Master's Thesis

Semantic approaches to citation recommendation

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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.

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 [1, 2], or by introducing explicit semantic representations of their content or interrelations to facilitate automated processing [3–5]. 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 [2, 9], 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

In the boradest 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 [10]. 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 therfore 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 [11]. 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

Entity and claim based models

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 [12].
- **(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: $a = b + c \quad (1)$,
- `https://en.wikipedia.org`
- Do not overuse footnotes[1] if possible.

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

2. Related Work

To the best of our knowledge there is, so far, almost no work investigating (1) the use of explicit senamtic representations for (2) the task of local citation recommendation. We will therefore present related work in two areas. First, semantic approaches to citation/paper recommendation in general (global as well as local). Second, local citation recommendation regardless of the specifics of the approach taken.

Note that SemCir [13] (see below) is the only case of a semantic approach to local citation recommendation we are aware of. The explicit semantic representations are, however, not generated from citation contexts (local) but from papers (global) that are textually (not necessarily semantically) similar to the citation contexts.

2.1. Semantic approaches to citation recommendation

At a point in time where publishing research papers online was an emerging trend, Middleton et al. [14] propose a system for paper recommendation making use of a topic ontology. Based on classifying papers into topics and recording which papers a researcher would access on the web, they employ content-based filtering, collaborative filtering and a feedback mechanism to suggest papers from new topics to users. Comparing the topic ontology to a flat list of topics in two user studies, they report 7–15% more user satisfaction for the ontology case.

In a similar vein, Zhang et al. [15] propose a hybrid recommender system for papers based on semantic concept similarity. They derive concepts from CiteULike[1] tags and use these to measure the semantic similarity of papers and users' interest. In their evaluation they compare different settings of the approach but do not compare to other work or alternative techniques.

Jiang et al. [16] use CiteULike tags as academic concepts to build a topic model applied to paper abstracts. In a content-based recommendation setting they let volunteers judge the relevance of recommendations for a test set of 30 papers. The evaluation includes a TFIDF baseline, latent Dirichlet allocation (LDA) and an approach combining LDA with their concept model. The reported MAP@5 and NDCG@5 values are best for the LDA+concept method.

In [17] Zarrinkalam et al. enrich their metadata on research papers using multiple Linked Open Data (LOD) sources to drive a hybrid recommender system. They compare a purely content-based method using only text similarity with a second method additionally utilizing collaborative filtering and a third method furthermore using the LOD enriched data. They report recall, co-cited probability and NDCG values for various cut-off values for which the LOD enriched method consistently achieves the best performance.

With SemCiR [13] Zarrinkalam et al. introduce a content-based, global citation recommendation approach that utilizes a semantic distance measure between papers. They furthermore introcude a method for extending the measure to determine the semantic distance between an input text and a paper, which is achieved by representing the input by textually similar papers. The distance measure suggested builds on six different relational features including shared authors, venue, and overlapping in- and outgoing citations. The approach is evaluated on a 12,500 paper subset of CiteSeerX [18] in a citation re-prediction setting, using as input a paper's title, abstract and contexts in other papers where it was referred to. An evaluation of different scenarios measuring recall, co-cited probability and NDCG leads the authors to conclude that recommendation results can be improved by

[1] See `http://citeulike.org/`.

using their semantic distance measure and including citation contexts in the measurement textual similarity.

2.2. Local citation recommendation

Probably one of the first investigations into local citation recommendation is the work of He et al. [19]. They propose a two-step system that first identifies recommendation candidates and then re-ranks them by concept similarity. While also discussing global citation recommendation in detail, for the local case they compare recommending for a single context and recommending for all contexts within a document simultaneously. In an evaluation on the CiteSeerX data set measured by recall, co-cited probability and NDCG they find that the single context task is harder, but also, that their approach to the all contexts task achieves results comparable to and even better than some global citation recommendation methods.

In a follow-up work Huang et al. [20] build upon above work by swapping out the computationally complex concept based re-ranking method with a translational model. In this model citation contexts are treated as the source language and cited papers as words in the target language. The resulting system, RefSeer, is evaluated on two smaller data sets (CiteULike and a CiteSeer subset) and one large one (all of CiteSeer). The authors report precision, recall, Bpref and MRR values for the two smaller data sets and conclude that their system can give correct recommendations in a realistic setting—such as when only the top 10 recommendations are shown.

