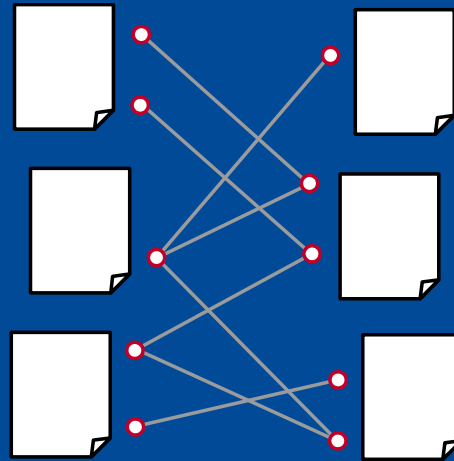


Semantic Approaches to Citation Recommendation



Albert-Ludwigs-Universität Freiburg

Tarek Saier
Master's Thesis

Examiners: Prof. Dr. Georg Lausen
Prof. Dr. Christian Schindelhauer



**UNI
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Overview



- Background
- Data Set
- Approaches
 - Entity based
 - Claim based
- Evaluation
 - Offline
 - User study
- Discussion





Background



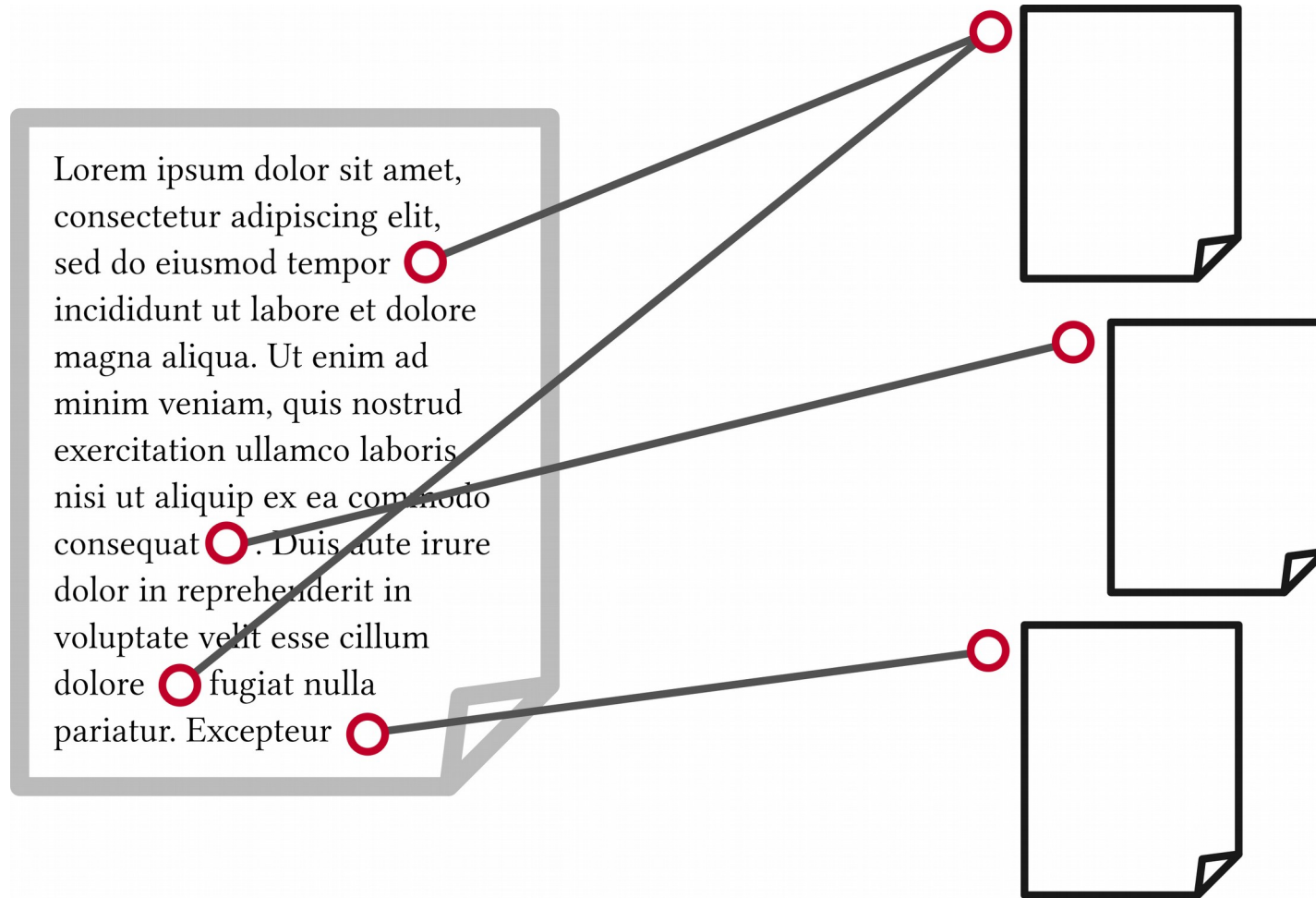
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voluptate velit esse cillum
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Background



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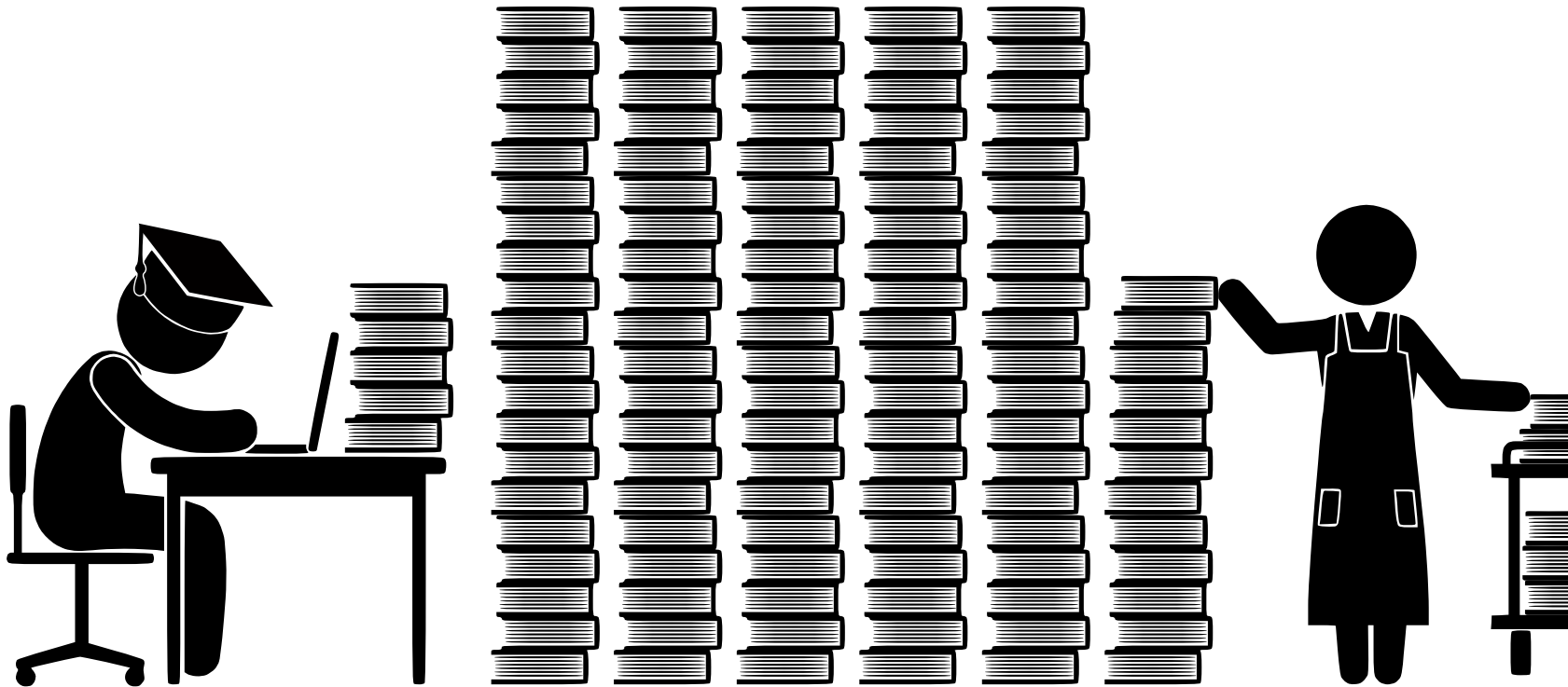
Background



