Linked Data as facilitator for TEL recommender systems in research & practice

Stefan Dietze

- RecSysTEL2012 -
Introduction

- **L3S Research Center** (Hannover, Germany)
  - [www.l3s.de](http://www.l3s.de)

- **Knowledge Media Institute (KMI)** of The Open University (Milton Keynes, UK)
  - [kmi.open.ac.uk](http://kmi.open.ac.uk)
Introduction

Research interests
- Semantic Web & Linked Data
- Data & knowledge integration: mapping, classification, interlinking
- Application domains: education/TEL, Web archiving, ...

Projects & activities
- EU funded research projects:
  - (Linked) Web data & education
  - „Linked Learning“ and „LALD“ workshops (eg LILE2012@WWW2012)
  - http://linkededucation.org

⇒ http://purl.org/dietze
Recommendation & personalisation (of OER)

Collab./content-based RecSys

Open Educational Resources

RecSys

TEL
Diversity of topics (eg @ RecSystTEL 2012)

- Affective modelling & sentiment analysis
- Trust-based social recommenders
- Extraction of qualitative attributes
- Cross-platform graph-based recommendations
- ...
- **TEL recommender systems** dependent on **availability of data**
  - “In the lab”: data for evaluation
  - “In the wild”: real-world TEL applications

- **Quantity, quality** (e.g. accessibility, interoperability) and **reusability** of Web data (in particular about OER) is crucial to successful TEL recommender systems
Educational Web data

State

- Vast **Open Educational Resource (OER) metadata** collections (e.g. OpenCourseware, OpenLearn, Merlot, ARIADNE)
- Usually exposed via **APIs/services**
- Competing Web **interfaces** (e.g. SQI, OAI-PMH, SOAP, REST)
- Competing **metadata standards** (e.g. IEEE LOM, ADL SCORM, DC...)
- Competing exchange **formats and serialisations** (e.g. JSON, RDF, XML)
- Fragmented use of **taxonomies**

Issues

- **Heterogeneity** & lack of interoperability
- Lack of **take-up**
Web-scale exploration of educational resources and data?

Recommendation & personalisation (of OER)

Collab./content-based RecSys

Open Educational Resources metadata

RecSys

TEL
(Linked) Open Data

"Stop hugging your data..."
Sir Tim Berners-Lee, 2009
(Linked) Open Data

Linked (Open) Data – “Semantic Web done right”
- Vision: well connected graph of open Web data
- W3C standards (RDF, SPARQL) to expose data, URIs to interlink datasets
- => vast cloud of interconnected datasets
- Crossing all sorts of domains

<table>
<thead>
<tr>
<th>Domain</th>
<th>Number of datasets</th>
<th>Triples</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>25</td>
<td>1,841,852,061</td>
<td>5.82%</td>
</tr>
<tr>
<td>Geographic</td>
<td>31</td>
<td>6,145,532,484</td>
<td>19.43%</td>
</tr>
<tr>
<td>Government</td>
<td>49</td>
<td>13,315,009,400</td>
<td>42.09%</td>
</tr>
<tr>
<td>Publications</td>
<td>87</td>
<td>2,950,720,693</td>
<td>9.33%</td>
</tr>
<tr>
<td>Cross-domain</td>
<td>41</td>
<td>4,184,635,715</td>
<td>13.23%</td>
</tr>
<tr>
<td>Life sciences</td>
<td>41</td>
<td>3,036,336,004</td>
<td>9.60%</td>
</tr>
<tr>
<td>User-generated content</td>
<td>20</td>
<td>134,127,413</td>
<td>0.42%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>295</strong></td>
<td><strong>31,634,213,770</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: [http://lod-cloud.net/state](http://lod-cloud.net/state), LOD cloud release September 2011
Datasets which might enhance (informal) learning

- **Publications & literature**: ACM, PubMed, DBLP (L3S), OpenLibrary
- **Domain-specific knowledge & resources**: Bioportal for Life Sciences, historic artefacts in Europeana, Geonames for geodata
- **Cross-domain knowledge**: DBpedia, Freebase, ...
- **Media resource metadata**: BBC, Flickr, ...

Schemas

- **FOAF** – Friend of a Friend
- **SIOC** – Semantically Interlinked Online Communities
- **CAM** – Contextualised Attention Metadata
- ...
(Linked) Open Data for Education

Educational schemas

- mEducator Educational Resources schema ([http://purl.org/meducator/ns](http://purl.org/meducator/ns))
- ...