Huang et al. improve RefSeer with a neural probabilistic model that learns distributed representations of words and documents in [21]. They evaluate their model for local citation recommendation on the whole of CiteSeer, splitting between train and test set at the year 2011 (9M contexts train, 1.5M contexts test). Measuring MAP, MRR and NDCG they show that their model outperforms 4 different state-of-the-art approaches. An analysis on the influence of papers' citation counts on recommendation performance shows that their approach especially exceeds other work in case of lesser cited papers (<100 citations).

In [22] Duma et al. test the effectiveness of using a variety of document internal and external text inputs to a TF-IDF model. Their data set is built from the ACL Anthology and contains 5446 citations. In a re-prediction setting the authors measure how reliably their models rank the correct paper at the top position. They conclude that a mixture of internal and external inputs outperforms either of the aforementioned used on their own.

The work presented in [23] by Duma et al. focusses on the rethorical function of sentences. The authors classify sentences using the Core Scientific Concepts (CoreSC) scheme and investigate how their distinction can be used to improve recommendation. Evaluating on one million papers from the PubMed Central Open Access Subset they measure NDCG values and find that for several classes of input sentences significant gains in recommendation quality can be made by focussing on certain rethoric passages of candidate documents when ranking text similarity.

The Neural Citation Network (NCN) proposed by Ebesu et al. in [24] is inspired by neural machine translation, learns citation context representations as well as auhtor representations and includes an attention mechanism. For their evaluation the authors use 4.5 million citation contexts from the RefSeer data set and report NDCG, MAP, MRR and recall values. They compare against a BM25 baseline, a citation translation model as well as two variations of their model that do not make use of author representations. While BM25 is outperformed by all of the other approaches to some degree the NCN's results lead the evaluation by a distinct margin.

Kobayashi et al. [25] describe a variation of local citation recommendation they call *context-based co-citation recommendation*. The input here is a citation context *plus* one publication referred to in that contexts. The goal then is to recommend other publications that also can be used as citations in that contexts. By classifying text sections into the discourse facets "objective", "method", and "result" the authors are able to train distributed vector representations per facet which are then used for the recommendation. They evaluate their approach on contexts from the ACL Anthology containing “enumerated co-citations” (e.g. *[27,42]*) and report NDCG values at a cut-off of 100. In comparison with two baseline methods their discourse facets are shown to be effective.

In [26] Jeong et al. introduce an appraoch to local citation recommendation using Graph Convolutional Networks (GCN) and Bidirectional Encoder Representations from Transformers (BERT). The GCN is used to capture information from the citation relationships between papers, while the pre-trained BERT is applied on the citation contexts themselves. The authors evaluate their approach on a subset of 6500 papers from the ACL Anthology and a self-created data set of close to 5000 papers. They report MAP, MRR and recall values at different cut-offs demostrating that their BERT+CGN approach outperforms several reduced versions of the aforementioned as well as a baseline model.

3. Background

explain all the things.

global/local citation (for local especially explain harvesting citation contexts and comparing aggregrates to input)

citation marker

four types of numbers (citing/cited documents, reference items citation context)

reference resolution

Algorithm 1

Algorithm 1 Construction of $R_{\mathrm{NP}}(c)$

```
NPs ← array()                                  ▷ empty array
w_c ← tokenize(c)                              ▷ c as an array of words
l ← len(w_c)                                   ▷ length of NP to search
while l > 0 do
    shift ← 0
    while m + shift ≤ len(w_c) do
        slice ← w_c[shift : (shift + l)]       ▷ l size slice of w_c
        if foo then
            bar
        end if
    end while
    l ← l − 1
end while
```