Background



Background



Background



- Automatic processing
 - Processing of documents *as is*
 - Semantic modelling of documents

- Automatic processing
 - Processing of documents *as is*
 - Semantic modelling of documents
- Several approaches
 - Development of ontologies (Peroni et al., 2012)
 - Document exploration (Berger et al., 2016)
 - Recommendation for reading (Beel et al., 2016)
 - Redommendation for citing
 - Global (Galke et al., 2018)
 - Local co-citation (Kobayashi et al., 2018)
 - Local (Ebesu et al., 2017)

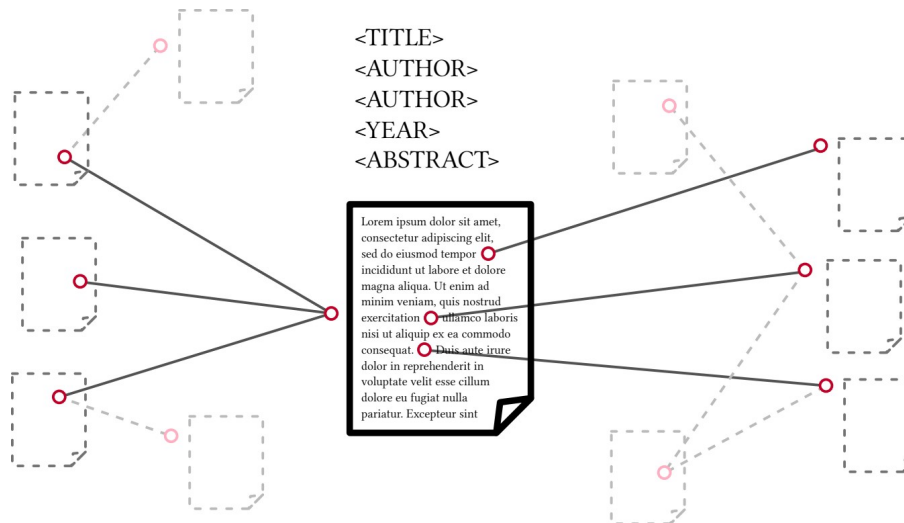
- Automatic processing
 - Processing of documents *as is*
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- Several approaches
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 - Local co-citation (Kobayashi et al., 2018)
 - Local (Ebesu et al., 2017) **this, and also semantic**

