Content visualization of scientific corpora using an extensible relational database implementation

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Management of Data, Information, and Knowledge Group

Introduction

- Goal: content-based visualization of scientific documents
- Scientific documents: rich and diverse
- Applied on three datasets
- Application on publications that share a common funding scheme (e.g. EU FP7-ICT): funding mining submodule
- Implemented in madIS: data analysis via extended relational db
- OpenAIRE+ EU project
    - “2nd-Generation Open Access Infrastructure for Research in Europe” - 283595
    - infrastructure of publication - data repositories
    - implements EC’s open access policies
    - connects publications to research data and funding
    - automatic content clustering and classification

Content-based classification (1)

- Document d representation:
  1. tokenization
  2. stop word removal
  3. stemming
  4. term frequency $df_d(t)$ calculation
- repeat for each class c
- estimate $P(t)$ and $P(t|c)$
- build for each class c:
  - a dictionary D_c
  - an array of respective weights W_c

Content-based classification (2)

- add term t if $\frac{P(t|c)}{P(t)} > T$
- $W_c(t) = \frac{P(t|c)}{P(t)}$
- classification based on sum of logs
- actually equivalent to the Naive Bayes classifier

Visualization of text corpora, Class representation - dimensionality reduction (1)

- Goal: class representation in 2D space
- Classes of similar content are close
- A dimensionality reduction task (classes instead of samples)
- Previous step: class represented by a set of terms and weights
- Compute similarity matrix:

$$S(c_1, c_2) = \frac{\sum_{i=1}^{N_1} W_{c_2}(k : D_{c_1}(i) = D_{c_2}(k))}{\sum_{i=1}^{N_2} W_{c_2}(i)} + \frac{\sum_{i=1}^{N_2} W_{c_1}(k : D_{c_2}(i) = D_{c_1}(k))}{\sum_{i=1}^{N_1} W_{c_1}(i)} \quad (1)$$

classes c_1 and c_2, dictionaries D_{c_1} and D_{c_2}, weights W_{c_1} and W_{c_2}, number of terms per dictionary N_1 and N_2

Visualization of text corpora, Class representation - dimensionality reduction (2)

- S: class distributions in the $\mathbb{R}^M$ space (M: #classes)
- Reduce dimension to 2 using discretized class representations
- Step 1: reduce the feature space via clustering (k clusters):
  - use rows of S as samples
  - compute distance between rows i of S and clusters j: $d(i, j)$
  - each class now represented by its distances from clusters
  - k feature space
- Step 2: use SOM to map k-dimensional space to 2D
- avoid numerical - computational issues in SOM training

Visualization of text corpora, Content visualization of unlabelled corpora

- "Batch" classification + visualization for a corpus
- For every document $i, i = 1, \ldots, N_d$:
  - apply the classifier
  - soft-outputs: $P_i(c)$ for each class $c = 1, \ldots, M$
- Collection of documents is represented for each class c, using:
  - the 2-D class estimated coordinates
  - the accumulated estimated content class probability

$$[X_c, Y_c, \frac{\sum_{i=1}^{N_d} P_i(c)}{N_d}]$$

  where, X_c, and Y_c are the estimated 2-D class coordinates
- Adopt a balloon representation

Fund Mining Module

- Goal: detect particular funding schemes
- Started with EU FP7-funded
- Recently extended to Wellcome Trust projects
- Currently: handle arbitrary number of funding
- Funding information important for: funding statistics - visual analytics.
- Here funding information is used to specify the types of documents being visualized
- Module either used on individual docs or in batch mode
- Preprocessing (stopwords removal, tokenization, etc)
- Find matches against known lists of project grant agreement numbers - acronyms
- Use contextual information to filter out false matches