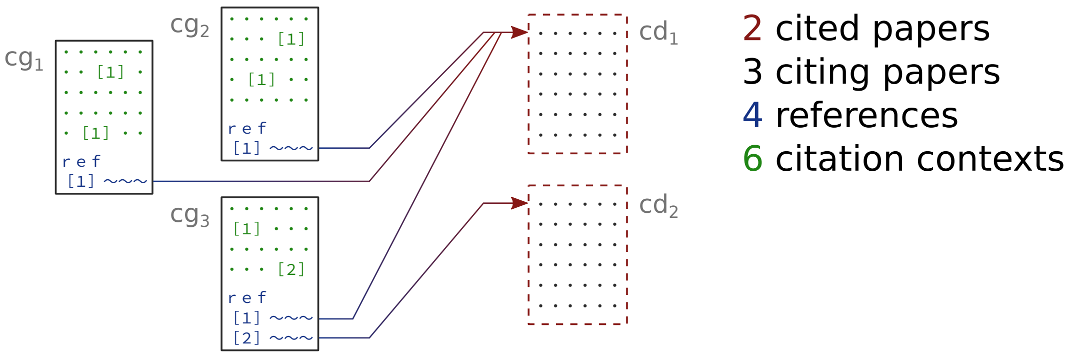

Figure 1.: Four types of numbers. A toy example with citation pairs $cg_1 \longrightarrow cd_1$, $cg_2 \longrightarrow cd_1$, $cg_3 \longrightarrow cd_1$, $cg_3 \longrightarrow cd_2$ resulting in 2 cited papers, 3 citing papers, 4 references and 6 citation contexts.

4. Data set

Recommender systems rely on data for their development, training and evaluation. It is therefore important to properly assess potential data sets in terms of their strengths and shortcomings—especially with regards to the task at hand. In citation recommendation, the goal is to identify papers relevant to a user input. Because of the large amount of available research, this means a recommender has to be able to find relevant publications in a large set of possible candidates in order to be considered fit for the task. As a comsequence, evaluation results are likely to be more meaningful when a large data set is used. Apart from the size, the quality of data is also crucial. For local citation recommendation this means that a clean citation context, precise position of citaiton markers and valid citation information are desirable. With these criteria in mind we assessed existing data sets and come to the conclusion that, for the relatively new task of local citation recommendation, the creation of a dedicated data set will bring considerable benefits.

The following sections describe the details of our assessment as well as the creation process and evaluation of our new data set.

4.1. Existing data sets

Table 1 gives an overview of relevant existing data sets. While various recommendation domains have established quasi standard data sets, this is not yet the case in citation

[1] `https://www.ncbi.nlm.nih.gov/pmc/tools/openftlist/`

Table 1.: Overview of existing data sets.
Listed are the number of papers, nature of citation contexts, covered disciplices of citing papers and the type of global reference identifiers.
(*extractable** is to indicate that extraction might be error-prone due to papers only being available as in PDF format.)

Data set	#Papers	Cit. context	Disciplines	Ref. IDs
CiteSeerX [18] / RefSeer [20]	5M	400 chars	(unrestricted)	internal
PubMed Central OAS[1]	2.3M	extractable	Biomed./Life Sci.	mixed
arXiv CS [27]	90K	1 sentence	CS	DBLP
Scholarly [28]	100K	extractable*	CS	-
ACL-AAN [29]	18K	extractable*	CS/Comp. Ling.	-
ACL-ARC [30]	11K	extractable*	CS/Comp. Ling.	-

recommendation. CiteSeerX is currently the most used in the field [2]. It is comparatively large, but many approaches only use subsets and generate them with varying filtering criteria. It includes pre-extracted citation contexts of 400 characters in length, whereby references are resolved to an internal set of identifiers. Unfortunately there are several quality issues with the data set. The main ones being inaccurate citaion information, noisy citation contexts and cut off words at the borders of citation contexts [31].

The PubMed Central Open Access Subset (PMC-OAS) is another large data set that has been used for citation based tasks [23, 32–34]. Contained publications are already processed and available in XML format. While the data set overall is comparatively clean, heterogeneous annotation of citations within the text and mixed usage of global reference identifiers (PubMed, MEDLINE, DOI, ...) make it difficult to retrieve high quality citation interlinkings of documents from the data set[2] [32].