Background

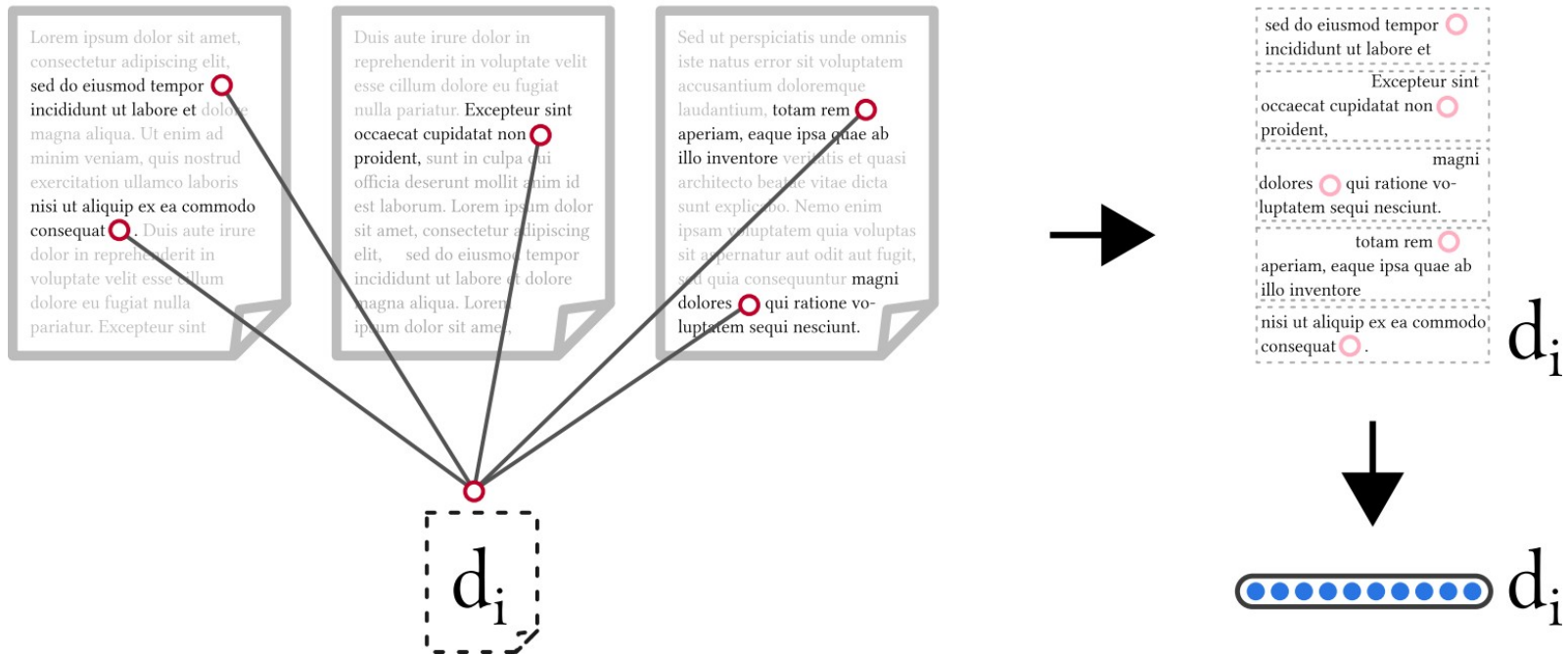


■ Redommendation for citing

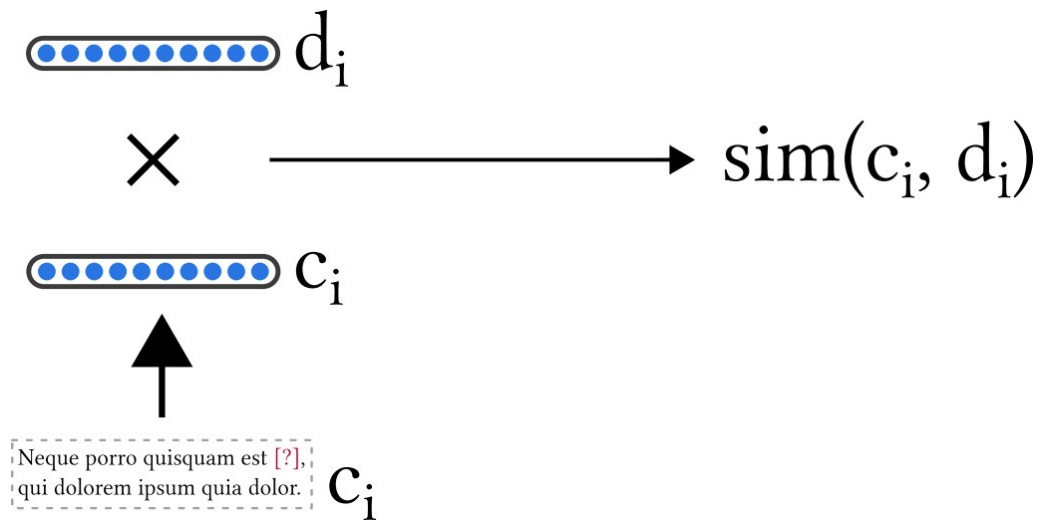
- | | | | |
|---------------------|---------------|---|----------|
| - Global | paper | → | paper(s) |
| - Local co-citation | sentence+cit. | → | paper(s) |
| - Local | sentence | → | paper(s) |



Background



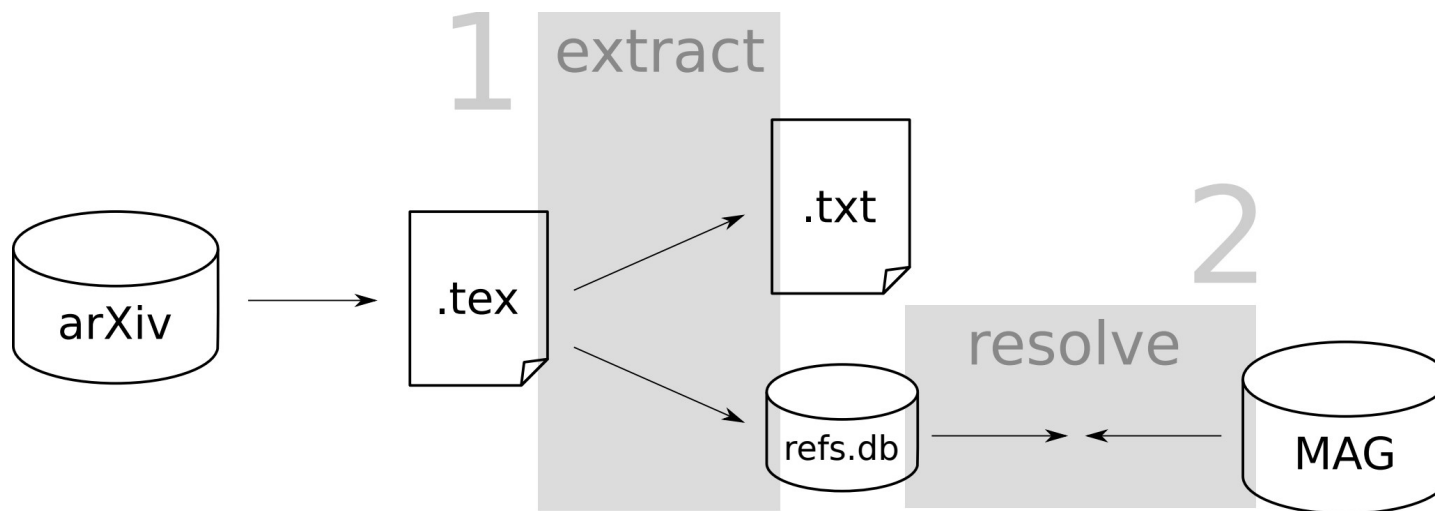
Background



- Existing data sets
 - Quality issues
 - No precise citation information (marker)
 - No citation interlinking (reference resolution)

- Create new data set

- Data sources
 - arXiv.org (LaTeX sources)
 - Microsoft Academic Graph (large)

