Metadata Topic Harmonization and Semantic Search for Linked-Data-Driven Geoportals -- A Case Study Using ArcGIS Online

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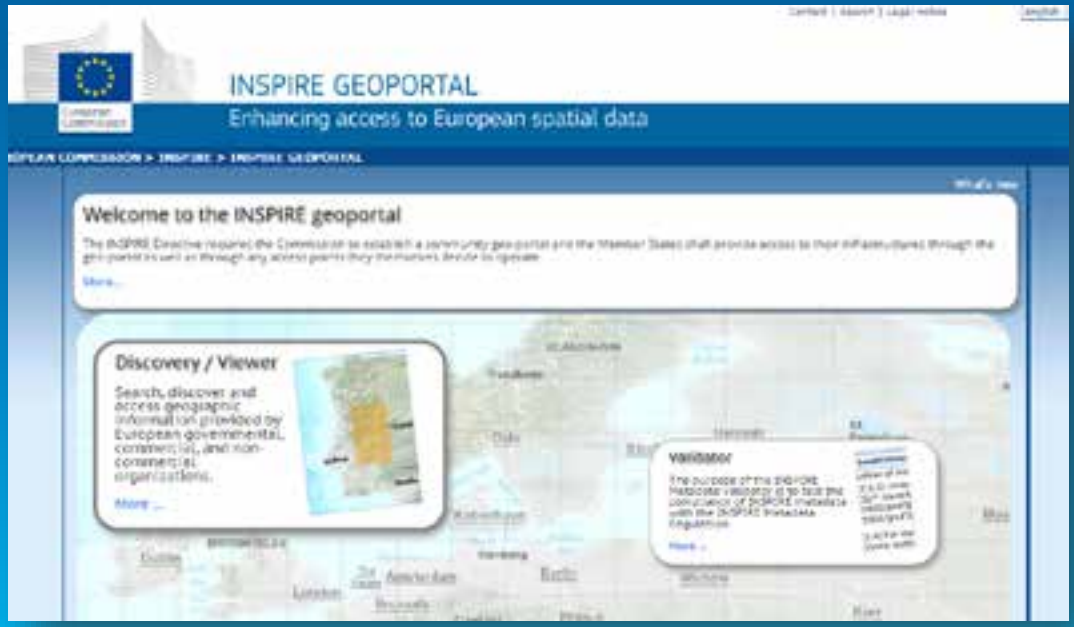
Outline

- Introduction and motivation
- Metadata Topic Harmonization
- Semantic Search on Linked Data
- Experiment and Evaluation
- Conclusions and Future Work