Consistent global reference identifiers are given in the arXiv CS data set in the form of DBLP IDs. Linking to an existing repository of publication (meta) data has the advantage that

[2]To be more precise, the heterogeneity makes the usage of the data set *as is* problematic. Resolving references retrospectively would be an option but comparatively challenging in the case of PubMed because of the frequent usage of special notation in publication titles; see also: `http://www.sciplore.org/files/citrec/CITREC_Parser_Documentation.pdf`

information about cited papers in readily available. The choice of DBLP restricts resolved references to the field of computer science though. Citations to, for example, publications in maths or statistics can not be resolved to a DBLP ID. A strength of the data set is that it was generated from LaTeX source files, which makes it possible to get very clean data.

For the remainig the data sets—Scholarly, ACL-AAN and ACL-ARC—citing papers are only available in PDF format and references are not resolved. The two ACL sets have the additional drawback of being very small.

Above observations lead us to the conclusion that it would be worthwhile to tackle the creation of a data set that is large (in the order of CiteSeerX/RefSeer/PMC-OAS), clean (like the PMC-OAS and arXiv CS) and also offers consitent global reference IDs that don't restrict the data set to citations within the same discipline. The creation and evaluation of this data set is described in the following sections.

4.2. Data set creation

Scientific publications are usually distributed in formats targeted at human consumption (e.g. PDF) or, in cases like arXiv.org, also as source files *for* the aforementioned (e.g. LaTeX sources for generating PDFs). Citation-based tasks, such as local citation recommendation, in contrast, require automated processing of the publications' textual contents as well as the documents' interlinking through citations. The creation of a data set for such tasks therefore encompasses two main steps: extraction of plain text and resolution of references. In the following we will describe how we approached these two steps using arXiv publication sources and the Microsoft Academic Graph (MAG) [35].

4.2.1. Used data sets

The following two resources are the basis of the data set creation process.

arXiv.org hosts over 1.4 million submissions from August 1991 onward [36]. They are available not only as PDF, but (in most cases) also as LaTeX source files. The discipline most prominently represented is physics, followed by mathematics, with computer science seeing a continued increase in percentage of submissions ranking third (see Fig. 5). The availability of LaTeX sources makes arXiv submissions particularly well suited for extracting high quality plain text and accurate citation information. So much so, that it has been used to generate ground truths for the evaluation of PDF to text conversion tools [37]. Approaches to automatically extract citation interlinks from arXiv sources by parsing LaTeX files have existed for over 20 years [38]. Nevertheless we are not aware of any existing data sets for citation based tasks generated from the whole of arXiv.

Microsoft Academic Graph (MAG) is a very large[3], automatically generated data set on publications, related entities (authors, venues, etc.) and their interconnections through citation. While citation contexts are available to some degree, full text documents are not. The size of the MAG makes it a good target for matching reference items against it, especially given that arXiv spans several fields of study.

4.2.2. Pipeline overview

As depicted in Figure 2, we start out with arXiv sources to create the data set. From these we generate, per publication, a plain text file with the document's textual contents and a set of database entries reflecting the document's reference section. Association between reference items and citations in the text are preserved by placing citation markers in the text. In a second step, we then iterate through all reference items in the database and match them against paper metadata records in the MAG. The result of this process are MAG paper records associated with one or more reference items, that in turn are associated with citation contexts in the plain text files. In other words, we end up with cited documents

[3]At the time of writing the MAG contains data on over 200 million publications.

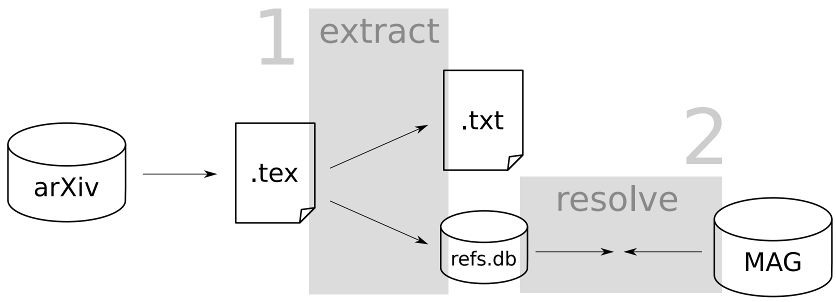

Figure 2.: Schematic representation of the data set generation process.

described by their MAG metadata and a distributed description of the document, consisting of citation contexts over many citing documents.

4.2.3. LaTeX Parsing

In the following we will describe the tools considered for parsing LaTeX, the challenges we faced in general and with regard to arXiv sources in particular, and our resulting approach.