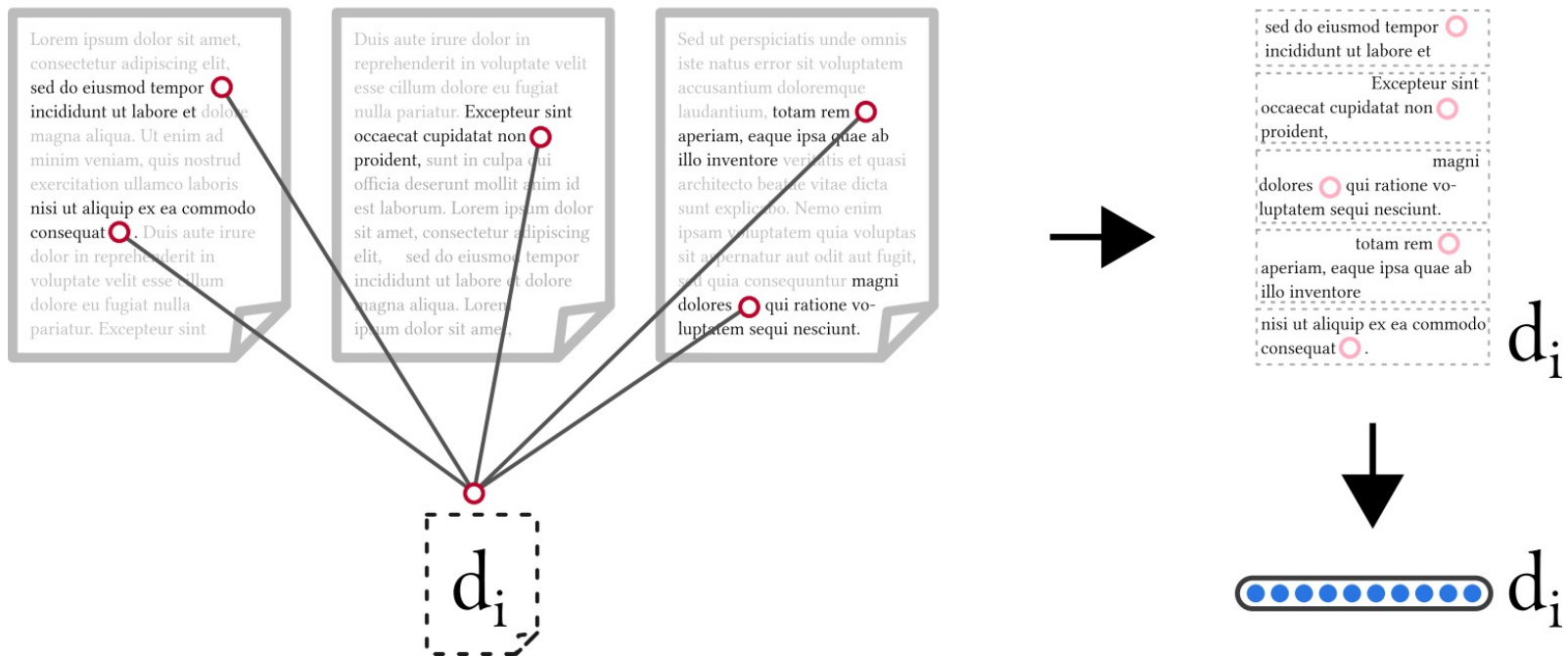


- arXiv data set (1991-2017)
 - large
 - 2.3M cited papers
 - 0.9M citing papers
 - 13M references
 - 25M citation contexts
 - accurate citation markers, interlinking
 - spanning multiple disciplines
 - flexible data format

- Quality of reference resolution
 - Manually check 300
 - 3 errors → accuracy estimate: $\geq 96\%$

#		Document
1	matched	<i>"The Maunder Minimum"</i> (John A. Eddy; 1976)
	correct	<i>"The Maunder Minimum: A reappraisal"</i> (John A. Eddy; 1983)
2	matched	<i>"Support Vector Machines"</i> (Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani; 2013)
	correct	<i>"1-norm Support Vector Machines"</i> (Ji Zhu, Saharon Rosset, Robert Tibshirani, Trevor J. Hastie; 2003)
3	matched	<i>"The Putative Liquid-Liquid Transition is a Liquid-Solid Transition in Atomistic Models of Water"</i> (David Chandler, David Limmer; 2013)
	correct	<i>"The putative liquid-liquid transition is a liquid-solid transition in atomistic models of water. II"</i> (David T. Limmer, David Chandler; 2011)

- Semantic modelling of citation contexts



Approaches



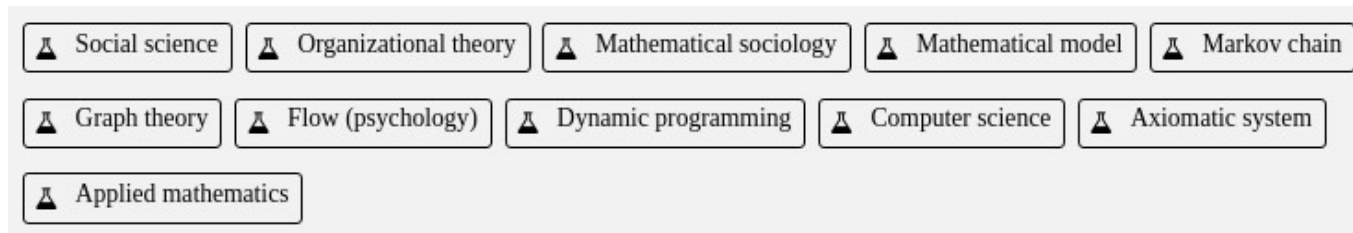
- Entities
 - Reference publications
 - Exemplifications
- Claims
 - Claims backed by citations

- Entities
 - “CiteSeer^x [18]” / “Neural ParsCit [53]”
 - “... approaches to citation recommendation [19–26]”
- Claims
 - “It has been shown, that ... [27].”
 - “A common argument for X is, that ... [3-7].”

Entity Based Approach



- Fields of Study in the MAG (230k)



- Noun phrases (2.8M)

- “*example*”
- “noun *phrase*”
- “context-based co-citation *recommendation*”

Entity Based Approach



- NP model

“We implement our M-CNN in the Caffe framework [1], with the proposed label prediction step as a new layer.”

- NPmarker model

“We implement our M-CNN in the Caffe framework [1], with the proposed label prediction step as a new layer.”

Claim Based Approach



- Identify claims with PredPatt
- Traverse parse trees
- Build predicate-argument tuples

Claim Based Approach



- Claim model
 - “The paper shows that context-based methods can outperform global approaches.”

Claim Based Approach



- Claim model

“The paper shows that context-based methods can outperform global approaches.”

?a shows ?b

?a : The paper

?b : SOMETHING := context-based methods
can outperform global approaches

?a can outperform ?b

?a : context-based methods

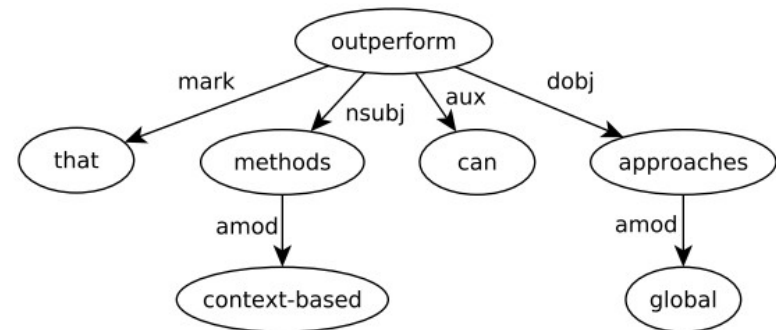
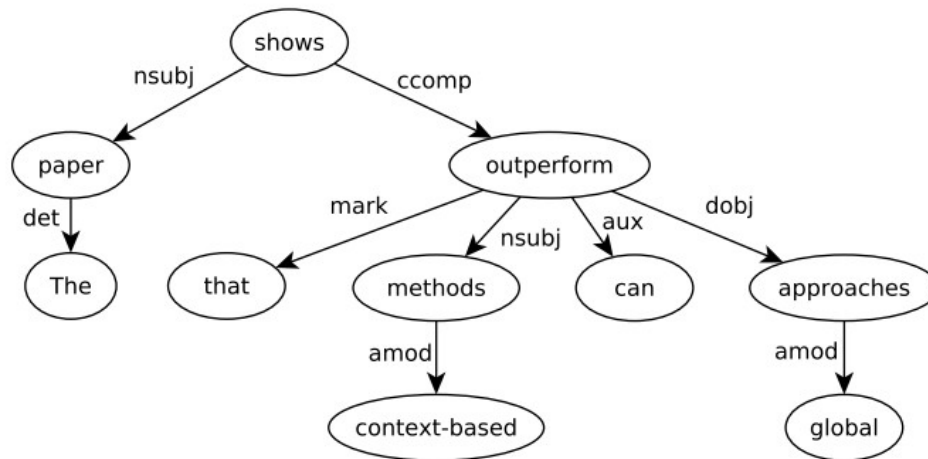
?b : global approaches

Claim Based Approach



- Claim model

“The paper shows that context-based methods can outperform global approaches.”