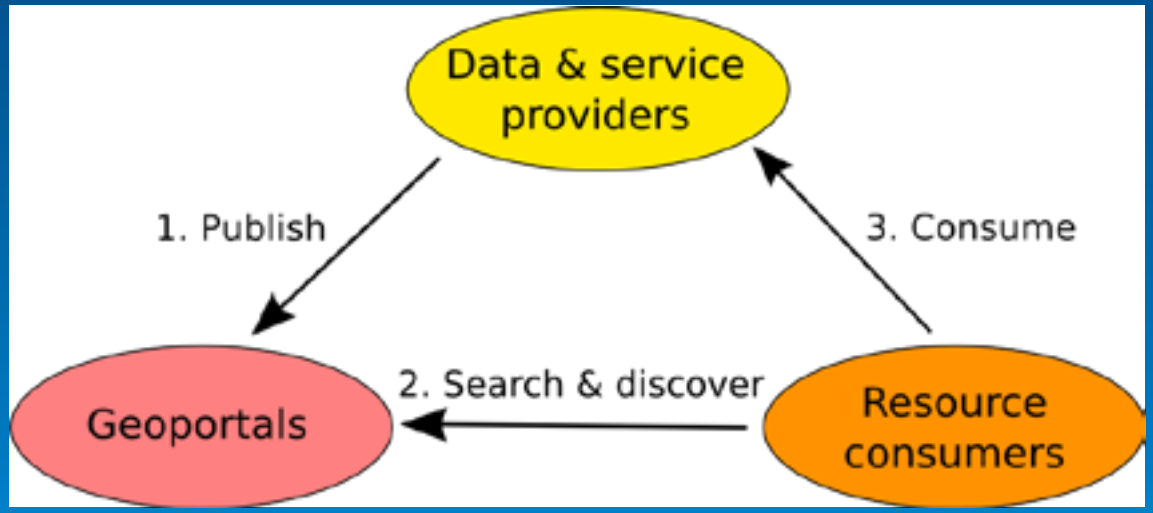
Introduction

- **Geoportals are Web gateways that provide integrated access to geospatial resources**
- **Geoportals are key components of Spatial Data Infrastructure (SDI)**
- **Existing geoportals:**
  - **Data.gov**
  - **INSPIRE**
  - **California geoportal**
  - **…**



Introduction

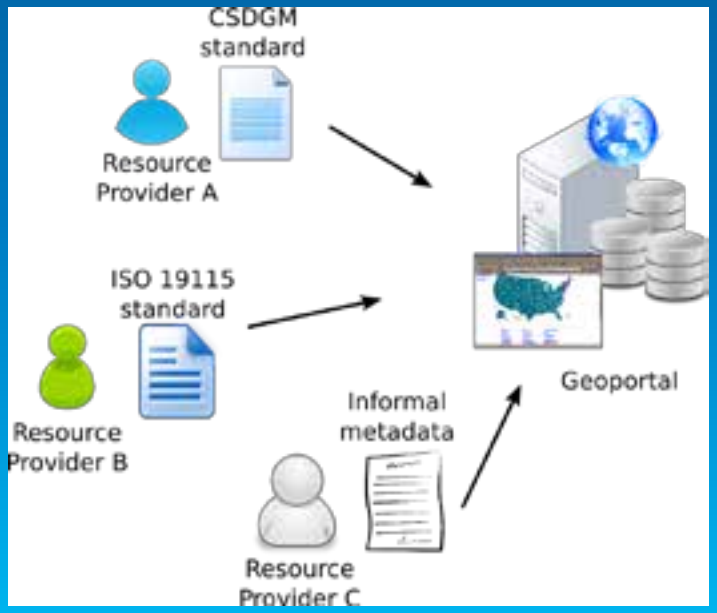
- **A typical *publish-find-bind* pattern has been used by many geoportals**



- **Two factors that influence the search capability of a geoportal:**
  - **Quality of metadata**
  - **Search functionality**

Introduction

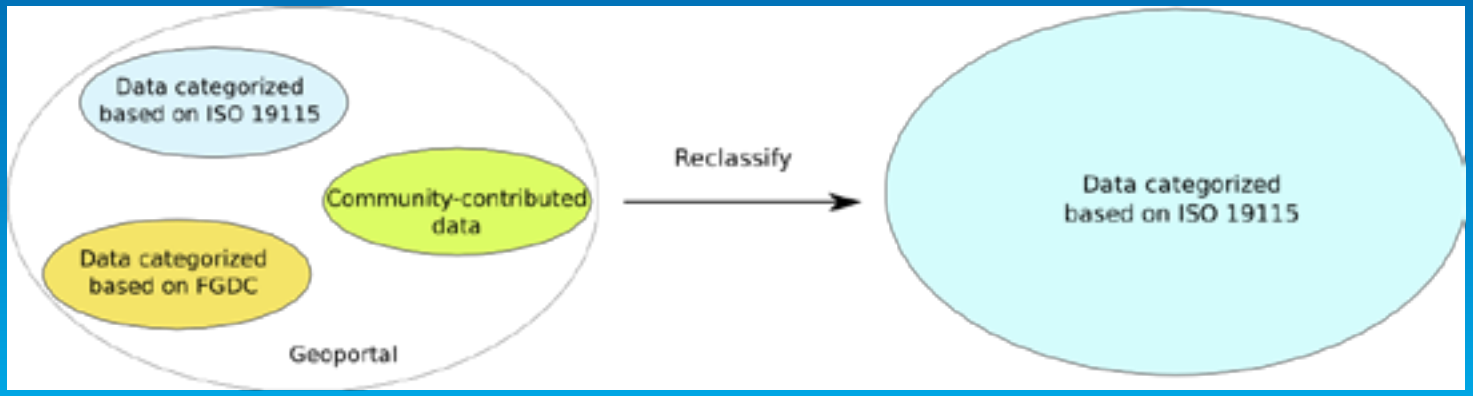
- **Quality of metadata**
  - **Multiple standards have been established to ensure the metadata quality, e.g., FGDC's CSDGM and ISO 19115**
  - **However, data contributed to the same geoportal may be in different standards**



developed standards. Since ISO 19115 and the associated standards are endorsed by the FGDC, federal agencies are encouraged to transition to ISO metadata as their agencies are able to do so. While the selection of

