Master's Thesis

Semantic approaches to citation recommendation

Tarek Saier

Examiners: Prof. Dr. Georg Lausen

Dr. Michael Färber

Albert-Ludwigs-University Freiburg

Faculty of Engineering

Department of Computer Science

Chair of Databases and Information Systems

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First Examiner

Prof. Dr. Georg Lausen

Second Examiner & Supervisor

Dr. Michael Färber

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Tarek Saier

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Dr. Michael Färber

Declaration

I hereby declare, that I am the sole author and composer of my thesis and that no other sources or learning aids, other than those listed, have been used. Furthermore, I declare that I have acknowledged the work of others by providing detailed references of said work. I hereby also declare, that my Thesis has not been prepared for another examination or assignment, either wholly or excerpts thereof.

_____
Place, Date

_____
Signature

Abstract

foo bar

Zusammenfassung

fu bar

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1 Introduction

1.1 Motivation

Citations are a central building block of scholarly discourse. They are the means by which scholars relate their research to existing work—be it in backing up claims, criticising, naming examples or engaging in any other form. Citing in a meaningful way requires an author to be aware of publications relevant to their work. Here, the ever increasing amount of new reseach publications per year poses a serious challenge. Even with academic search engines like Goolge Scholar and CiteSeerX at our disposal, identifying publications that are worthwhile to examine and appropriate to reference remains a time consuming task.

It is therefore not suprising that methods to aid researchers in these tasks have been and still are being actively researched. While diverse in nature, the common core of these efforts is the goal to utilize the automated processing of publications. This can be achieved by either extracting information from publications as they are today [1, 2], or by introducing explicit semantic representations to facilitate automated processing [3, 4, 5]. Once processed, a typical method is to harvest human made citations, analyze them [6, 7, 8] and use them for example to recommend papers [2] or aid in document exploration [9]. Although systems like this have existed for over 20 years [10, 2], there is not a lot of work looking into the use of explicit semantic representations for the recommendation of papers. This is why this thesis will investiage their application. More specifically, we will concentrate on the task of recommending papers for citation—as opposed to, for example, discovery. What this encompasses will be described in more detail in the following section.

1.2 Problem setting

1.3 Method

generate a data set fit for investigation of citation recommendation employing named entities and claims

devise citation recommendation approach implement and evaluate

1.4 Document structure

foo bar

1.5 Example Section

Copypasta of useful stuff below.

- Put a tilde (nbsp) in front of citations [11].
- **(TODO: Do this!)**
- **(EXTEND: Write more when new results are out!)**
- **(DRAFT: Hacky text!)**
- Chapter 1
- the colors of the Uni
    - UniBlue
    - UniRed
    - UniGrey
- a command for naming matrices $\mathbf{G}$, and naming vectors $\mathbf{a}$. This overwrites the default behavior of having an arrow over vectors, sticking to the naming conventions normal font for scalars, bold-lowercase for vectors, and bold-uppercase for matrices.

- named equations:

$$d(a, b) = d(b, a) \tag{1}$$

symmetry

- Use "these" for citing, not "these"
- If an equation is at the end of a sentence, add a full stop. If it's not the end, add a comma: $a = b + c$ (1),
- `https://en.wikipedia.org`
- Do not overuse footnotes[1] if possible.

---

[1] `https://en.wikipedia.org`

2 Related Work

lots. pick wisely.