Tools

We took several tools for the conversion from LaTeX to plain text or to intermediate formats into consideration and evaluated them. Table 2 gives an overview of our results. Half of the tools failed to produce any output for a large amount of arXiv submissions we used as test input and were therefore deemed not robust enough. *GrabCite* is able to parse 78.5% of arXiv CS submissions but integrates resolving references against DBLP into the parsing process and therefore would require significant modification to fit our system architecture. *LaTeXML* and *Tralics* are both robust and can be used as LaTeX conversion

[4]`https://github.com/tiarno/plastex`
[5]`https://github.com/alvinwan/texsoup`
[6]`https://github.com/pkubowicz/opendetex`
[7]`https://www.freebsd.org/cgi/man.cgi?query=detex`
[8]`https://github.com/brucemiller/LaTeXML`
[9]`https://www-sop.inria.fr/marelle/tralics/`

Table 2.: Comparison of tools for parsing LaTeX.

Tool	Output	Robust	Usable w/o modification
plastex[4]	DOM	no	yes
TexSoup[5]	document tree	no	yes
opendetex[6]/detex[7]	plain text	no	yes
GrabCite [27]	plain text + resolved ref.	yes	no
LaTeXML[8]	XML	yes	yes
Tralics[9]	XML	yes	yes

tools as is. On subsequent tests we note that *LaTeXML* needs on average 7.7 seconds (3.3 if formula environments are heuristically removed beforehand) to parse an arXiv submission while *Tralics* needs 0.09. Because the quality of their output seemed comparable we chose to use *Tralics*.

Challenges

Apart from the general difficulty of parsing LaTeX due to its feature richness and people's free-spirited use of it, we especially note difficulty in dealing with extra packages not included in submissions' sources[10]. While *Tralics* is supposed to for example deal with *natbib* citations[11], normalization of such citations lead to a decrease of citation markers not being able to be matched to their reference item from 30% to 5% in a sample of 565,613 citations we tested.

Resulting approach

Our LaTeX parsing solution consists of two steps. First, we flatten each arXiv submission's sources to a single LaTeX file using *latexpand*[12,13] and normalize `\cite` commands to prevent

[10]arXiv.org specifically suggest the omission of such (see `https://arxiv.org/help/submit_tex#wegotem`)

[11]See `https://www-sop.inria.fr/marelle/tralics/packages.html#natbib`

[12]See `https://ctan.org/pkg/latexpand`

[13]We also tested flatex (`https://ctan.org/pkg/flatex`) and flap (`https://github.com/fchauvel/flap`) but got the best results with `latexpand`.

parsing problems later on. In the second step, we then generate an XML representation of the LaTeX document using *Tralics*, replace formulas, figures, tables and non citation references with replacement tokens and extract the plain text. Furthermore, each reference item is assigned a unique identifier, its text is stored in a database and corresponding citation markers are placed in the plain text.

4.2.4. Reference resolution

Resolving references to globally consistent identifiers (e.g. detecting that the references (1), (2), and (3) in Listing 4.1 all reference the same document) is a challenging and still unsolved task [1]. Given it is, by itself, the most distinctive part of a publication, we base our reference resolution on the title of the cited work and use other pieces of information (e.g., authors' names) only in secondary steps. In the following we will describe the challenges we faced, matching arXiv.org submissions' reference items against MAG paper records and how we approached the task.

Listing 4.1: Examples of reference items.

```
(1) V. N. Senoguz and Q. Shafi, arXiv:hep-ph/0412102
(2) V.N. Senoguz and Q. Shafi, Phys. Rev. D 71 (2005) 043514.
(3) V. N. Şenoğuz and Q. Shafi, ‘‘Reheat temperature in supersymmetric
     hybrid inflation models,’’ Phys. Rev. D 71, 043514 (2005) [hep-ph
    /0412102].
(4) V.Sauli, JHEP 02, 001 (2003).
(5) Aaij, Roel, et al. "Search for the $B^{0}_{s} \to \eta^{\prime}\
    phi$ decay" Journal of High Energy Physics 2017.5 (2017): 158.
(6) According to the numerous discussions with my colleagues <removed>
     and <removed> an experimental verification of our theoretical
    predictions is feasible.
```

Challenges

Reference resolution can be challenging when reference items contain only minimal amounts of information, when formulas are used in titles or when they refer to non publications (e.g., Listing 4.1 (4)-(6)). A further problem we encountered was noise in the

MAG. Our mechanism matched 13,041 reference items like `K. Kondo, hep-th/0303251.` and `T. Heinzl, hep-th/9812190.` to a MAG paper with the title *"hep-th."* with one of the author's names being *"He"* (paper ID 2811252340).