Introduction

- **Quality of metadata**
  - **How to harmonize metadata in different standards?**
    - **Some elements can be automatically mapped using, e.g., NOAA's metadata transformation tool**
    - **Some others have to be transformed manually, e.g., the topics**



Introduction

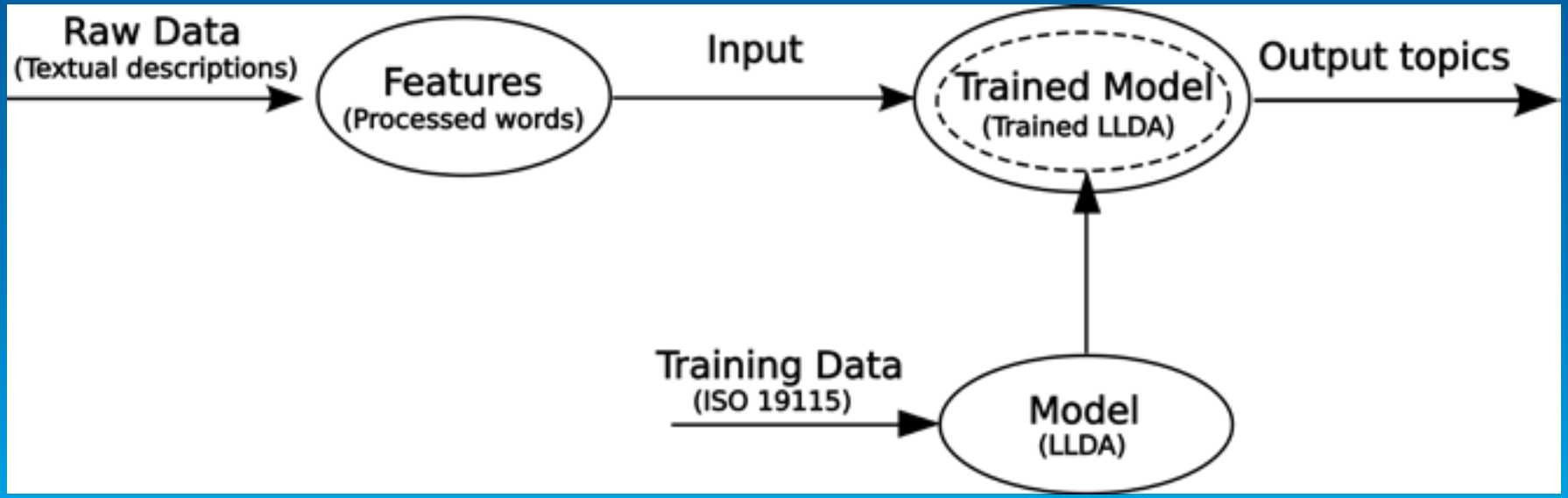
- **Search functionality**
  - **Traditional keyword-based search**
    - **Based on keyword matching**
    - **E.g., A search of “natural disaster” can only return maps which contain “natural” or “disaster”**
  - **Semantic search**
    - **Find maps based on the meaning of input query**
    - **E.g., return different disasters, such as wildfire, hurricane, earthquake…**

Introduction

- **Search functionality**
  - **The emerging of Linked-Data-driven Geoportals**
    - **Accommodate heterogeneous data using RDF data model**
    - **Graph-based data storage and browsing**
    - **Help discover the links hidden in data**
  - **Semantic search functionality for RDF data is not available for these novel geoportals**

