CAMO: Integration of Linked Open Data for Multimedia Metadata Enrichment

Wei Hu¹, Cunxin Jia¹, Lei Wan²
Liang He², Lixia Zhou², Yuzhong Qu¹

1. Nanjing University, China
2. Samsung Electronics (China) R&D Center
Outline

- **Introduction**
- System architecture
- **Approaches**
  - Matching ontologies with DBpedia
  - Linking instances with DBpedia
  - Integrating legacy relational databases
- **Evaluation**
- **Conclusion**
Introduction

- **Metadata** is vital to multimedia content services
  - Search, browsing, content management …

- Existing multimedia metadata models and standards
  - do not provide formal semantics
  - typically focus on a single media type, incompatible with others
    - EXIF is incompatible with MPEG-7

- Different media types **coexist** in a multimedia presentation
  - A movie may have a theme music and a poster
Introduction

- To realize the vision of digital convergence (home network)
  - Ontology Modelling & Annotating for Convergence (CAMO)
Introduction

- To realize the vision of digital convergence (home network)
  - Ontology Modelling & Annotating for Convergence (CAMO)
  - making use of LOD to enrich multimedia metadata
A motivating example

Beauty and the Beast (A film video)
A motivating example

**Beauty and the Beast (A film video)**
- Low-level metadata: runtime, location

- **LinkedMDB**
  - linkedmdb:330
    - rdf:type linkedmdb:film
    - linkedmdb:director linkedmdb:11264
    - dc:title "Beauty and the Beast"

- **DBpedia**
  - dbpedia:Beauty_and_the_Beast_(1991_film)
    - rdf:type dbpedia:Film
    - dbpedia:director dbpedia:Gary_Trousdale
    - rdfs:label "Beauty and the Beast"
    - dbpedia:abstract "... is a 1991 American animated ..."

- **DBpedia**
  - dbpedia:Beauty_and_the_Beast_(Soundtrack)
    - rdf:type dbpedia:Soundtrack
    - dbpedia:genre dbpedia:Pop_music
    - rdfs:label "Beauty and the Beast"

CAMO: Integration of LOD for Multimedia Metadata Enrichment
A motivating example

*Beauty and the Beast (A film video)*
- Low-level metadata: runtime, location
- LOD: LinkedMDB, DBpedia
  - Different ontologies (terms), different instances
A motivating example

**Beauty and the Beast (A film video)**

- Low-level metadata: runtime, location
- LOD: LinkedMDB, DBpedia
  - Different ontologies (terms), different instances

Accurate ontology matching and instance linkage

```
linkedmdb:330
  rdf:type    linkedmdb:film
  linkedmdb:director    linkedmdb:11264
  dc:title        "Beauty and the Beast"
```

```
dbpedia:Beauty_and_the_Beast_(1991_film)
  rdf:type    dbpedia:Film
  dbpedia:director    dbpedia:Gary_Trousdale
  rdfs:label        "Beauty and the Beast"
  dbpedia:abstract    "...is a 1991 American animated ..."
```

```
dbpedia:Beauty_and_the_Beast_(Soundtrack)
  rdf:type    dbpedia:Soundtrack
  dbpedia:Pop_music
  rdfs:label        "Beauty and the Beast"
```

```
dbpedia:Alan_Menken
  dbpedia:musicComposer
  dbpedia:producer
```
Our approach

- To enrich multimedia metadata via integrating LOD
  - Select **DBpedia as the mediation** and match with others
  - Link DBpedia instances with other entities, and then aggregate their descriptions
  - Integrate legacy relational databases, from content providers
Our approach

- To enrich multimedia metadata via integrating LOD
  - Select DBpedia as the mediation and match with others
  - Link DBpedia instances with other entities, and then aggregate their descriptions
  - Integrate legacy relational databases, from content providers
  - Moreover, develop a mobile app for browsing and searching multimedia content on Android devices
  - Assess the advantages of integrating LOD into multimedia metadata
System architecture

LOD

Data integration

......