Leveraging Semantic Annotations to Link Wikipedia and News Archives[12]

Using NEL + dependency trees for music recommendation[13]

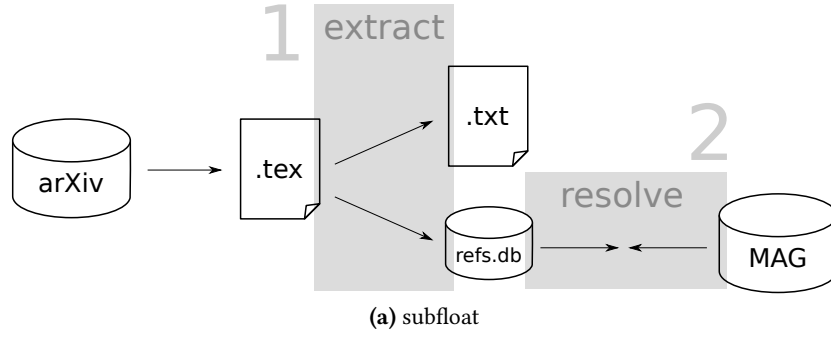# 3 Background

explain all the things.

(a) subfloat

Figure 1: Caption that appears under the fig—do I want this in bold tho?

Algorithm 1 Stochastic Gradient Descent: Neural Network

Create a mini batch of m samples $\mathbf{x}_0 \ldots \mathbf{x}_{m-1}$

foreach sample $\mathbf{x}$ **do**

    $\mathbf{a}^{\mathbf{x},0} \leftarrow \mathbf{x}$ $\triangleright$ Set input activation

    foreach Layer $l \in \{1 \ldots L - 1\}$ **do** $\triangleright$ Forward pass

        $\mathbf{z}^{\mathbf{x},l} \leftarrow \mathbf{W}^l \mathbf{a}^{\mathbf{x},l-1} + \mathbf{b}^l$

        $\mathbf{a}^{\mathbf{x},l} \leftarrow \varphi(\mathbf{z}^{\mathbf{x},l})$

    end for

    $\boldsymbol{\delta}^{\mathbf{x},L} \leftarrow \nabla_{\mathbf{a}} C_{\mathbf{x}} \odot \varphi'(\mathbf{z}^{\mathbf{x},L})$ $\triangleright$ Compute error

    foreach Layer $l \in L - 1, L - 2 \ldots 2$ **do** $\triangleright$ Backpropagate error

        $\boldsymbol{\delta}^{\mathbf{x},l} \leftarrow ((\mathbf{W}^{l+1})^T \boldsymbol{\delta}^{\mathbf{x},l+1}) \odot \varphi'(\mathbf{z}^{\mathbf{x},l})$

    end for

end for

foreach $l \in L, L - 1 \ldots 2$ **do** $\triangleright$ Gradient descent

    $\mathbf{W}^l \leftarrow \mathbf{W}^l - \frac{\eta}{m} \sum_{\mathbf{x}} \boldsymbol{\delta}^{\mathbf{x},l} (\mathbf{a}^{\mathbf{x},l-1})^T$

    $\mathbf{b}^l \leftarrow \mathbf{b}^l - \frac{\eta}{m} \sum_{\mathbf{x}} \boldsymbol{\delta}^{\mathbf{x},l}$

end for

---

4 Data set

approach approach.

4.1 Existing data sets

and why a new one was necessary

MAG[14] (use/analysis: [15, 16, 17])

use of PMC OAS[18, 19, 20, 21] (PMC OAS problems: [18])

4.2 Data set creation

foo

survey paper on extraction of meta data (author, year, ...) and classification of sentences (method, goal, ...) from publications[1]

evaluation of reference string parsers[22], a dataset for reference string parsing[23]

4.3 Data set evaluation

bar

5 Semantic approaches to citation recommendation

types of citations (naming an entity, backing up a claim, etc.)

how citations are embedded in sentences (integral/non-integral[24, 25, 26, 27, 28])

5.1 Fields of Study as names entities

name name

5.2 Claims

5.2.1 Tools for extracting claims

tools tools

also: Survey on open information extraction[29]

context specific claim detection[30]

if only papers where semantically annotated as proposed in [3]

5.2.2 A model of aboutness closely tied to claim structure

unfeasibility of use of PredPatt output as is

resulting compromise model

predpatt[31, 32]

alternative view: model gives a very selective citation context derived from claim structure (cf. concept of reference scope as sub part of citation context sentence[33, 34]

6 Evaluation

evaluate evaluate

implemetation pain and bad evaluation scores[35]

6.1 Special considerations for citation recommendation

train/test splitting (per cited doc, temporal, ...), re-recommendation, number of contexts describing a recommendation item, ...

a cited doc's role (how it is cited) can develop over time[36, 37]

relevance of time[38]

candidates are only citations within current paper[39]

6.2 Offline evaluation

pre-filtering experiments (knn[21], lsi, lda, fos, ...)

different evaluation settings (all, CSonly, comparison to MAG, ...)