Educational datasets

- **University Linked Data:**
  - The Open University (UK): [http://data.open.ac.uk](http://data.open.ac.uk)
  - Southampton University (UK): [http://data.southampton.ac.uk/](http://data.southampton.ac.uk/)
  - University of Munster (DE): [www.lodum.de](http://www.lodum.de)
  - [http://education.data.gov.uk](http://education.data.gov.uk)
  - ...

- **OER Linked Data:**
  - mEducator Linked ER ([http://ckan.net/package/meducator](http://ckan.net/package/meducator))
  - Open Learn LD
  - ARIADNE RDF ...

=> for details, see also: [http://linkededucation.org](http://linkededucation.org) & [http://linkeduniversities.org](http://linkeduniversities.org)
Applications of educational LOD (eg from past projects & LILE2012)

- Web-wide search of educational courses/OER (educational graph)
- Game-based learning & automatic generation of assessment items from LOD facts
- Enrichment of learning resources (facilitating more exploratory learning approaches)....
Web-scale TEL data integration
- data quality (ambiguity, richness, ...)
- data heterogeneity (semantic),
- data interlinking

Web-scale TEL data exploitation
Applications/tools exploiting TEL Web data for recommendation/exploration:
- scalability
- performance, robustness

Challenges
- Recommendation & personalisation (of OER)
- Educational Linked Data
- Linked Open Data
- Open Educational Resources
- Collab./content-based RecSys
- RecSys
- TEL
- Semantic Web
- Linked Open Data
- Educational Linked Data
- Open Educational Resources
- Semantic Web
- Recommendation & personalisation (of OER)
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Recommendation & personaliation (of OER)
Collab/content-based RecSys
Open Educational Resources
Linked Open Data
Semantic Web
Educational Linked Data

mEducator

- EC-funded eContentPlus Best Practice Network (BPN),
- May 2009 – May 2012 (3 years duration)

- 14 partners:

http://www.meducator.net
Challenges & approach

1. Improving **OER metadata interoperability and Web-wide search by applying LOD principles**...

2. ...**WHILE exploiting existing OER metadata and infrastructures**
Challenges & approach

1. Improving OER metadata interoperability and Web-wide search by applying LOD principles...

2. ...WHILE exploiting existing OER metadata and infrastructures
Application context: biomedical education

Metamorphosis+ => http://metamorphosis.med.duth.gr/

Tailored (L)CMS plugins => http://www.meducator3.net/

Data/services integration & retrieval/search APIs
Approach: educational service integration

- **Lifting educational data out of heterogeneous repositories** via Linked Data-based services integration techniques
- **Transformation of heterogeneous data formats** (XML, JSON...) and **schemas** (eg. IEEE LOM, Dublin Core) into **RDF** (pre-requisite for LOD compliance)
SmartLink for services annotation & discovery

- Store/API registry: Linked Data about (educational/scientific) data repositories, their services and APIs

- Semantic search & execution of educational data services via dedicated API: data retrieval, transformation/lifting (eg, get resource metadata in RDF from educational, English stores in biomedicine)

⇒ http://ckan.net/package/smartlink
⇒ http://purl.org/smartlink
SmartLink: data lifting into RDF (via lifting templates)

Open database of over 22 M records of biomedical resources (12 M full text) => www.pubmed.gov

original XML resource description from PubMed

RDF resource description lifted via SmartLink
Approach: educational data integration

- **Issues**: often poorly structured metadata, use of free-text and proprietary taxonomies (if at all)

- **Approach**:
  - Improvement of lifted, semi-structured (RDF) data by using public **LOD vocabularies**
  - **Tighter interlinking of educational data** to provide a coherent and well-connected RDF graph of educational data (across disparate stores and repositories)
Data integration: enrichment, interlinking, clustering

3-step approach to enrich and interlink resulting RDF into a coherent **educational data graph**:

1) **Enrichment** with references to LOD datasets (DBpedia, Freebase, BioPortal)

2) **Structural clustering** and correlation based on shared enrichments/metadata

3) **Linguistic clustering** and correlation based on metadata similarity

⇒ [http://ckan.net/package/meducator](http://ckan.net/package/meducator)
⇒ [http://linkededucation.org/meducator](http://linkededucation.org/meducator)
(1) Enrichment: automated via DBpedia & Freebase

```
- <rdf:RDF xml:base="http://purl.org/meducator/instances/">
  - <mdc:Resource rdf:about="http://purl.org/meducator/resources/25a8c581-66d7-4186-9411-f9f0f783463e">
    - <mdc:identifier>
      http://www.med.helsinki.fi/tuke/meducator/Kansio_1004/Patient%201004.pdf
    </mdc:identifier>
    <mdc:title> Patient case 1012 viral infections and HPV </mdc:title>
    <mdc:rights rdf:resource="http://purl.org/meducator/licenses/Attribution-Non-Commercial-Share-Alike"/>
    <mdc:metadataLanguage>English</mdc:metadataLanguage>
  </mdc:Resource>
```