Metadata Topic Harmonization

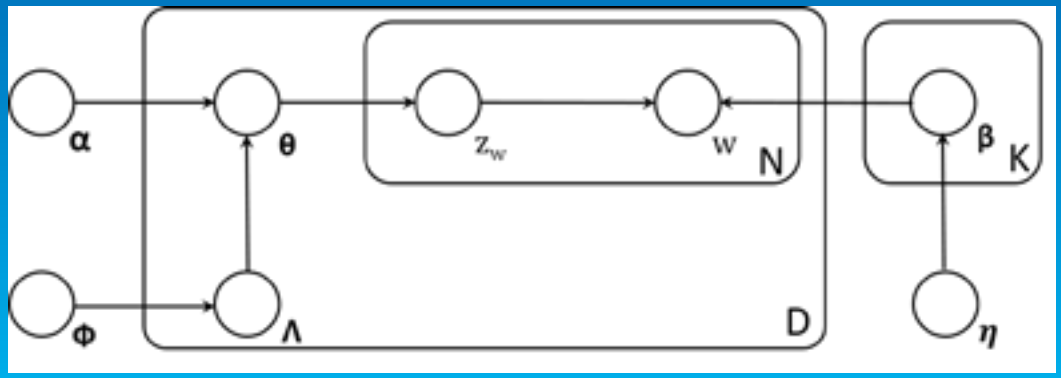
- A machine learning based approach
  - A multi-label classification problem
  - One metadata can be associated with multiple topics
  - Based on titles and descriptions of each metadata entry



Metadata Topic Harmonization

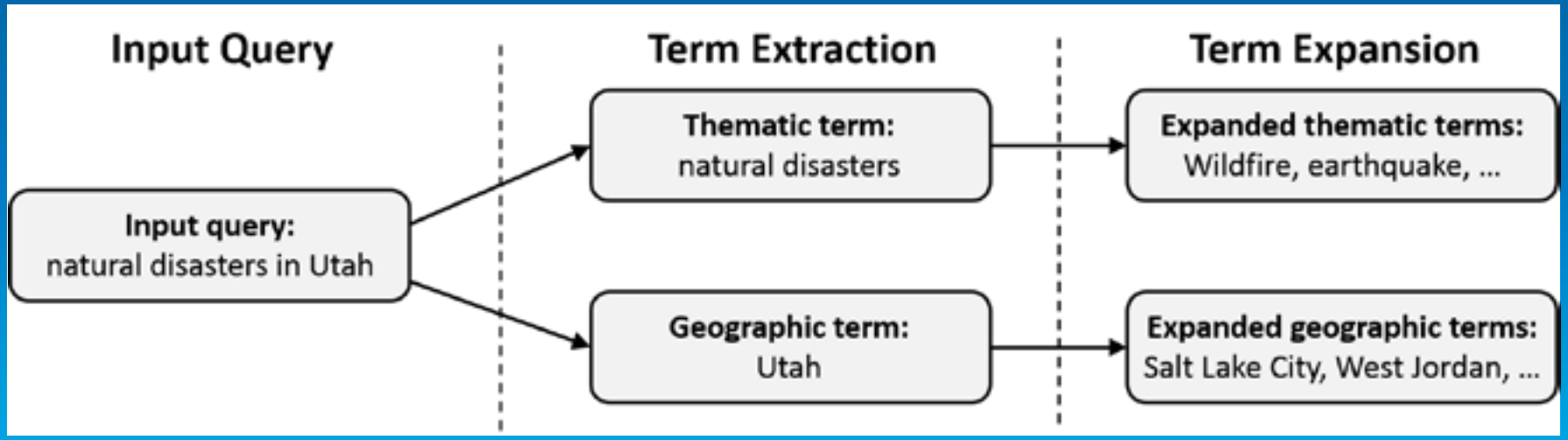
- LLDA (Labeled Latent Dirichlet Allocation)
  - An extension of LDA by adding a component of supervised learning
- Advantages of LLDA for topic harmonization compared with typical naïve Bayesian approach
  - Considers each document as a mix of multiple topics
  - Robust estimation for prior probabilities of topics
  - Avoid overfitting for long descriptions

$$P(t_i|d) \propto \prod_{j=1}^{N} P(w_j|t_i) \times P(t_i)$$



Semantic Search for Linked Data

- **Query expansion**
  - **Extracting concepts and entities from the input query**
  - **Expanding them using related concepts and entities**
    - **Thematic concepts: Latent Semantic Analysis (LSA) and Wordnet**
    - **Geographic entities: Gazetteer service (Geonames)**