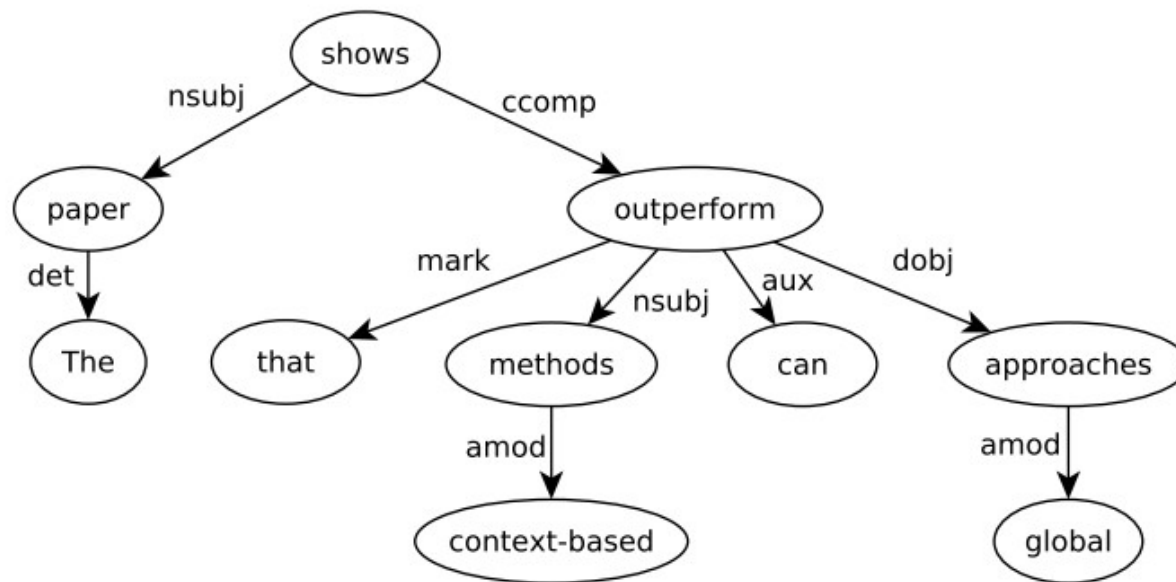


Claim Based Approach



- Claim model

“The **paper** **shows** that **context-based** methods can outperform **global** approaches.”

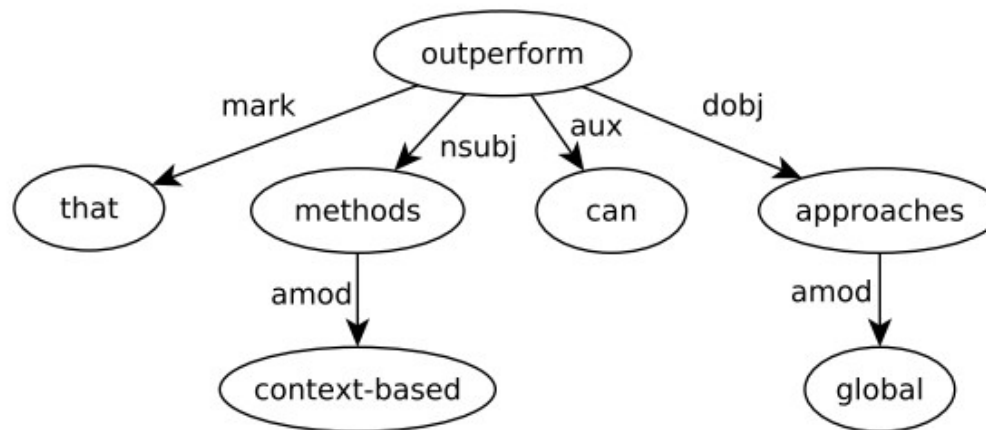


Claim Based Approach



- Claim model

“The paper shows that **context-based methods** can **outperform global approaches**.”



Claim Based Approach



- Claim model

“The paper shows that context-based methods can outperform global approaches.”

show:paper

show:context based methods

show:global approaches

outperform:context based methods

outperform:global approaches

→ sequential invariance

Approaches - Recommendation



- Similarity measure
 - Entities: cosine similarity
 - Claims: cosine similarity of TFIDF weighted vectors

- In both cases
 - Candidates: aggregated contexts of cited docs
 - Input: single citation context

Evaluation

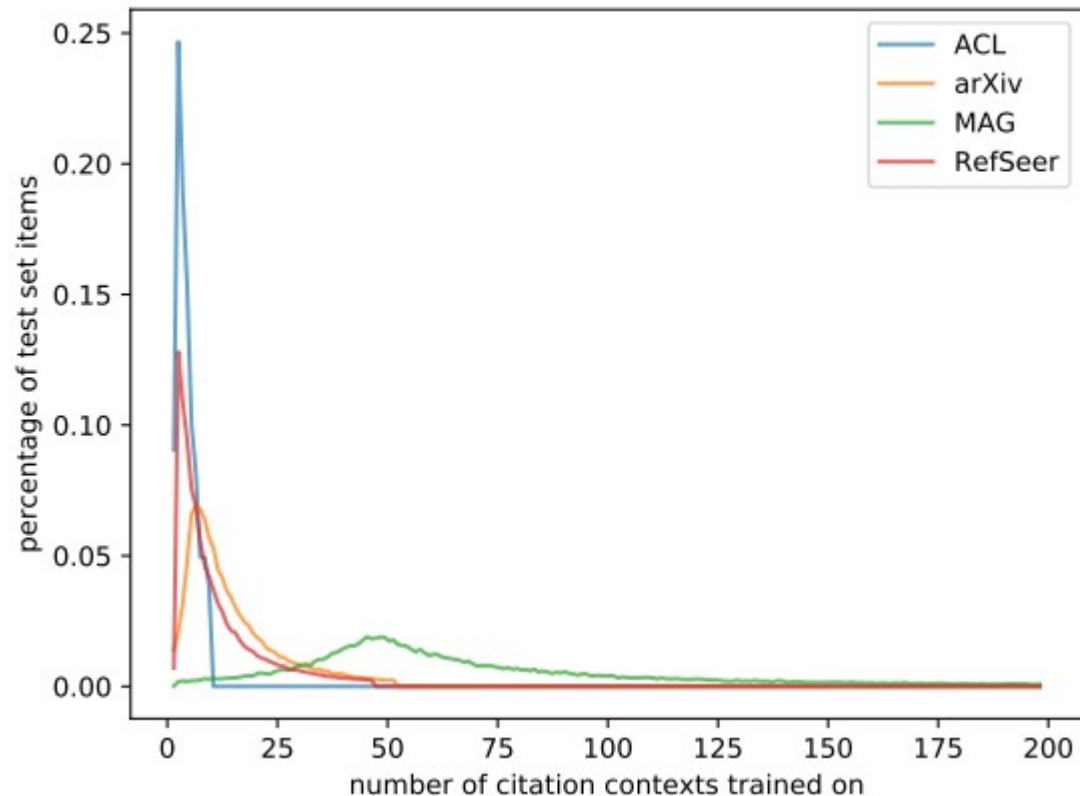


- Offline evaluation
 - Large scale
 - Limited assessment of relevance
- User study
 - Thorough assessment of relevance
 - Limited in scale