Semi-structured RDF description of educational resource
(1) Enrichment: automated via DBpedia & Freebase

Semi-structured RDF description of educational resource

HPV (disambiguation)
From Wikipedia, the free encyclopedia

HPV may refer to:
- Human papillomavirus, a virus which causes warts
- Human Powered Vehicle, a land, water or air vehicle powered by human
- High Production Volume Chemicals
- Hypoxic pulmonary vasoconstriction, a physiological phenomenon of the
- Health Purchasing Victoria
- Hepatic portal vein
(1) Enrichment: automated via DBpedia & Freebase

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Disambiguation via

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About: Human papillomavirus
An Entity of Type: disease, from Named Graph: http://dbpedia.org
within Data Space: dbpedia.org

Human papillomavirus (HPV) is a virus from the papillomavirus family that is capable of infecting humans. Like all papillomaviruses, HPV establishes productive infections only in keratinocytes of the skin or mucous membranes. While the majority of the known types of HPV cause no symptoms in most people, some types can cause warts (verrucae), while others can – in a minority of cases – lead to cancers of the cervix, vulva, vagina, penis, oropharynx and anus.

Property
Value
- Virus del papiloma humano (VPH) es una expresión genética que de que infecten la piel y mucosas a humanos e otros animales. Podrían genitales y algunos tipos de cáncer. Se transmite por contacto directo, vagadas en relaciones sexuales (en el caso de los tipos de virus que afectan a los genitales) y en las áreas mucosas (en el caso de los tipos que infectan a la piel). La Generalitat de Catalunya estima que de un 99% al 100% de la superficie de la infección e infección de los 15 tipos de HPV más frecuentes, más del 50% de infecciones de estos virus son curables.

 Powered transport, in some cases the only type available, especially in underdeveloped or inaccessible regions.

In the transport sector, walking and cycling transport are often grouped together under active transport, compared to such other transport forms as public transport, or freight traffic, which is energy-intensive.
(1) Enrichment: semi-automated

Example: OER annotation in MetaMorphosis+

http://metamorphosis.med.duth.gr/
(1) Enrichment: semi-automated

Access to 324 ontologies and over 5 Mio entities
http://bioportal.bioontology.org/

1. User-specified term during learning resource annotation

BioPortal

Bio-portal response:
ECG, Cancer Research and Management ACGT Master Ontology, ECG | MedDRA, Electrocardiografia | Descritores en Ciencias de la Salud (Spanish MeSH), Electrocardiographic monitoring | SNOMED Clinical Terms, Electrocardiography | Read Codes, Clinical Terms Version 3 (CTV3)

2. Suggested Entities

3. Selected entities from BioPortal used to describe discipline, keywords of resource

http://metamorphosis.med.duth.gr/
(2) Structural clustering of related resources

Number of resources per DBpedia reference/enrichment (subject) in mEducator dataset

<table>
<thead>
<tr>
<th>Subject</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical_cancer</td>
<td>59</td>
</tr>
<tr>
<td>Screening</td>
<td>31</td>
</tr>
<tr>
<td>Cervical</td>
<td>29</td>
</tr>
<tr>
<td>Hpv</td>
<td>29</td>
</tr>
<tr>
<td>Oxygenation</td>
<td>26</td>
</tr>
<tr>
<td>Childhood</td>
<td>22</td>
</tr>
<tr>
<td>differential_diagnosis</td>
<td>19</td>
</tr>
<tr>
<td>Knowledge</td>
<td>18</td>
</tr>
<tr>
<td>Learning</td>
<td>17</td>
</tr>
<tr>
<td>decision_making</td>
<td>16</td>
</tr>
<tr>
<td>Training</td>
<td>15</td>
</tr>
<tr>
<td>Lecture</td>
<td>15</td>
</tr>
<tr>
<td>Risk</td>
<td>15</td>
</tr>
<tr>
<td>hpv_infection</td>
<td>15</td>
</tr>
<tr>
<td>Fear</td>
<td>15</td>
</tr>
<tr>
<td>pap_smear</td>
<td>15</td>
</tr>
<tr>
<td>Abnormal</td>
<td>14</td>
</tr>
<tr>
<td>Ventilation</td>
<td>14</td>
</tr>
<tr>
<td>Ecg</td>
<td>14</td>
</tr>
</tbody>
</table>