Semantic Search for Linked Data

- **Constructing Matching Features**
  - **Is this matching happens in title or in description?**
  - **Is this matching a thematic matching or geographic matching?**
  - **Is this an exact matching or a similar matching?**
  - **Resulted in 8 matching features (2 x 2 x 2)**

Title Thematic Exact match (TTE)	Title Thematic Similar match (TTS)
Title Geographic Exact match (TGE)	Title Geographic Similar match (TGS)
Snippet Thematic Exact match (STE)	Snippet Thematic Similar match (STS)
Snippet Geographic Exact match (SGE)	Snippet Geographic Similar match (SGS)

Semantic Search for Linked Data

- **Constructing Matching Features**
  - **An additional feature: Thematic-Geo Interaction (TGI)**

$$TGI = (TTE + TTS + STE + STS) \times (TGE + TGS + SGE + SGS)$$

  - **Rationale for introducing this interaction feature:**
    - **Thematic or geo matching alone cannot determine the relevance**
    - **E.g., Searching “Crime in California”**
    - **“Crime in Florida” or “Waterbody in California” may not be what users want**
    - **“Robberies in Los Angeles” may be relevant**

$$R(q,m) = \lambda_1 TTE + \lambda_2 TTS + \lambda_3 TGE + \lambda_4 TGS + \lambda_5 STE + \lambda_6 STS + \lambda_7 SGE + \lambda_8 SGS + \lambda_9 TGI$$