CAMO: Integration of LOD for Multimedia Metadata Enrichment
System architecture

Server side
- The **DBpedia 3.6 ontology** as the mediation
- Global-as-View solution of data integration

Client side
- Android-based mobile app
  - Search & browse multimedia content
  - Integrate with a multimedia player
System architecture

Server side
- The DBpedia 3.6 ontology as the mediation
- Global-as-View solution of data integration

Datasets
- Music: DBpedia, DBTune, MusicBrainz
- Movie: DBpedia, LinkedMDB, DBTropes

Client side
- Android-based mobile app
  - Search & browse multimedia content
  - Integrate with a multimedia player
Outline

- Introduction
- System architecture
- Approaches
  - Matching ontologies with DBpedia
  - Linking instances with DBpedia
  - Integrating legacy relational databases
- Evaluation
- Conclusion and lessons learned
Matching ontologies with DBpedia

- Different LOD sources may use different ontologies
  - DBpedia, Music ontology …

- **Falcon-AO:** an automatic ontology matching tool
  - Linguistic matchers: V-Doc (TF-IDF) & I-Sub (edit distance)
  - Structural matcher: GMO (similarity propagation)

- Extend with domain knowledge to support synonym identification
  - *track* vs. *song*
Linking instances with DBpedia

- Instance linkage helps merge all descriptions in different sources that refer to the same multimedia content
Linking instances with DBpedia

- Instance linkage helps merge all descriptions in different sources that refer to the same multimedia content

  in knowledge
  ↓

- Training set construction
  - Positive examples: semantically equivalent, owl:sameAs, skos:exactMatch.
  - Negative examples: owl:differentFrom, approximation

- Class-based **discriminative property** learning
  - Information gain: \( IG(p_i, p_j) = H(D) - H(D_{(p_i,p_j)}) \)

- Instance linking (online)
Integrating legacy relational DBs

- There are still a great deal of legacy data stored in RDBs
- Some data in LOD are generated from their relational versions
Integrating legacy relational DBs

- There are still a great deal of **legacy** data stored in RDBs
- Some data in LOD are generated from their relational versions

1. Element types classification
   - Element classification
     - e.g., entity table and relationship table
   - Element matching
   - Instance linkage
Integrating legacy relational DBs

- There are still a great deal of *legacy* data stored in RDBs
- Some data in LOD are generated from their relational versions

1. Element types classification
   - e.g., entity table and relationship table
2. Schema matching
3. Instance linkage

- Element classification
- Element matching
- Instance linkage

Similar to ontology matching and instance linkage
Outline

- Introduction
- System architecture
- Approaches
  - Matching ontologies with DBpedia
  - Linking instances with DBpedia
  - Integrating legacy relational databases
- Evaluation
- Conclusion and lessons learned
Evaluation

- A mobile app on Android devices
- Two experiments
  - Usability and effectiveness of the mobile app
  - Integration accuracy in the multimedia domain
(1) Usability & effectiveness

- 3 comparative apps
  - Music domain: Last.fm
  - Movie domain: IMDb
  - Cross-domain: Wikipedia Android app
(1) Usability & effectiveness

- 3 comparative apps
  - Music domain: Last.fm
  - Movie domain: IMDb
  - Cross-domain: Wikipedia Android app

- 6 testing tasks

<table>
<thead>
<tr>
<th>Domain</th>
<th>Task description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Music</td>
<td>T1. X is a Lady Gaga’s song whose name is started with letter “P”. Please find the album of X.</td>
</tr>
<tr>
<td></td>
<td>T2. X is a Coldplay’s song whose name is started with letter “Y”. Please find the writer of X.</td>
</tr>
<tr>
<td>Movie</td>
<td>T3. X is the producer of The Godfather. Please find X’s name and any two films for which X won the Academy Award.</td>
</tr>
<tr>
<td></td>
<td>T4. X is the music composer of The Terminator. Please find X’s name and any two films of which X was also the music composer.</td>
</tr>
<tr>
<td>Cross-domain</td>
<td>T5. X is the director of Michael Jackson’s movie Michael Jackson’s That Is It, and Y is the album of Michael Jackson’s song Beat It. Please find the names of X and Y, respectively.</td>
</tr>
<tr>
<td></td>
<td>T6. X is the distributor of Will Smith’s movie The Pursuit of Happiness, and Y is an Will Smith’s album named “Born to Reign”. Please find X’s name and the release date of Y.</td>
</tr>
</tbody>
</table>
(1) Usability & effectiveness

- 3 comparative apps
  - Music domain: Last.fm
  - Movie domain: IMDb
  - Cross-domain: Wikipedia Android app