Resulting approach

Our reference resolution procedure can be broken down in two steps: title identification and matching. If possible, title identification is done by arXiv ID or DOI (where we retrieve the title from an arXiv metadata dump or via crossref.org[14]); otherwise we use Neural ParsCit [39]. The identified title is matched against the normalized titles of all publications in the MAG. Resulting candidates are considered, if at least one of the author's names is present in the reference string. If multiple candidates remain, we judge by the citation count given in the MAG. The last step particularly helped mitigate rouge almost-duplicate entries in the MAG that often have few to no citations.

4.2.5. Result format

Listing 4.2 shows some example content from the data set. While the data set in and of itself consists of plain text files and a references database, citation contexts of successfully resolved references are straightforward to extract and use as input for a recommender. The bottom part of Listing 4.2 shows an example of a 3 sentence context with `cited doc MAG ID`, `MAG IDs of adjacent citations`, `citing doc arXiv ID` and `text` in a CSV format.

Listing 4.2: Excerpts from (top to bottom) a plain text file, corresponding data base entries in the references DB, entries in the MAG and extracted citation context CSV.

```
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.

[uuid]          [in_doc]    [mag_id]      [reference_string]
9ad20b7d-87d1   1412.3684   2081580037    George A. Miller (1995). WordNe
```

[14] See `https://www.crossref.org/`

```
-47f5-aeed-..                         t: A Lexical Database for Eng..
298db7f5-9ebb  1412.3684  2038721957  Christiane Fellbaum (1998), ""W
-4e98-9ecf-..                         ordNet: An Electronic Lexical..

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

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 .
```

4.3. Evaluation of reference resolution

To evaluate the quality of our reference resolution results, we take a random sample of 300 matched reference items and manually check if the correct record in the MAG was identified by our method. Given the 300 items, we obtained 3 errors, giving us an accuracy estimate of 96% at the worst, as shown in Table 3.

Table 3.: Confidence intervals for a sample size of 300 with 297 positive results as given by Wilson score interval and Jeffreys interval [40].

Confidence level	Method	Lower limit	Upper limit
0.99	Wilson	0.9613	0.9975
	Jeffreys	0.9666	0.9983
0.95	Wilson	0.9710	0.9966
	Jeffreys	0.9736	0.9972

The three incorrectly identified references were as follows (MAG IDs in square brackets):

1. *"Eddy, J.A.: 1983, The maunder minimum - a reappraisal. Solar Phys. 89, 195. ADS."*
   - matched: [2024069573]
     "The Maunder Minimum" (John A. Eddy; 1976)

- correct: [2080336740]

  "The Maunder Minimum: A reappraisal" (John A. Eddy; 1983)

2. *"J. Zhu, S. Rosset, T. Hastie, and R. Tibshirani. 1-norm support vector machines. In Advances in Neural Information Processing Systems (NIPS), volume 16, pages 49–56, 2004."*
   - matched: [2249237221]

     "Support Vector Machines" (Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani; 2013)
   - correct: [2130698119]

     "1-norm Support Vector Machines" (Ji Zhu, Saharon Rosset, Robert Tibshirani, Trevor J. Hastie; 2003)
3. *"D. T. Limmer and D. Chandler. The putative liquid-liquid transition is a liquid-solid transition in atomistic models of water. The Journal of Chemical Physics, 135(13):134503, 2011."*
   - matched: [2599889364]

     "The Putative Liquid-Liquid Transition is a Liquid-Solid Transition in Atomistic Models of Water" (David Chandler, David Limmer; 2013)
   - correct: [1977410206]

     "The putative liquid-liquid transition is a liquid-solid transition in atomistic models of water. II" (David T. Limmer, David Chandler; 2011)

In all three cases the misidentified document's title is contained in the correct document's title, and there is a large or complete author overlap between correct and actual match. This shows that authors sometimes title follow-up work very similarly, which leads to hard to distinguish cases. Another observation that can be made, is that longer titles are more distincitive. As certain publication titles might be sub-strings of of other publication's title, a matching mechanic should always try to first match a long title before trying shorter candidates. The full details of the evaluation can be found in Appendix A.