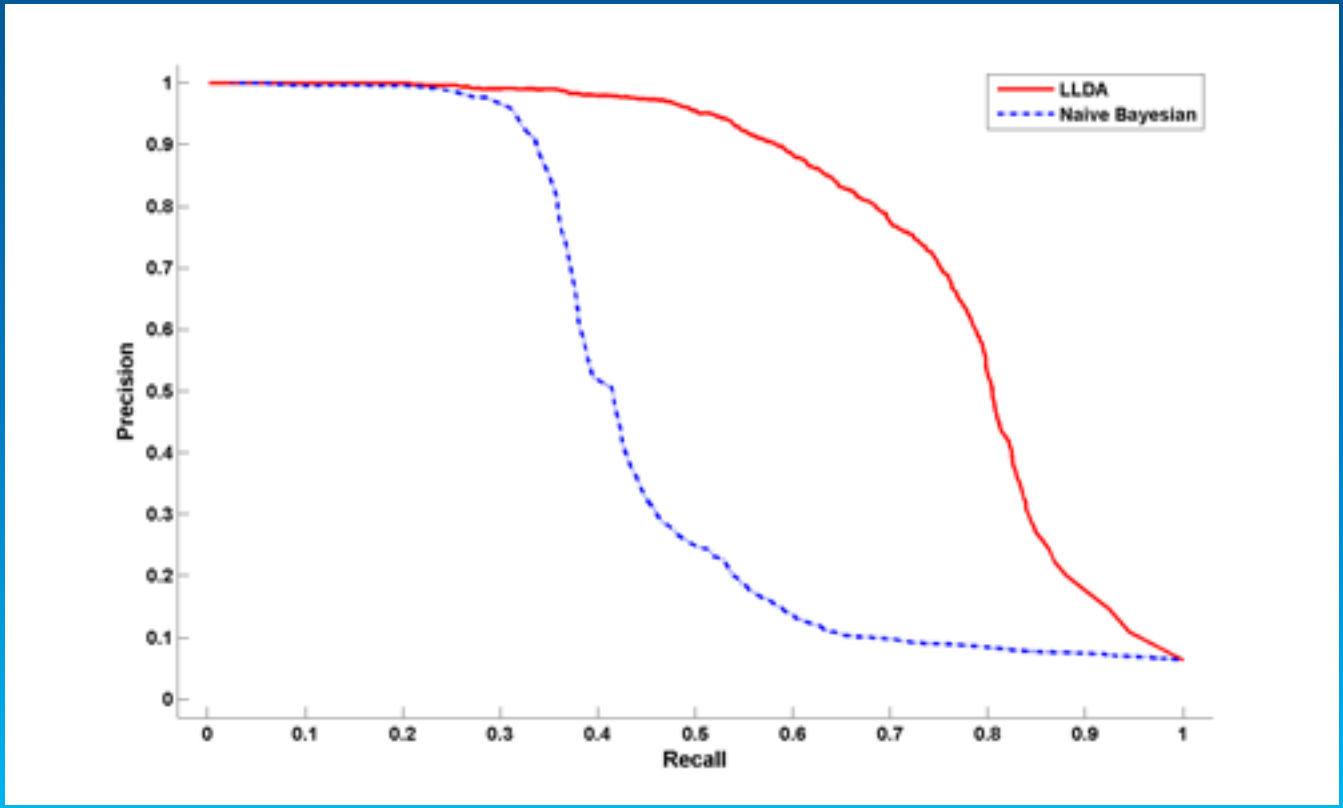
Experiments and Evaluation

- **Experimental data:**
  - **26, 917 metadata records from Data.gov in ISO 19115**
  - **10, 201 metadata records from ArcGIS Online**

- **Experiment procedure:**
- **Use metadata from Data.gov to evaluate the performance of the LLDA-based workflow by comparing it with a naive Bayesian baseline**
- **Apply the trained LLDA to the unstandardized ArcGIS Online data to automatically assign ISO 19115 topics**
- **Test the semantic search function using human participant experiment experiment, and evaluate the quality of the search results.**

Experiments and Evaluation

- Comparing the LLDA based approach with naïve Bayesian based approach
- Precision and recall curves



Experiments and Evaluation

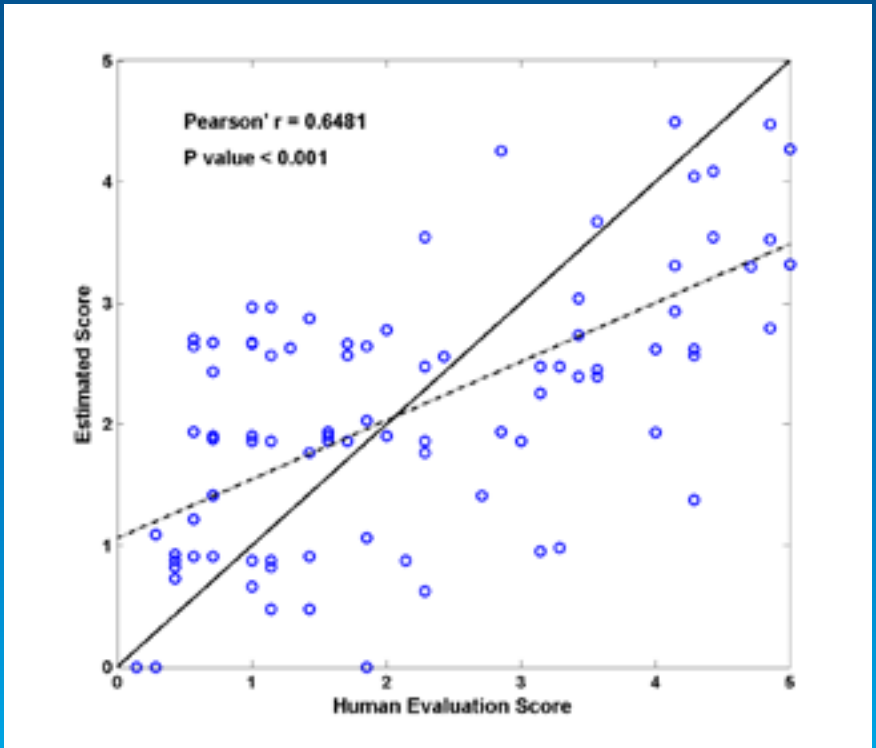
- **Human participant experiment**
  - **7 human participants**
  - **Each person evaluate 10 queries and each query has 10 candidate maps**
  - **For each query and candidate, provide a score [0, 5]**