FoS alone, restrictively combined w/ BOW, only directly preceeding, ...

PP model alone, combined, ...

6.3 Online evaluation

Data set	#Papers	Cit. context	Disciplines	Full text	Ref. IDs
arXiv CS	90K	1 sentence	CS	yes	DBLP
CiteSeerX /RefSeer	1M	400 chars	all	no	no
PubMed Central OA[1]	2.3M	extractable	Biomed./Life Sci.	yes	mixed
Scholarly v2[2]	100K	extractable	CS	yes	no
ACL-ARC	11k	extractable	CS/comp. ling.	yes	no
ACL-AAN	18k	extractable	CS/comp. ling.	yes	no

Table 1: **Table caption.** foo bar...

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[1] `https://www.ncbi.nlm.nih.gov/pmc/tools/openftlist/`
[2] `http://www.comp.nus.edu.sg/~sugiyama/SchPaperRecData.html`

7 Conclusion

conclude conclude.

8 Future work

As a first step identify types of citations more systematically.

For different types, different models.

Proper claim model. (that could also include assessing credibility[40])

Argumentative structures. (Argumentation mining[41, 42, 43])

Bibliography

[1] Z. Nasar, S. W. Jaffry, and M. K. Malik, "Information extraction from scientific articles: a survey," *Scientometrics*, vol. 117, pp. 1931–1990, Dec 2018.

[2] J. Beel, B. Gipp, S. Langer, and C. Breitinger, "Research-paper recommender systems: a literature survey," *International Journal on Digital Libraries*, vol. 17, pp. 305–338, Nov 2016.

[3] S. Buckingham Shum, E. Motta, and J. Domingue, "Scholonto: an ontology-based digital library server for research documents and discourse," *International Journal on Digital Libraries*, vol. 3, pp. 237–248, Oct 2000. r (ch 1-3).

[4] J. Schneider, T. Groza, and A. Passant, "A review of argumentation for the social semantic web," *Semant. web*, vol. 4, pp. 159–218, Apr. 2013.

[5] A. Kitamoto and Y. Nishimura, "Digital criticism platform for supporting evidence-based interpretation of sources," in *IPSJ SIG Computers and the Humanities Symposium 2015*, pp. 211–218, 12 2015. (in Japanese).

[6] A. Abu-Jbara, J. Ezra, and D. Radev, "Purpose and polarity of citation: Towards nlp-based bibliometrics," in *Proceedings of the 2013 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies*, pp. 596–606, Association for Computational Linguistics, 2013.

[7] S. Teufel, A. Siddharthan, and D. Tidhar, "Automatic classification of citation function," in *Proceedings of the 2006 Conference on Empirical Methods in Natural Language Processing*, EMNLP '06, (Stroudsburg, PA, USA), pp. 103–110, Association for Computational Linguistics, 2006.

[8] S. Teufel, A. Siddharthan, and D. Tidhar, "An annotation scheme for citation function," in *In Proceedings of the 7th SIGdial Workshop on Discourse and Dialogue*, 2006.

[9] M. Berger, K. McDonough, and L. M. Seversky, "Cite2vec: Citation-driven document exploration via word embeddings," *IEEE Transactions on Visualization and Computer Graphics*, vol. 23, pp. 1–1, 01 2016.