- 6 testing tasks

- 50 participants
  - 10 graduates
  - 22 undergraduates
  - 18 engineers

<table>
<thead>
<tr>
<th>Domain</th>
<th>Task description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Music</td>
<td>T1. X is a Lady Gaga’s song whose name is started with letter “P”. Please find the album of X.</td>
</tr>
<tr>
<td></td>
<td>T2. X is a Coldplay’s song whose name is started with letter “Y”. Please find the writer of X.</td>
</tr>
<tr>
<td>Movie</td>
<td>T3. X is the producer of The Godfather. Please find X’s name and any two films for which X won the Academy Award.</td>
</tr>
<tr>
<td></td>
<td>T4. X is the music composer of The Terminator. Please find X’s name and any two films of which X was also the music composer.</td>
</tr>
<tr>
<td>Cross-domain</td>
<td>T5. X is the director of Michael Jackson’s movie Michael Jackson’s That Is It, and Y is the album of Michael Jackson’s song Beat It. Please find the names of X and Y, respectively.</td>
</tr>
<tr>
<td></td>
<td>T6. X is the distributor of Will Smith’s movie The Pursuit of Happiness, and Y is an Will Smith’s album named “Born to Reign”. Please find X’s name and the release date of Y.</td>
</tr>
</tbody>
</table>
(1) Usability & effectiveness

- System Usability Scale (SUS) & post-task questionnaire

<table>
<thead>
<tr>
<th>Question description</th>
<th>Score (1–5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1. The app has an accurate description about content.</td>
<td>1 for strongly disagree, and 5 for strongly agree.</td>
</tr>
<tr>
<td>Q2. The app has a comprehensive coverage about content.</td>
<td></td>
</tr>
<tr>
<td>Q3. The app helps me easily find content that I am interested in.</td>
<td></td>
</tr>
<tr>
<td>Q4. The app provides few redundant and irrelevant information.</td>
<td></td>
</tr>
<tr>
<td>Q5. The app often shows me some unexpected facts in browsing.</td>
<td></td>
</tr>
</tbody>
</table>

- Result

<table>
<thead>
<tr>
<th>SUS</th>
<th>CAMO 87.88</th>
<th>Last.fm 79.81</th>
<th>IMDb 89.62</th>
<th>Wikipedia 84.04</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Music</th>
<th>Movie</th>
<th>Cross-domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAMO</td>
<td>Last.fm</td>
<td>CAMO</td>
<td>IMDb</td>
</tr>
<tr>
<td>Q1.</td>
<td>4.92</td>
<td>4.53</td>
<td>5.00</td>
</tr>
<tr>
<td>Q2.</td>
<td>4.69</td>
<td>2.38</td>
<td>4.46</td>
</tr>
<tr>
<td>Q3.</td>
<td>4.69</td>
<td>2.92</td>
<td>4.62</td>
</tr>
<tr>
<td>Q4.</td>
<td>4.31</td>
<td>4.23</td>
<td>4.38</td>
</tr>
<tr>
<td>Q5.</td>
<td>3.61</td>
<td>2.54</td>
<td>3.54</td>
</tr>
</tbody>
</table>

CAMO: Integration of LOD for Multimedia Metadata Enrichment
(2) Integration accuracy

**Ontology matching**
- 78 mappings
  - incl. 18 RDB mappings

**Instance linkage**
- 60 thousand links
  - 100 samples per dataset
Conclusion & lessons learned

- **CAMO** leverages ontology matching and instance linkage for data integration and supports users to browse and search multimedia content on mobile devices.
Conclusion & lessons learned

- **CAMO** leverages ontology matching and instance linkage for data integration and supports users to browse and search multimedia content on mobile devices.

- **Lessons learned**
  - Ontology matters: trade-off between expressiveness and ease of use
  - Data integration quality: human computation + machine learning
  - Mobile app design: conciseness, ranking scheme
Conclusion & lessons learned

- **CAMO** leverages ontology matching and instance linkage for data integration and supports users to browse and search multimedia content on mobile devices.

- Lessons learned
  - Ontology matters: trade-off between expressiveness and ease of use
  - Data integration quality: human computation + machine learning
  - Mobile app design: conciseness, ranking scheme

- Future work
  - Generate complex mappings for semantic query reformulation
  - Extend to user-generated content
Thank you for your attention!

For more information about CAMO: [http://ws.nju.edu.cn/camo/](http://ws.nju.edu.cn/camo/)

**Acknowledgements.** This work is supported by the National Natural Science Foundation of China (Nos. 61370019, 61223003 and 61321491), the Natural Science Foundation of Jiangsu Province (No. BK2011189), and the Samsung Electronics.