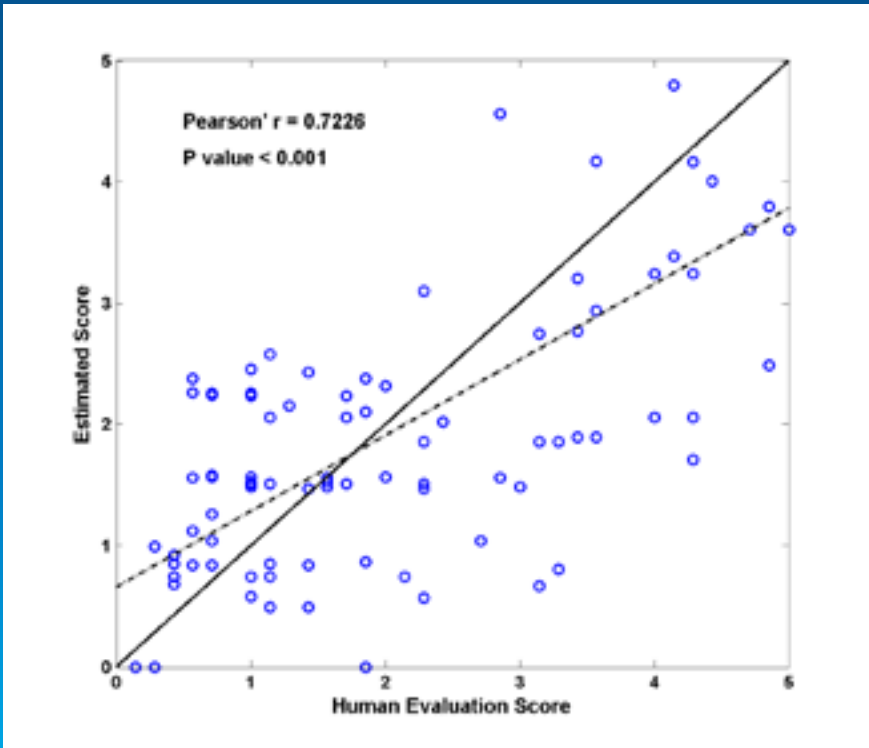
Query 3: "california population density"

Map	Link of the Map
3.1  **Los Angeles Population Density** This map emphasizes areas with the highest population density (more than 50,000 persons per square kilometer).	http://www.arcgis.com/home/webmap/viewer.html?webmap=4971065a7a734e31a7079ace59a19f27