[10] K. D. Bollacker, S. Lawrence, and C. L. Giles, "Citeseer: An autonomous web agent for automatic retrieval and identification of interesting publications," in *Proceedings of the Second International Conference on Autonomous Agents*, AGENTS '98, (New York, NY, USA), pp. 116–123, ACM, 1998.

[11] M. J. Moravcsik and P. Murugesan, "Some results on the function and quality of citations," *Social Studies of Science*, vol. 5, no. 1, pp. 86–92, 1975.

[12] A. Mishra and K. Berberich, "Leveraging semantic annotations to link wikipedia and news archives," in *Advances in Information Retrieval* (N. Ferro, F. Crestani, M.-F. Moens, J. Mothe, F. Silvestri, G. M. Di Nunzio, C. Hauff, and G. Silvello, eds.), (Cham), pp. 30–42, Springer International Publishing, 2016. r (ch 1-3).

[13] M. Sordo, S. Oramas, and L. Espinosa-Anke, "Extracting relations from unstructured text sources for music recommendation," in *Natural Language Processing and Information Systems* (C. Biemann, S. Handschuh, A. Freitas, F. Meziane, and E. Métais, eds.), (Cham), pp. 369–382, Springer International Publishing, 2015.

[14] A. Sinha, Z. Shen, Y. Song, H. Ma, D. Eide, B.-J. P. Hsu, and K. Wang, "An overview of microsoft academic service (mas) and applications," in *Proceedings of the 24th*

International Conference on World Wide Web, WWW '15 Companion, (New York, NY, USA), pp. 243–246, ACM, 2015. r.

[15] D. Herrmannova and P. Knoth, "An analysis of the microsoft academic graph," *D-Lib Magazine*, vol. 22, no. 9/10, 2016. r.

[16] B. Paszcza, "Comparison of microsoft academic graph with other scholarly citation databases," 11 2016. r (ch 1,""3"").

[17] S. E. Hug, M. Ochsner, and M. P. Brändle, "Citation analysis with microsoft academic," *Scientometrics*, vol. 111, pp. 371–378, Apr 2017. r.

[18] B. Gipp, N. Meuschke, and M. Lipinski, "Citrec : An evaluation framework for citation-based similarity measures based on trec genomics and pubmed central," in *iConference 2015 Proceedings*, iSchools, 2015.

[19] D. Duma, E. Klein, M. Liakata, J. Ravenscroft, and A. Clare, "Rhetorical classification of anchor text for citation recommendation," *D-Lib Magazine*, vol. 22, 2016.

[20] L. Galke, F. Mai, I. Vagliano, and A. Scherp, "Multi-modal adversarial autoencoders for recommendations of citations and subject labels," in *Proceedings of the 26th Conference on User Modeling, Adaptation and Personalization*, UMAP '18, (New York, NY, USA), pp. 197–205, ACM, 2018.

[21] C. Bhagavatula, S. Feldman, R. Power, and W. Ammar, "Content-based citation recommendation," in *NAACL-HLT*, 2018.

[22] D. Tkaczyk, A. Collins, P. Sheridan, and J. Beel, "Machine learning vs. rules and out-of-the-box vs. retrained: An evaluation of open-source bibliographic reference and citation parsers," in *Proceedings of the 18th ACM/IEEE on Joint Conference on Digital Libraries*, JCDL '18, (New York, NY, USA), pp. 99–108, ACM, 2018.

[23] S. Anzaroot and A. McCallum, "A new dataset for fine-grained citation field extraction," in *ICML Workshop on Peer Reviewing and Publishing Models*, 2013.

[24] J. Swales, *Genre analysis: English in academic and research settings.* Cambridge University Press, 1990.

[25] K. Hyland, "Academic attribution: citation and the construction of disciplinary knowledge," *Applied Linguistics*, vol. 20, no. 3, pp. 341–367, 1999.

[26] P. Thompson, *A pedagogically-motivated corpus-based examination of PhD theses: Macrostructure, citation practices and uses of modal verbs.* PhD thesis, University of Reading, 2001.