Datasets

- arXiv (arxiv.org)
  - coverings 7 categories
  - 2 level hierarchy (2nd: 130 classes 2nd level - 7 general categories)
  - only use 2nd level labels
  - arXiv.org API used to retrieve the docs (450K abstracts used)
- BASE (www.base-search.net).
  - open access archive of scientific docs
  - operated by Bielefeld University Library
  - DDC categorization (Dewey Decimal Classification)
  - 35K annotated documents in the English language
  - 2 DDC levels (i.e. 100 classes)
- WoS (Web of Science)
  - http://thomsonreuters.com/web-of-science
  - 180 class labels (non-hierarchical)
  - 18K labelled abstracts

Implementation Issues (1)

- Training and testing (both classification and visualization modules):
  - implemented in Python
  - external libraries, e.g. NumPy, NLTK,...
- *But:* need a release version for the testing case:
  - implementation in the context of a data processing workflow,
  - easily transferred to a distributed environment
- Achievable? Yes: adopted scheme only involves text segmentation, dictionary terms retrieval and a simple weights computation

Implementation Issues (2)

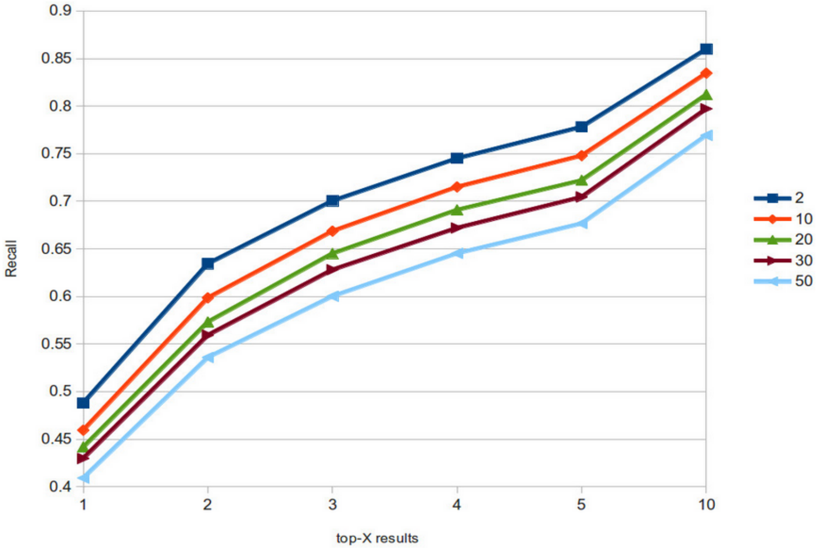
- Implemented in madIS (https://code.google.com/p/madis/)
- Data analysis via an extended relational database
- Built on top of the SQLite database with Python extensions
- Feels like Hadoop SQL without the overhead but also without the distributed processing capabilities
- madSQL, an SQL-based: extended with UDFs (User Defined Functions)
- Eliminates the effort using UDFs (UDFs are first class citizens in the query language itself)
- UDF categories:
  - row: analogous to the Map operator of Map/Reduce systems
  - aggregate: capture arbitrary aggregation functionality beyond the one predefined in SQL (SUM(), AVG(), ...).Analogous to the Reduce operator
  - virtual table: (table functions in Postgresql and Oracle) used to create virtual tables

Implementation Issues (3)

- UDF functionality + traditional relational DB facilities (UDFs closely tied to the relational DB engine): eliminates the communication cost between the two execution layers (functional/relational)
- Naive bayes classification example:
  - use a UDF to split documents into words
  - use the relational facilities to calculate word frequencies
  - use aggregate UDFs to compute sum of logs
  - ALL done in one madSQL query, completely within madIS
- every process (classification, visualization) is implemented in terms of an (extended) SQLite query:

  create temp table if not exists resultsTable as select ontop(5, p, title,class,matches,p) from (select title,class,jgroup(term,p) as matches,sum(p) as p from (select * from (select title,textwindow((summary),0,0,2) from abstractTable),arxiv where middle = term or regexpr('(\S+)(\s)(\S+)',middle,'1') = term) group by title,class) group by title ;

