

Master's Thesis

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**Semantic approaches to citation  
recommendation**

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Master-Thesis

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# 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.

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Place, Date

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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 research publications per year poses a serious challenge. Even with academic search engines like Google 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 surprising 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 [1, 2], or by introducing explicit semantic representations of their content to facilitate automated processing [3, 4, 5]. Once processed, a typical method is to harvest human made citations, analyze them [6, 7] and use them for example to recommend papers [2] or aid in document exploration [8]. Although systems like this have existed for over 20 years [9, 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 investigate 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

In the broadest sense, recommending papers for citation means given an input text, suggest publications that can be referred to from within that text. In scale this can vary from specific recommendations for a section of a sentence (*local* or *context based*), to general recommendations for a whole input document (*global*). The task can also include deciding whether or not the input contains parts that would justify inserting a citation in the first place. In this thesis, we will focus on local citation recommendation with the assumption that the input always allows for/requires a citation to be put in.

Another distinction to be made is between personalized and general citation recommendation. Some approaches make use of user specific information such as an author's prior citations. Collaborative filtering approaches by nature include a user model and therefore fall into this category. While personalization can improve recommendation, it limits the approach to users that are willing to share personal information. We therefore limit ourselves to purely content based filtering approaches.

A last clarification has to be made concerning the term *explicit semantic representations*. This is to be understood as a differentiation from the mere use of unstructured text. A most prominent example for explicit semantic representations would be the structure of the Semantic Web [10]. In the context of citation recommendation as briefly outlined above this means representing citations in a semantically meaningful way as opposed to just relying on syntactical information like n-grams or bag-of-words representations.

The problem setting can be summarized as follows. To investigate is, the applicability of and requirements for the use of explicit semantic representations for content based, local citation recommendation. The following section will outline how this investigation is performed.

## 1.3 Method

In order to assess if and how explicit semantic representations can benefit citation recommendation we investigate the use of named entities as well as claim structures. For the evaluation of our models in a realistic setting we generate a large data set that allows for the extraction of precise citation marker positions. To ensure comparability with other approaches we also perform evaluations on existing data sets as far as possible.

Extend to mention offline and online eval

Extend moar

## 1.4 Contributions

The data set

Two models (even though they don't perform that well)

Insights into open problems with building claim models around citations (b/c of non-integral citation styles)

## 1.5 Document structure

foo bar

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 **G**, and naming vectors **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<sup>1</sup> if possible.

---

<sup>1</sup><https://en.wikipedia.org>

## 2 Related Work

lots. pick wisely.

### 2.1 Semantic approaches to recommendation

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

Using NEL + dependency trees for music recommendation[13]

use citeulike tags as "academic concepts" for paper recommendation[14]

Capturing knowledge of user preferences: ontologies in recommender systems[15, 16]

A multi-criteria hybrid citation recommendation system based on linked data[17]

SemCiR: A Citation Recommendation System Based on a Novel Semantic Distance Measure[18]

DiNoia[19]

A Paper Recommender for Scientific Literatures Based on Semantic Concept Similarity[20]

## 2.2 Local citation recommendation

penn state: [21] was prototype of [22], improved (multi-layered neural network) [23], and there's also [24]

[17] (also in section above)

[25, 26]

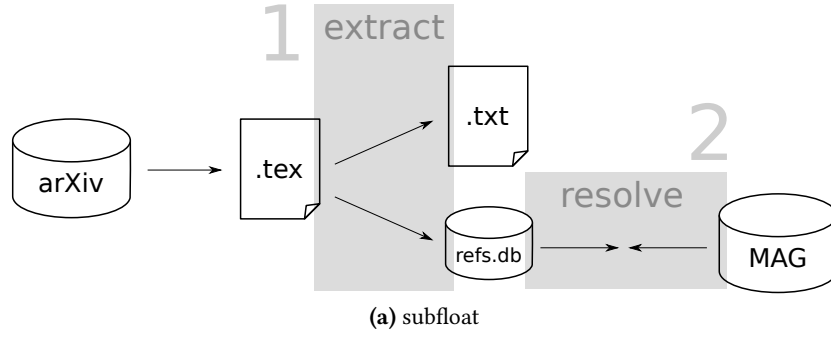
[27]

[28]



## 3 Background

explain all the things.



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

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**Algorithm 1** Stochastic Gradient Descent: Neural Network

---

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

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

$\mathbf{a}^{\mathbf{x},0} \leftarrow \mathbf{x}$

▷ Set input activation

**foreach** Layer  $l \in \{1 \dots L-1\}$  **do**

▷ 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**

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

▷ Compute error

**foreach** Layer  $l \in L-1, L-2 \dots 2$  **do**

▷ Backpropagate error

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

**end for**

**end for**

**foreach**  $l \in L, L-1 \dots 2$  **do**

▷ Gradient descent

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

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

**end for**

---

## 4 Data set

approach approach.

### 4.1 Existing data sets

and why a new one was necessary

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 <sup>1</sup>	2.3M	extractable	Biomed./Life Sci.	yes	mixed
Scholarly v2 <sup>2</sup>	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...

MAG[29] (use/analysis: [30, 31, 32])

use of PMC OAS[33, 26, 34, 35] (PMC OAS problems: [33])

<sup>1</sup><https://www.ncbi.nlm.nih.gov/pmc/tools/openftlist/>

<sup>2</sup><http://www.comp.nus.edu.sg/~sugiyama/SchPaperRecData.html>

## 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[36], a dataset for reference string parsing[37]

## 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[38, 39, 40, 41, 42])

### **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[43]

context specific claim detection[44]

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[45, 46]

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[47, 48])

## 6 Evaluation

evaluate evaluate

implemetation pain and bad evaluation scores[49]

### 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[50, 51]

relevance of time[52]

candidates are only citations within current paper[25]

### 6.2 Offline evaluation

pre-filtering experiments (knn[35], lsi, lda, fos, ...)

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

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

PP model alone, combined, ...

-> not *generally* applicable/beneficial but for certain citation types ...

## **6.3 Online evaluation**

online online



## 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[53])

Argumentative structures. (Argumentation mining[54, 55, 56])



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