Offline Evaluation



- Data sets
 - arXiv
 - MAG
 - RefSeer
 - ACL-ARC

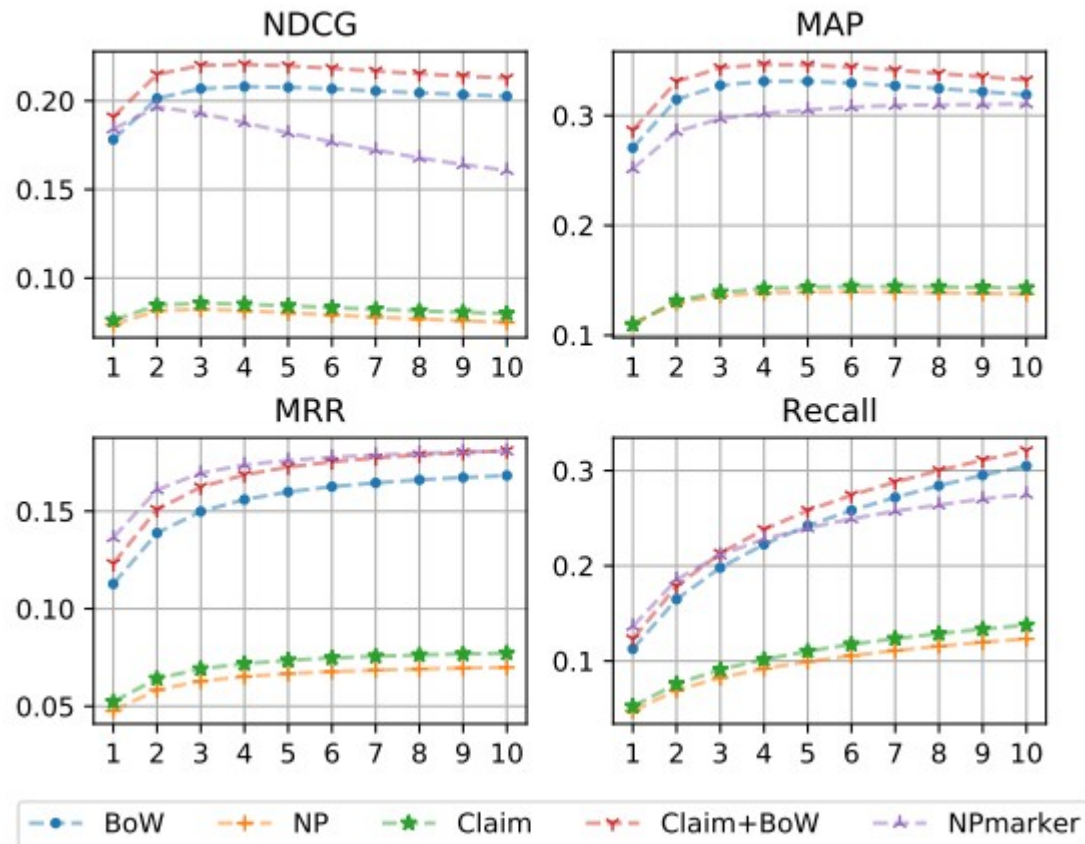


- Models
 - Bag-of-Words baseline
(punctuation, stop words, TFIDF)
 - NP
 - NPmarker
 - Claim
 - Claim+BoW
(combination of similarity scores)