[27] A. Okamura, "Citation forms in scientific texts: Similarities and differences in l1 and l2 professional writing," *Nordic Journal of English Studies*, vol. 7, no. 3, pp. 61–81, 2008.

[28] W. Lamers, N. J. v. Eck, L. Waltman, and H. Hoos, "Patterns in citation context: the case of the field of scientometrics," in *STI 2018 Conference proceedings*, pp. 1114–1122, Centre for Science and Technology Studies (CWTS), 2018.

[29] C. Niklaus, M. Cetto, A. Freitas, and S. Handschuh, "A survey on open information extraction," in *Proceedings of the 27th International Conference on Computational Linguistics*, pp. 3866–3878, Association for Computational Linguistics, 2018.

[30] R. Levy, Y. Bilu, D. Hershcovich, E. Aharoni, and N. Slonim, "Context dependent claim detection," in *Proceedings of COLING 2014, the 25th International Conference on Computational Linguistics: Technical Papers*, (Dublin, Ireland), pp. 1489–1500, Dublin City University and Association for Computational Linguistics, August 2014. r.

[31] A. S. White, D. Reisinger, K. Sakaguchi, T. Vieira, S. Zhang, R. Rudinger, K. Rawlins, and B. Van Durme, "Universal decompositional semantics on universal dependencies," in *Proceedings of the 2016 Conference on Empirical Methods in Natural Language Processing*, pp. 1713–1723, Association for Computational Linguistics, 2016.

[32] S. Zhang, R. Rudinger, and B. V. Durme, "An evaluation of predpatt and open ie via stage 1 semantic role labeling," in *IWCS 2017 — 12th International Conference on Computational Semantics — Short papers*, 2017.

[33] A. Abu-Jbara and D. Radev, "Reference scope identification in citing sentences," in *Proceedings of the 2012 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies*, NAACL HLT '12, (Stroudsburg, PA, USA), pp. 80–90, Association for Computational Linguistics, 2012.

[34] R. Jha, A.-A. Jbara, V. Qazvinian, and D. R. Radev, "Nlp-driven citation analysis for scientometrics," *Natural Language Engineering*, vol. 23, no. 1, p. 93–130, 2017.

[35] J. Beel and S. Dinesh, "Real-world recommender systems for academia: The pain and gain in building, operating, and researching them [long version]," *CoRR*, vol. abs/1704.00156, 2017.

[36] J. Swales, "Citation analysis and discourse analysis," *Applied Linguistics*, vol. 7, no. 1, pp. 39–56, 1986.

[37] J. He and C. Chen, "Temporal representations of citations for understanding the changing roles of scientific publications," in *Front. Res. Metr. Anal.*, 2018.

[38] J. Beel, "It's time to consider "time" when evaluating recommender-system algorithms [proposal]," *CoRR*, vol. abs/1708.08447, 2017.

[39] D. Duma and E. Klein, "Citation resolution: A method for evaluating context-based citation recommendation systems," in *Proceedings of the 52nd Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers)*, vol. 2, pp. 358–363, 2014.

[40] K. Popat, S. Mukherjee, J. Strötgen, and G. Weikum, "Credibility assessment of textual claims on the web," in *Proceedings of the 25th ACM International on Conference on*

Information and Knowledge Management, CIKM '16, (New York, NY, USA), pp. 2173–2178, ACM, 2016.

[41] C. Stab and I. Gurevych, "Parsing argumentation structures in persuasive essays," *CoRR*, vol. abs/1604.07370, 2016.

[42] M. Lippi and P. Torroni, "Argumentation mining: State of the art and emerging trends," *ACM Trans. Internet Technol.*, vol. 16, pp. 10:1–10:25, Mar. 2016.

[43] I. Habernal and I. Gurevych, "Argumentation mining in user-generated web discourse," *Comput. Linguist.*, vol. 43, pp. 125–179, Apr. 2017.