4.4. Statistics and key figures

4.4.1. Creation process

We used an arXiv source dump containing all submissions up until the end of 2017 (1,340,770 documents). 100,240 of these were only available in PDF format, leaving 1,240,530 sources. Our pipeline output 1,151,707 (92.8%) plain text files, 1,018,976 (82.1%) of which contained citation markers. The number of reference items identified is 35,053,329, for which 56,077,906 citation markers were placed within the plain text files. This first part of the process took 59 hours to run, unparallalized on a 8 core Intel Core i7-7700 3.60GHz machine with 60 GB of memory.

Of the 35,053,329 reference items, we were able to match 14,046,239 (40.07%). For 33.14% of the reference items we could neither find an arXiv ID or DOI, nor was Neural ParsCit able to identify a title. For the remaining 26.79% a title was identified but could not be matched with the MAG. Of the matched 14 million items' titles, 50.67% were identified via Neural ParsCit, 29.67% by DOI and 19.66% by arXiv ID. Of the identified DOIs 26.8% were found as is while 73.2% were heuristically determined[15]. The matching process took 103 hours, run in 10 parallel processes on a 64 core Intel Xeon Gold 6130 2.10GHz machine with 500 GB of memory.

4.4.2. Resulting data set

The resulting data set consists of *2,343,585 cited papers, 926.644 citing papers, 13,303,373 references and 24,558,560 citation contexts.* Note that references with no citation markers (due to parsing errors) are not counted here.

Figure 3 shows the number of citing documents for all cited documents. There is one document with close to 10,000 citations, another three with more than 5,000 and another

[15]This was possible because the DOIs of articles in journals of the American Physical Society follow predictable patterns.

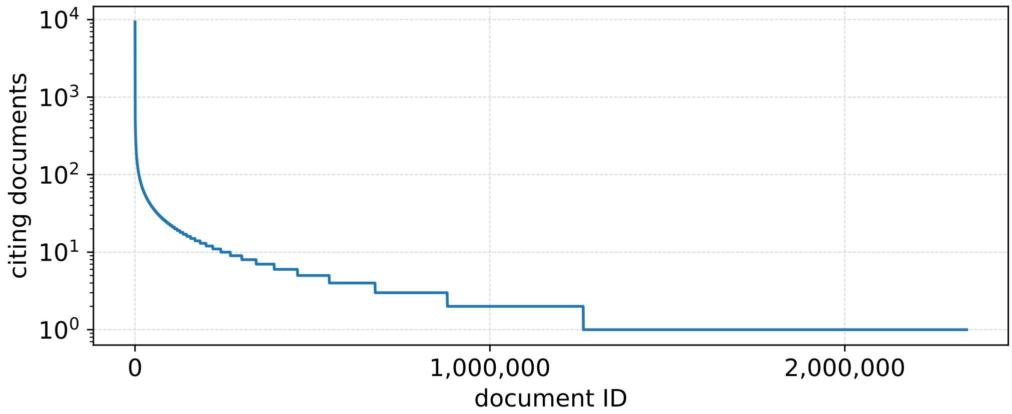

Figure 3.: Number of citing documents per cited document.