Offline Evaluation



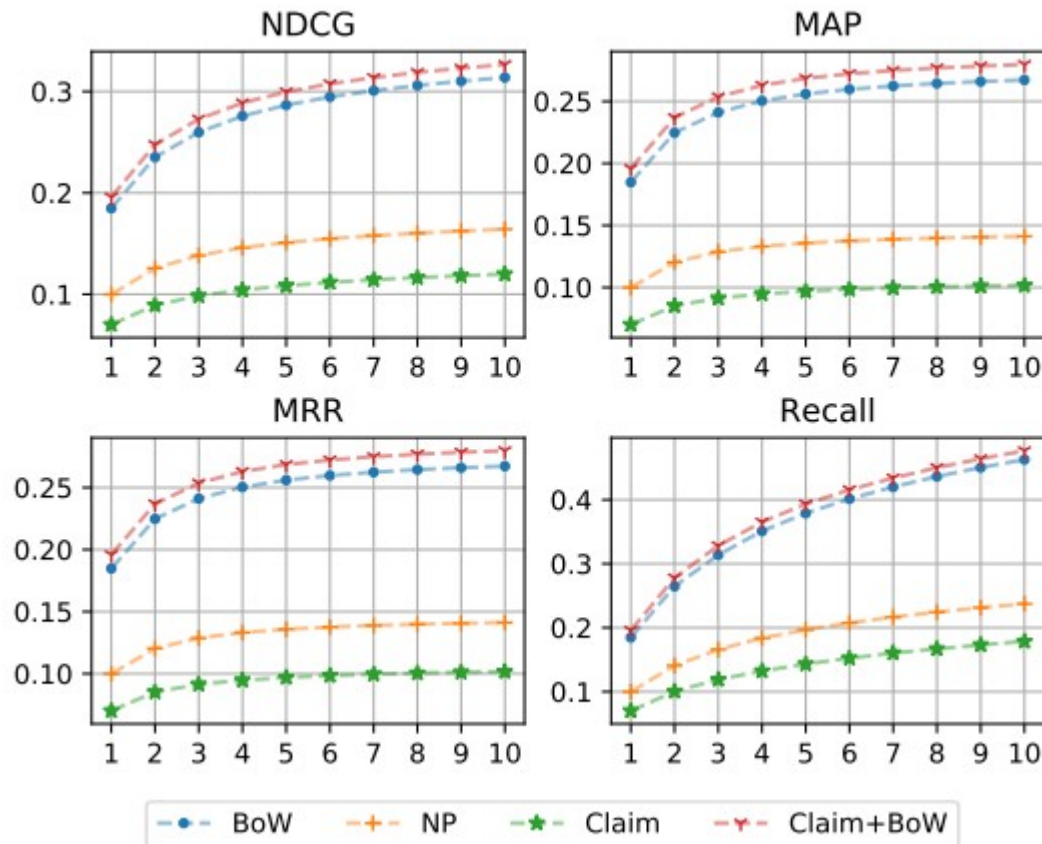
- arXiv data



Offline Evaluation



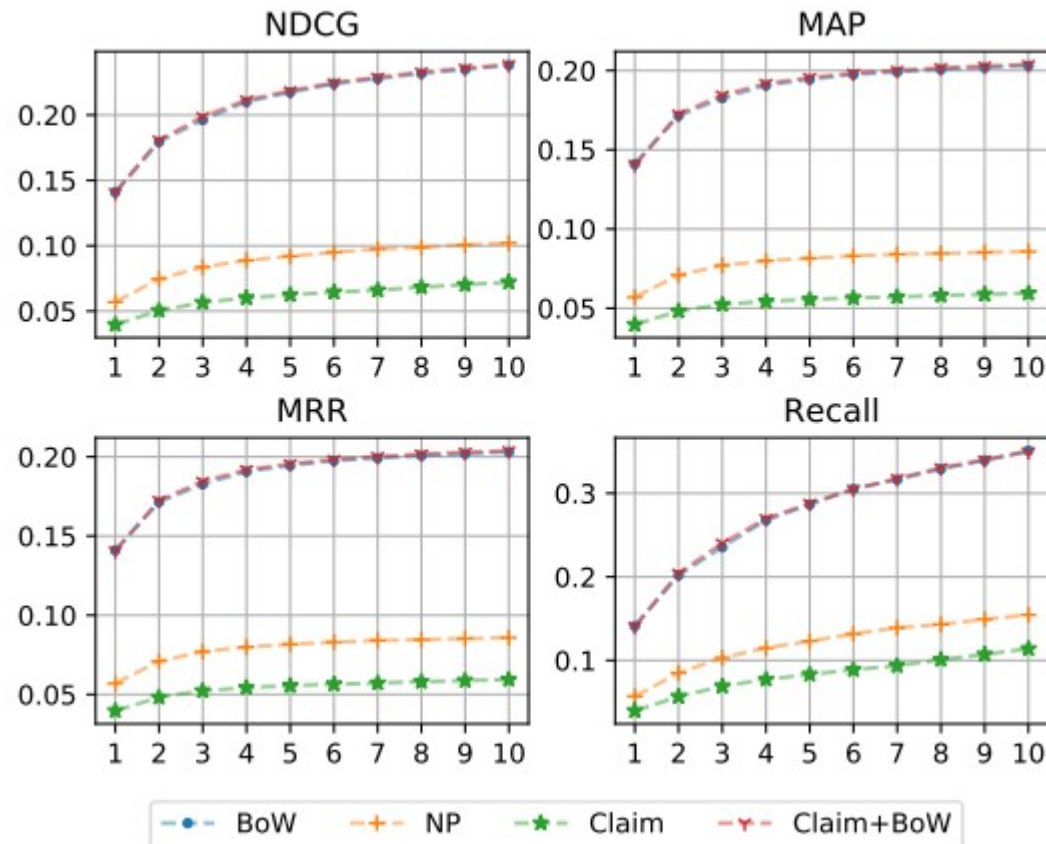
- MAG data



Offline Evaluation



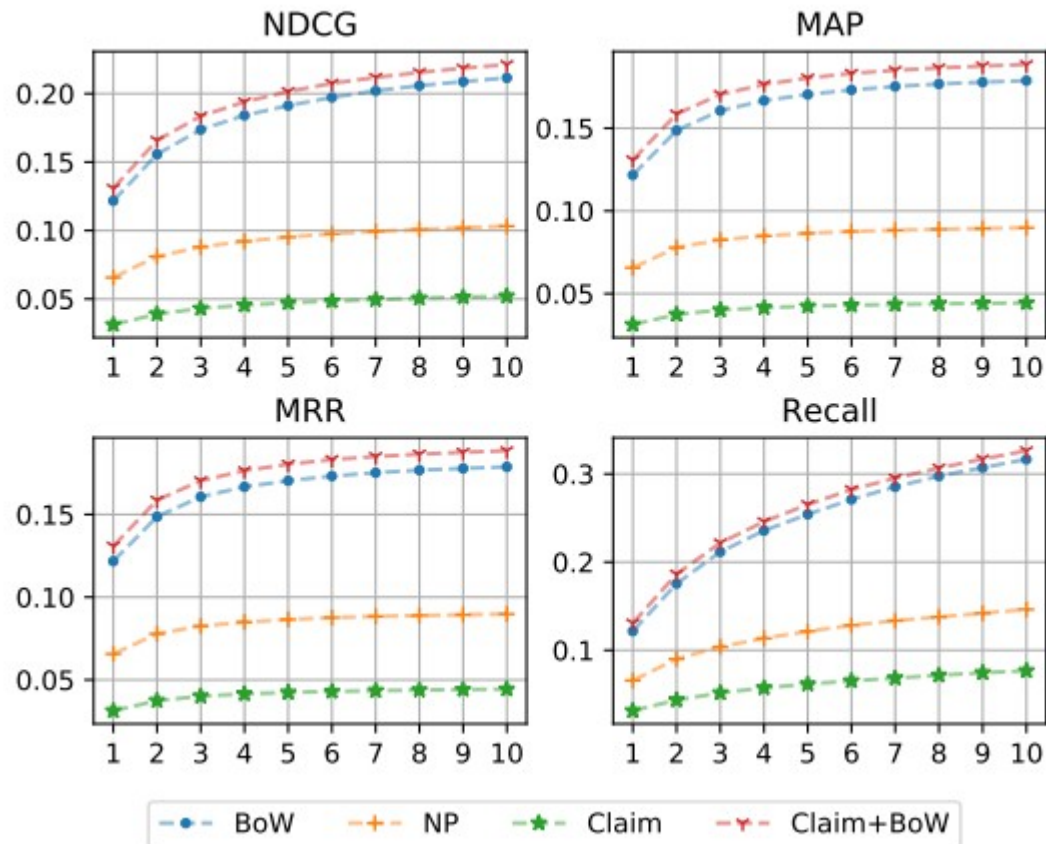
- ACL data



Offline Evaluation



- RefSeer data



- Motivation
 - Insight into offline evaluation data
 - Human judgement of recommendations
- Setting
 - 2 raters
 - 100 citation contexts
 - Top 5 recommendations of models
BoW, Claim+BoW, NPmarker
 - Citation characteristics (type / author's name / ...)