DBpedia references used most frequently to describe the “subject” of particular educational resources
## (2) Structural clustering of related resources

### Number of resources per DBpedia reference/enrichment (subject) in mEducator dataset

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<td>decision_making</td>
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<td>Lecture</td>
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<td>14</td>
</tr>
</tbody>
</table>

Cluster of educational resources relating to „cervical cancer“ subject

Clustering of resources graph (blue nodes: resources, green nodes: enrichments)
## (2) Enrichment/clustering: evaluation

### Evaluation categories:

<table>
<thead>
<tr>
<th>Category</th>
<th>Example source text</th>
<th>Enrichment example</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B) – broad match</td>
<td>“… in safety critical and restrictive environments, such as in aviation, <a href="http://dbpedia.org/resource/Space">space</a>, automobile and heavy industrial machinery operation”</td>
<td><a href="http://dbpedia.org/resource/Space">http://dbpedia.org/resource/Space</a></td>
</tr>
<tr>
<td>(C) – no match</td>
<td>“EASA started its work in the <a href="http://dbpedia.org/resource/Fields_Medal">fields</a> of Airworthiness and will soon its competencies...”</td>
<td><a href="http://dbpedia.org/resource/Fields_Medal">http://dbpedia.org/resource/Fields_Medal</a></td>
</tr>
</tbody>
</table>

### Evaluation results (sample size = 200):

<table>
<thead>
<tr>
<th>Category</th>
<th>n# enrichments</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>184</td>
<td>92</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>
Vector-based similarity computation based on:

1) **Data indexing** => Doc-Term Matrix (term frequencies in given resource metadata)

2) **Creation of similarity matrices** => similarity values between resources

3) **Clustering** (based on similarity thresholds)
Exploratory search enabled via clustering

Example: search results of OER in MetaMorphosis+

Educational resources retrieved based on particular user query

Find additional results by clicking the checkbox of the items above you are most interested in
Exploratory search enabled via clustering

Example: search results of OER in MetaMorphosis+

Find additional results by clicking the checkbox of the items above you are most interested in.

Related resources (ranked)
Data so far: SmartLink/mEducator in LOD cloud

- **SmartLink**
  - [http://ckan.net/package/smartlink](http://ckan.net/package/smartlink)
  - > 2000 triples so far
  - > 300 links to iServe
  - APIs used by several applications

- **mEducator**
  - [http://ckan.net/package/meducator](http://ckan.net/package/meducator)
  - > 35000 triples so far
  - > 1000 links to DBpedia & Bioportal ontologies
  - APIs used by 4 applications
Web-scale TEL data integration
- data quality (ambiguity, richness, ...)
- data heterogeneity (semantic)
- data interlinking

Web-scale TEL data exploitation
Applications/tools exploiting TEL Web data for recommendation/exploration:
- scalability
- performance, robustness
Educational Web data: open issues

Motivation

- Quality and quantity of (educational) Web data constantly improving
- However: usage of Web data usually limited to few, mostly isolated datasets, large-scale exploitation still missing

Linking Web Data for Education Project – Open Challenge in Web-scale Data Integration

- EC Support Action, start November 2012, coordinated by L3S
  => [http://linkedup-project.eu](http://linkedup-project.eu)
- Goals
  - Push forward adoption of Web data/Linked Data in educational context
  - Drive technological advancement of Web data integration technologies (applications, IR technologies, recommender systems)
- Approach
  - Open data competition incl. technical, legal and financial support; open education as big data scenario
LinkedUp in a nutshell

3 stages of the LinkedUp competition

Stage 1 - Initialisation
- Lowest requirements level for participation
- Initial prototypes and mockups, use of data testbed required
- 10 to 20 projects are expected

Stage 2
- Medium requirements level for participation
- Working prototypes, minimum amount of data sources, clear target user group
- 5 to 10 projects are expected

Stage 3
- Deployment in real-world use cases
- Sustainable technologies, reaching out to critical amount of users,
- 3 to 5 projects are expected

Stage 4

Web data
- Linked Open data (30+ billion statements)
- General Web data (OAI-PMH feeds, web metadata etc)
- ...

Applications and tools
- TEL environments and applications
- Data integration tools: storage, analytics, mining, integration, mapping
- ...

