Scholarly Big Data Information Extraction and Integration in the CiteSeerX Digital Library

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Scholarly Big Data

- Scholarly Big Data includes all academic research output
  - Journal and conference publications
  - Books
  - Theses
  - Slides, data, course materials…

- Often found in data repositories
  - Google Scholar, Arxiv, Microsoft Academic, CiteSeerX, PubMed, University Libraries, etc.
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Estimate of amount of scholarly documents on the Web
How Much is Available?

- Estimate at least 114 million documents
  - Google Scholar has nearly 100 million

- At least 24% of these documents are publicly available
  - 27 Million
  - Though it varies a lot by field

- Estimates that 43% of articles published between 2008-2011 are freely available online (Archambaul et al., 2013)
Why is it Useful?

- Analyze scholarly and research trends
- Evaluation of investments in science and scholarship
- Identify opportunities for collaboration
- Evaluate individual scientist, groups and organizations
Challenges

- Integration from multiple data sources
- Heterogenous data
- Duplication
- Entity Linking and disambiguation
- Scalability
- Reuse
The CiteSeerX Digital Library

- A (almost) fully automated digital library and search engine for scholarly big data
  - Focused crawling to retrieve and integrate scholarly data

- Information Extraction
  - Metadata, citations, figures, tables, acknowledgements, algorithms

- Entity linking and disambiguation
  - Document and citation clustering
  - Name disambiguation
<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Documents</td>
<td>3.5 million</td>
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<tr>
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<tr>
<td>Individual Users</td>
<td>800,000</td>
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<tr>
<td>Hits per day</td>
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</table>
Focused Crawling

- CiteSeerX crawls freely accessible scholarly data on the Web
  - Maintain a whitelist of URLs that are okay to visit and are likely to be good links
  - Only retrieve PDF and PostScript files

- 50,000-100,000 document retrieved per day
  - Document classification module based on regular expressions to only keep academic documents

- Aggregates and integrate all documents in a single location
Information Extraction

- Fully automated information extraction from scholarly documents
  - Different types of information that can be extracted
  - Used for search, browsing, services, research

- All extracted data is indexed and integrated for search via CiteSeerX

- Needs to be robust to variations among scholarly documents
Header Extraction

- Contains some of the most important information in scholarly documents
  - Authors, title, abstract, venue, etc.

- Performed using SVM-based extractor
  - Tags each entity

- Sometimes errors or missing information
  - Allow for user corrections on CiteSeerX website
  - Match and link records with DBLP
Citation Extraction

- One of the key features of CiteSeerX

- Allows for autonomous citation indexing
  - Build up citation statistics for authors, venues, etc
  - Calculate h-index

- Citation extracted using CRF-based tool
  - Each entity in a citation string is tagged
Other IE

• Scholarly data has many other sources of information
  ○ CiteSeerX extracts figures, acknowledgements, tables and algorithms from papers

• Build services based on this extracted data
  ○ AckSeer, TableSeer, AlgorithmSeer, etc

• All data is all linked to the original source
Challenges for Automatic IE

● Accuracy of automatic IE
  ○ Needs to work on heterogeneous input data
  ○ Can be improved through linking
  ○ Coverage/accuracy

● Scholarly data is growing and scalability poses a major challenge
  ○ Improved algorithms?
  ○ Distributed extraction
Deduplication and Clustering

- Multiple versions of papers might exist on the Web that have minor differences
  - Estimate that as many as 30% of papers in CiteSeerX might be duplicates
  - Not bitwise identical

- Cluster near duplicates under a single ID based on automatically extracted metadata
  - But this can be wrong with bad metadata extraction
  - Looking into other more advanced methods
Citation Clustering and Linking

- Like duplicate papers, many citations exist to single papers

- Match citations to papers
  - Allows us to calculate citation statistics
  - Assign to same clusters as papers

- Citations can be used to improve paper metadata
Author Name Disambiguation

- Classic problem in digital libraries
  - “C. L. Giles” vs “Lee Giles”

- Important to allow proper attribution
  - Citations, contributions, search, etc.

- Build a similarity profile for each author and cluster authors
Sharing Data

- Important to foster collaboration and research

- Sharing data is challenging
  - Copyright issues
  - Take down notices
  - Big data - 6TB and growing by 10-20GB per day
  - How to share and distribute this?

- Make metadata available via OAI-PMH
  - About 5000 requests per month
  - Also make data available on Amazon S3
Sharing Code

● We open source all our software
  ○ Allows other groups to run their own versions of CiteSeerX and make improvements

● CiteSeerX forked 8 times since moving to GitHub

https://github.com/SeerLabs
Services

- Moving towards a service platform
- People may not be interested in running CiteSeerX, but rather integrating CiteSeerX components into their own workflows
- CiteSeerExtractor provides API access to information extraction modules
- Repository API provides access to repository
Conclusions

● Scholarly big data is rich and useful
  ○ Linking entities provides an opportunity to better understand scholarly undertaking

● But integrating scholarly data is challenging due to heterogeneity and scale

● Research opportunities in information extraction, integration and entity linking
Thanks

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- The many contributors to CiteSeerX