User Study



“To get an idea of the state space, it is not hard to see that there are FORMULA ways to partition and order FORMULA where FORMULA is the number of possible ways to divide a set of FORMULA objects into FORMULA partitions, otherwise known as Stirling numbers of second kind **MAINCIT** .”

not enough information / pass (I can't judge the relevance)

☐ author name inc. ☐ marker has gramm. func. | citation type: NE/concept ▼

check all relevant:

model 1

1. ☒ [Concrete Mathematics: A Foundation for Computer Science](#)
2. ☐ [Deciding DPDA Equivalence Is Primitive Recursive](#)
3. ☒ [Introductory Combinatorics](#)
4. ☐ [Asymptotic estimates of Stirling numbers](#)
5. ☐ [A Bayesian View of the Poisson-Dirichlet Process](#)

model 2

1. ☒ [Introductory Combinatorics](#)
2. ☒ [Concrete Mathematics: A Foundation for Computer Science](#)
3. ☐ [Deciding DPDA Equivalence Is Primitive Recursive](#)
4. ☐ [Asymptotic estimates of Stirling numbers](#)
5. ☐ [A Bayesian View of the Poisson-Dirichlet Process](#)

model 3

1. ☒ [Introductory Combinatorics](#)
2. ☒ [A Course in Combinatorics](#)
3. ☐ [On the Product of Independent Complex Gaussians](#)
4. ☐ [Asymptotic estimates of Stirling numbers](#)
5. ☒ [Combinatorics: Topics, Techniques, Algorithms](#)

Rate

■ Inter rater agreement

- Overall: 87%
- Author's name: 100%
- Non-/syntactic: 100%
- Relevance: 86%
- Citation type: 78%

		Rater 1			
Rater 2		Claim	NE/concept	Exemplific.	Other
	Claim	12	0	1	0
	NE/concept	1	15	2	0
	Exemplific.	2	1	9	1
	Other	2	0	0	3

- Contexts
 - 7/100 author's name
 - 5/100 syntactic
- Models
 - Claim+BoW only outperforms BoW in Recall metric
 - NPmarker best for NE/concept type
 - Claim+BoW best for claim type

Discussion



- Data Set
- Semantic models
- Semantic citation recommendation

- Data Set
 - Exact position of marker → especially useful for semantic models
 - Several disciplines → comparative analysis
 - Flexible format → experiments w/ e.g. context length
- From hereon
 - Update w/ recent papers (Saier & Färber, 2019)
 - Formulas (Aizawa et al., 2014; Zanibbi et al., 2016)

- Semantic models
 - First step towards semantic citation rec.
 - Citations in general
 - Can enhance recommendation
 - Applied to specific citation types
 - Suitable for conceptualized type
 - From hereon
 - Marker aware model (solve non-syntactic citations)
 - Test on more data (NPmarker)

- Semantic citation recommendation
 - Refined search based on claim model, e.g.:

is:NP-hard
improve:local citation recommendation
- From hereon
 - Thorough & systematic examination of cit. types
 - Specialized models
 - Closer to LD modelling
 - Credibility of claims, argumentative structures, ...

- Peroni, S. & Shotton, D. *FaBiO and CiTO: Ontologies for describing bibliographic resources and citations*, Journal of Web Semantics, 2012, 17, 33 - 43
- Berger, M.; McDonough, K. & M. Seversky, L. *Cite2vec: Citation-Driven Document Exploration via Word Embeddings*, IEEE Transactions on Visualization and Computer Graphics, 2016, 23, 1-1
- Beel, J.; Langer, S.; Genzmehr, M.; Gipp, B.; Breitingner, C. & Nürnberger, A. *Research Paper Recommender System Evaluation: A Quantitative Literature Survey*, Proceedings of the International Workshop on Reproducibility and Replication in Recommender Systems Evaluation, ACM, 2013, 15-22
- Galke, L.; Mai, F.; Vagliano, I. & Scherp, A. *Multi-Modal Adversarial Autoencoders for Recommendations of Citations and Subject Labels*, Proceedings of the 26th Conference on User Modeling, Adaptation and Personalization, ACM, 2018, 197-205
- Kobayashi, Y.; Shimbo, M. & Matsumoto, Y. *Citation Recommendation Using Distributed Representation of Discourse Facets in Scientific Articles*, Proceedings of the 18th ACM/IEEE on Joint Conference on Digital Libraries, ACM, 2018, 243-251
- Ebesu, T. & Fang, Y. *Neural Citation Network for Context-Aware Citation Recommendation*, Proceedings of the 40th International ACM SIGIR Conference on Research and Development in Information Retrieval, ACM, 2017, 1093-1096

Saier, T. & Färber, M. *Bibliometric-Enhanced arXiv: A Data Set for Paper-Based and Citation Based Tasks*, Proceedings of the 8th International Workshop on Bibliometric-enhanced Information Retrieval (BIR), 2019, 14-26

Aizawa, A.; Kohlhase, M.; Ounis, I. & Schubotz, M. *NTCIR-11 Math-2 Task Overview*, Proceedings of the 11th NTCIR Conference, 2014, 11, 88-98

Zanibbi, R.; Aizawa, A.; Kohlhase, M.; Ounis, I.; Topic, G. & Davila, K. *NTCIR-12 MathIR Task Overview*, Proceedings of the 12th NTCIR Conference, 2016, 12



Thank you.

Citation Types



Function	Construct	Examples (semantic construct <i>highlighted</i>)
Attribution	claim	“Berners-Lee et al. [57] argue that <i>structured collections of information and sets of inference rules are prerequisites for the semantic web to function.</i> ”
	NE	“A variation of this task is ‘ <i>context-based co-citation recommendation</i> ’ [25].”
	-	“In [22] Duma et al. test the effectiveness of using a variety of document internal and external text inputs with a TFIDF model.”
Exemplification	NE	“We looked into approaches to <i>local citation recommendation</i> such as [19–26] for our investigation.”
Further reference	-	“See [58] for a comprehensive overview.”
Statement of use	NE	“We use <i>CiteSeer</i> ^x [18] for our evaluation.”
Application	NE	“Using this mechanism we perform ‘ <i>context-based co-citation recommendation</i> ’ [25].”
Evaluation	-	“The use of DBLP in [40] restricts their data set to the field of computer science.”
Establishing links between sources	claim	“A common motivation brought forward for research on citation recommendation is that <i>finding proper citations is a time consuming task</i> [11, 19, 24, 25].”
	-	“Lamers et al. [32] base their definition on the author’s name whereas Thompson [30] focusses on the grammatical role of the citation marker.”
Comparison of own work with sources	claim	“Like [40] we find that, albeit written in a structured language, <i>parsing L^AT_EX sources is a non trivial task.</i> ”

■ Format

1412.3684.txt

[...] It has over 79 million images stored at the resolution of FORMULA . Each image is labeled with one of the 75,062 non-abstract nouns in English, as listed in the Wordnet{{cite:9ad20b7d-87d1-47f5-aeed-10a1cf89a2e2}} {{cite:298db7f5-9ebb-4e98-9ecf-0bdda28a42cb}} lexical database. [...]

refs.db

uuid	in_doc	mag_id	reference_string
9ad20b...	1412.3684	2081580037	George A. Miller (1995). Wo...
298db7...	1412.3684	2038721957	Christiane Fellbaum (1998),...

Data Set Format



■ Format

MAG

paperid	originaltitle	publisher	
2081580037	WordNet : an electronic lexical database	MIT Press	
2038721957	WordNet: a lexical database for English	ACM	...

extracted_contexts.csv

2038721957 | 2081580037 | 1412.3684 | It has over 79 million images stored at the resolution of FORMULA . Each image is labeled with one of the 75,062 non-abstract nouns in English, as listed in the Wordnet CIT MAINCIT lexical database. It has been noted that many of the labels are not reliable CIT .

Data Set Citation Flow