Educational data & resources
- OER metadata
- OpenLearn
- OpenCourseware
- Ariadne
- iTunesU
- EU project results

LinkedUp Challenge Environment
- LinkedUp Evaluation Framework
- Methods and Test Cases
- LinkedUp Data Testbed
- Competitor ranking list

LinkedUp Support Actions
- Dissemination (events, training)
- Data sharing initiatives
- Community building & clustering
- Technology transfer
- Cashprice awards & consulting

Network of supporting organisations
(see 3.2 Spreading excellence, exploiting results, disseminating knowledge)

...provides support:
- Financial awards
- Legal & technical guidance
- Data
LinkedUp consortium

Scientific expertise from three areas:

- Data integration, Web technologies & evaluation
- Educational technologies, (meta)data and resources
- Dissemination and exploitation of open Web data
LinkedUp consortium
Dissemination & exploitation of Web data

**Elsevier, NL**
- Leading scientific & educational publisher
- Innovative research on the future of publishing & extensive experience in data competitions

**CELSTEC, The Open University, NL**
- R&D institute in educational technologies and part of the largest distance university in the Netherlands

**The Open Knowledge Foundation, UK**
- Not-for-profit organisation to promote open knowledge and data; global network
- Host of key events (OKCon) and platforms (eg CKAN)

**KMI, The Open University, UK**
- Leading R&D institute in areas related to LinkedUp
- World’s largest distance university (over 200,000 students)

**Exact Learning Solutions, IT**
- SME in educational technologies and services with long-standing experience in (EC-funded) R&D projects

**L3S Research Center, Leibniz University, DE**
- Leading institute in Web science & data technologies as well as technology-enhanced learning
- Coordinator and leader of LinkedUp Challenge WP
**LinkedUp**

**Evaluation criteria**

### Domain (education) aspects (DEA)
- **DEA.1** Effectiveness of learning (e.g., higher skill level, or grades)
- **DEA.2** Efficiency of learning (e.g., less study time for equal outcomes)
- **DEA.3** Attractiveness of learning (e.g., increases motivation or offers new insights by combining data sources)

### Technical aspects (TA)
- **TA.1** Data coverage (e.g., amount of used data sources, size of dataset, data quality)
- **TA.2** Scalability (e.g., possibility to scale up to large datasets and add new data sources)
- **TA.3** Performance (e.g., response time, amount of bugs)
- **TA.4** Accuracy (e.g., information retrieval measures like Precision, Recall, F1)

### Usability aspects (UA)
- **UA.1** Understandability (e.g., difficulty of logical, or navigation concept)
- **UA.2** Learnability (e.g., effort to get used to a new software)
- **UA.3** Collaboration patterns (e.g., connection to social networks and other user information)

### Deployment aspects (DA)
- **DA.1** User scenario (e.g., matching to LinkedUp vision and project target group)
- **DA.2** Reach (e.g., number of target domains and users)
- **DA.3** Privacy (e.g., privacy regulations or user agreements)
- **DA.4** Multi-linguality (e.g., number of supported languages, access to data in other languages)
LinkedUp

Next steps

Ongoing preparations to enable quickstart (1 November 2012)

- Challenge design, community & clusters
- Challenge kickoff: initial calls expected by February 2013
  (http://www.linkedup-project.eu)

Participate!

- As challenge participant
  - Submission of innovative application/tool tackling one or more of the challenge goals
  - LinkedUp offers: financial, technical and legal support
- As associated partner
  - Participate as evaluation panelist, use case or data contributor & benefit from access to large network of organisations in Linked Data and TEL
  - Take advantage of innovative research results
    (LinkedUp challenge submissions, evaluation framework)
  - Promote your own data and tools
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Recommendation & personalisation (of OER)
- Collab./content-based RecSys
- Open Educational Resources
- Educational Linked Data
- Linked Open Data
- Semantic Web
- Semantic Web
Conclusions

Linked Data & TEL RecSys – a symbiotic relationship

Linked Data for education

- Wealth of relevant data available on the Web, improving in terms of quantity and quality
- Challenge: exploration and recommendation in large-scale distributed data

Require highly efficient & scalable recommendation & IR mechanisms

TEL recommender systems

- Improving in terms of scalability, accuracy, etc
- Challenges: availability of diverse, high-quality, interoperable data

Require high-quality, interoperable & accessible data
Thank you!

http://purl.org/dietze
http://linkededucation.org
http://linkedup-project.eu

Some upcoming events

- Knowledge Extraction and Consolidation from Social Media (KECSM2012), workshop at ISWC2012, http://blogs.ecs.soton.ac.uk/knowledgeextraction/

- Keynote @ 6th tele-TASK Symposium 2012, 8-9 October, http://www.hpi.uni-potsdam.de/meinel/lehrstuhl/symposia/6th_tele_task_symposium_2012.html