Experiments and Evaluation

- **Ten-fold cross validation using Pearson's r**





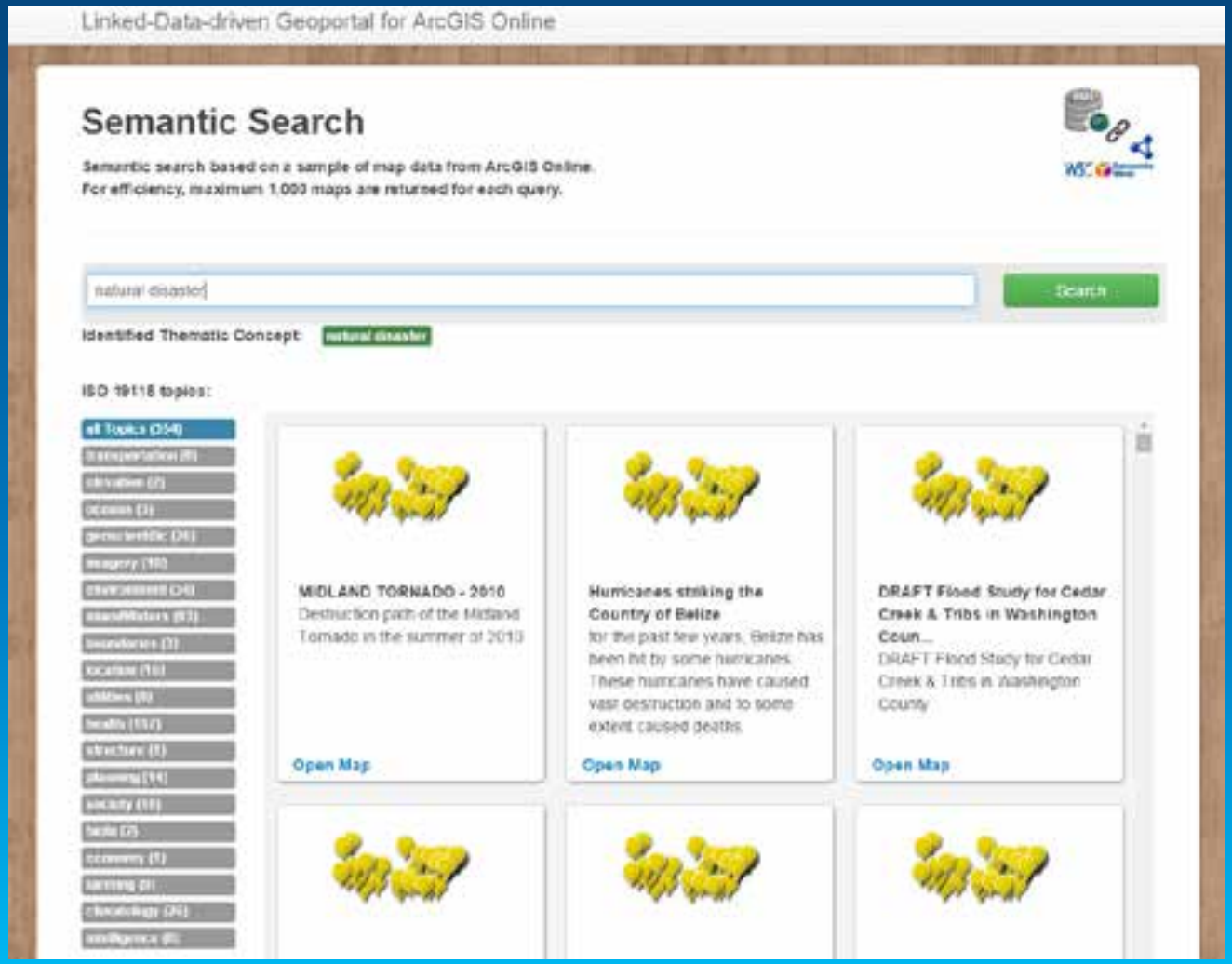
Semantic Search for Linked Data

- **Embedding the semantic search to a geoportal**
  - **A SPARQL query to implement the regression model**

```
SELECT ?item (COUNT(?titleThematicExact) AS ?TTE
(COUNT(?titleThematicSimilar) AS ?TTS)
(COUNT(?titleGeoExact) as ?TGE)
(COUNT(?titleGeoSimilar) as ?TGS)
(COUNT(?snipThematicExact) as ?STE)
(COUNT(?snipThematicSimilar) as ?STS)
(COUNT(?snipGeoExact) as ?SGE)
(COUNT(?snipGeoSimilar) as ?SGS)
(((?TTE+?TTS+?STE+?STS)*(?TGE+?TGS+?SGE+?SGS)) as ?TGI)
(( λ1*?TTE + λ2*?TTS + λ3*?TGE + λ4*?TGS + λ5*?STE + λ6*?STS +
λ7*?SGE + λ8*?SGS + λ9*?TGI) as ?ranking)
WHERE {
  OPTIONAL {
   ?item :hasTitleThematicTerm ?titleThematicExact .
   FILTER ( ?titleThematicKey = :exactThematicTerm ) }
  OPTIONAL {
   ?item :hasTitleThematicTerm ?titleThematicSimilar .
   FILTER ( ?titleThematicSimilar = :expandedThematicTerm ) }
  OPTIONAL {
   ?item :hasTitleGeoTerm ?titleGeoExact .
   FILTER ( ?titleGeoExact = :exactGeoTerm ) }
  OPTIONAL {
   ?item :hasTitleGeoTerm ?titleGeoSimilar .
   FILTER ( ?titleGeoSimilar = :expandedGeoTerm ) }
```

Interactive prototype

- **http://stko-exp.geog.ucsb.edu/linkedportal**



Conclusions and Future Work

- Geoportals provide integrated access to geospatial resources
- The quality of metadata and the capability of the search function are two major factors affecting resource discovery
- We present a LLDA-based approach for harmonizing metadata topics, as well as enabled semantic search for RDF data
- Limitations and future work
  - Small scale human participants test need to be expanded
  - Increase the response efficiency of semantic search

Thank you!

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