extended precision and recall

- **Problems with classical P and R**
  - Do not make difference between a nearly good alignment and a bad one
  - P and R do not recognise two equivalent alignments
  - If they are not the same exact correspondence they score zero
  - How to know if an alignment is closer to the expected?

- **Solution**
  - Measuring the “proximity” of alignments: generalizing precision and recall
Extended precision and recall

$A_2$ – reasonable

\[
\begin{align*}
<\text{o1:Car, o2:Thing, =, 1.0}> \\
<\text{o1:hasSpeed, o2:hasProperty, =, 1.0}> \\
<\text{o1:MotorKA1, o2:Marcsporsche, =, 1.0}> \\
<\text{o1:250kmh, o2:fast, =, 1.0}>
\end{align*}
\]

$R$

\[
\begin{align*}
<\text{o1:Object, o2:Thing, =, 1.0}> \\
<\text{o1:Car, o2:Automobile, =, 1.0}> \\
<\text{o1:Speed, o2:Characteristic, =, 1.0}> \\
<\text{o1:250kmh, o2:fast, =, 1.0}> \\
<\text{o1:PorscheKA123, o2:Marcsporsche, =, 1.0}>
\end{align*}
\]

$A_3$ – wrong

\[
\begin{align*}
<\text{o1:Object, o2:Thing, =, 1.0}> \\
<\text{o1:Owner, o2:Volkswagen, =, 1.0}> \\
<\text{o1:Boat, o2:Porsche, =, 1.0}> \\
<\text{o1:hasOwner, o2:hasMotor, =, 1.0}> \\
<\text{o1:Marc, o2:fast, =, 1.0}>
\end{align*}
\]
Relaxed P and R  [Ehrig and Euzenat 2005]

- Generalises classical P and R by using a **proximity** function $\omega$ instead of $|A \cap R|$
- Three concrete extensions proposed.

**Definition (Relaxed precision and recall)**

Given a reference alignment $R$ and an overlap function $\omega$ between alignments

\[
P_\omega(A, R) = \frac{\omega(R \cap A)}{|A|}
\]

\[
R_\omega(A, R) = \frac{\omega(R \cap A)}{|R|}
\]
Relaxed P and R \cite{Ehrig2005} 

\[ \omega(A, R) = \sum_{<a,r> \in M(A,R)} \sigma(a, r) \]

Symmetric

\[ \sigma_{\text{pair}}(<e_a, e'_a>, <e_r, e'_r>) \]
\[ \sigma_{\text{rel}}(r_a, r_r) \]
\[ \sigma_{\text{conf}}(n_a, n_r) \]

- distance 0 at class, 0.5 sub classe, 1 others
- 1 correct relations in both \( r_a \) and \( r_r \), 0.5 if found equivalence but correct is subsumption
- complement of the difference
Relaxed P and R [Ehrig and Euzenat 2005]

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Semantic P and R [Euzenat 2007]

- Previous solution: syntactic
- P and R semantically grounded
  - correspondences that are consequences of the evaluated alignment: recalled
  - correspondences that are consequences of the reference alignment: correct

Definition (Semantic precision and recall)

Given a reference alignment R, the precision of some alignment A is given by

$$P_{sem}(A, R) = \frac{|A \cap Cn(R)|}{|A|}$$

and recall is given by

$$R_{sem}(A, R) = \frac{|Cn(A) \cap R|}{|R|}$$
### OAEI 2009 dataset

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OAEI 2009 participants

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SEALS Project

Semantic Evaluation at Large Scale
http://www.seals-project.eu/

- Scalability and new metrics
- New open platform for semantic technology evaluation
- Automated test infrastructure
- Organize integrated evaluation campaigns
- Online evaluation
- Participants run the evaluation for themselves
Alignment API

- [http://alignapi.gforge.inria.fr/](http://alignapi.gforge.inria.fr/)

- Reads two OWL/RDF ontologies
- Computes the alignment between these ontologies
- Displays the result (OWL, SWRL, XSTL)
- Evaluate the alignment (precision, recall, f-measure, extended precision and recall)
- Display the evaluation results (graphs, tables)
Alignment API

Alignment format

```xml
<Alignment>
  <xml>yes</xml>
  <level>0</level>
  <type>11</type>
  <onto1>http://oaei.ontologymatching.org/2009/benchmarks/101/onto.rdf</onto1>
  <uri1>http://oaei.ontologymatching.org/2009/benchmarks/101/onto.rdf</uri1>
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      <relation>==</relation>
    </Cell>
  </map>
  ...
</Alignment>
</rdf:RDF>
```
Alignment API

Examples evaluation output
10 Challenges  [Shvaiko and Euzenat, 20008]

1. large-scale evaluation
2. performance of ontology-matching techniques
3. discovering missing background knowledge
4. uncertainty in ontology matching
5. matcher selection and self-configuration
6. user involvement
7. explanation of matching results
8. social and collaborative ontology matching
9. alignment management: infrastructure and support
10. reasoning with alignments
Acknowledges

- Thanks to Jérôme Euzenat for sharing some material.
- Thanks to Renata Vieira for the opportunity.
- Thank you for the attention.