Results - Classification Evaluation on the arXiv dataset



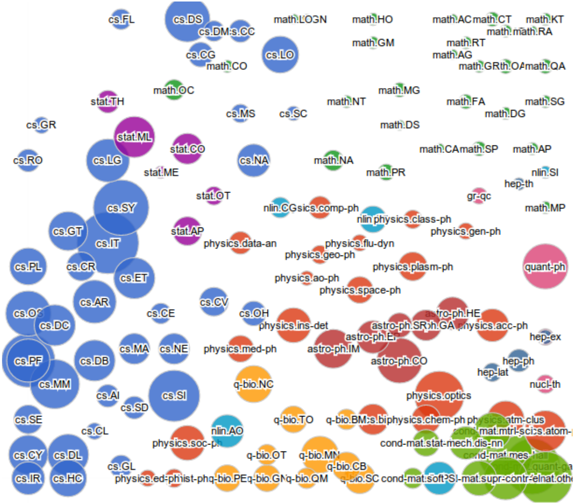
(different probability ratio thresholds)

Results - Classification Module Execution Times

Table: Average execution times per abstract. Higher dictionary thresholds (less dictionary terms) obviously lead to faster classifications. Times are in msecs

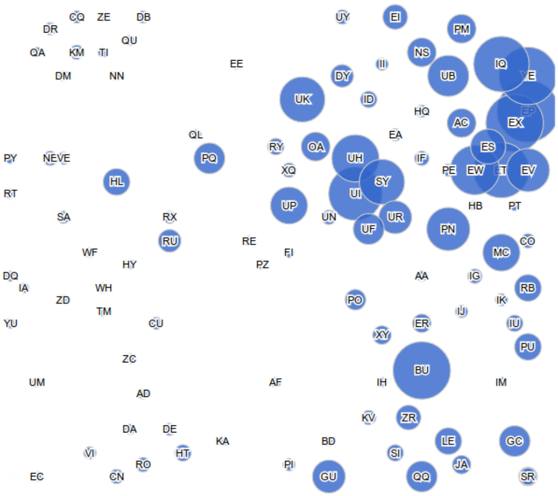
# abstracts	T = 2	T = 10	T = 20	T = 30	T = 50
10	63	27	21	20	17
15000	57	23	15	13	10

Results - Visualization Example: FP7 - ICT calls - ARXIV



arXiv	
astro-ph.GA	Astroph. - Galaxy Astrophysics
astro-ph.SR	Astroph. - Solar and Stellar
cs.DB	CS - Databases
cs.DL	CS - Digital Libraries
cs.IT	CS - Information Theory
cs.LG	CS - Machine Learning
cs.PF	CS - Performance
cond-mat.other	Condensed Matter - Other
hep-lat	High Energy Physics - Lattice
hep-th	High Energy Physics - Theory
physics.geo-ph	Physics - Geophysics
physics.optics	Physics - Optics
physics.space-ph	Physics - Space Physics
quant-ph	Quantum Physics
q-bio.CB	Quantitative Biology - Cell Behavior
stat.ML	Statistics - Machine Learning

Results - Visualization Example: FP7 - ICT calls - WOS



WOS	
BU	Astronomy - Astrophysics
GC	Geochemistry & Geophysics
GU	Ecology
IQ	Engineering, Electrical & Electronic
EX	Computer Science, Theory & Methods
HL	Health Care Sciences
LE	Geosciences, Multidisc.
PU	Mechanics
RU	Neurosciences
UB	Physics, Applied
UK	Physics, Condensed Matter
UI	Physics, Multidisc.
UP	Physics, Particles & Fields
YE	Tellecom.

OpenAIRE mining service BETA

- http://hatter.madgik.di.uoa.gr:8080/openaireplus/classifier
- returns a jason-like result (for several taxonomies, not only arXiv)

Ongoing work

- Detailed *Evaluation* (visualization functionality)
- Visualization enhancement (e.g, a tag cloud for each estimated class probability)
- Semi-supervised techniques (e.g., probabilistic topic modeling).