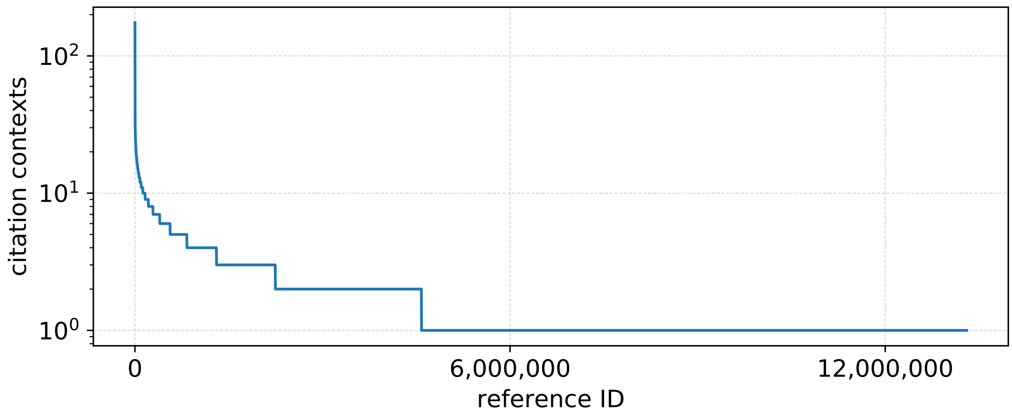

Figure 4.: Number of citation contexts per reference.

ten with more than 3,000. 1,262,861 (53.89%) of the documents have at least two citations, 547,036 (23.34%) have at least five. The mean number of citations is 5.68 (SD 26.82). Figure 4 shows the number of citation context per reference. 8,722,795 (65.57%) references have only one citation context, the maximum is 278, the mean 1.85 (SD 2.02). This means a cited document is described by on average $1.85 \times 5.68 \approx 10.5$ citation contexts.

Figure 5 depicts the flow of citations by field of study for all 13.3 million matched reference items. Fields of study with very small numbers of references are combined to *other* for legibility reasons. For the citing document's side, these are economics, electrical engineering

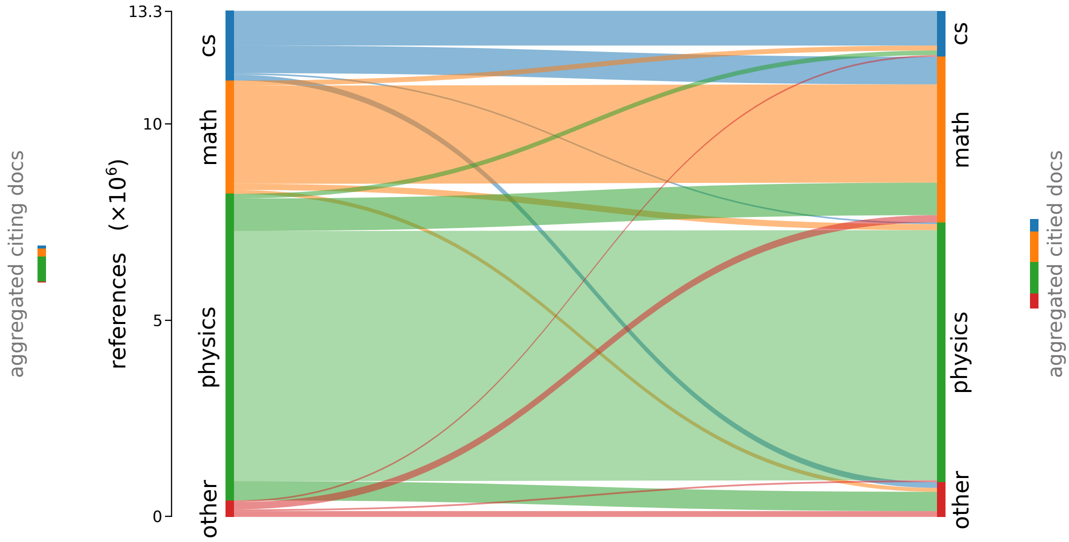

Figure 5.: Citation flow by field of study for 13.3 million reference items. For reference, the number of citing and cited documents per field of study are plotted on the sides.

and systems science, quantitative biology, quantitative finance and statistics. Combined on the cited document's side are chemistry, biology, engineering, materials science, economics, geology, psychology, medicine, business, geography, sociology, political science, philosophy, environmental science and art. To no surprise, publications in each field are cited the most from within the field itself. Notable is, however, that the incoming citations in mathematics are the most varied (physics and computer science combined make up 38% of the citations).

By generating our data set from LaTeX sources we were able to ensure clean text output as well as accurate citation information and exact citation marker positions. In terms of size it is closer to CiteSeerX and PMC-OAS than the smaller data sets available. The fact that the data set spans multiple disciplines also allows for comparisons in citing behaviour between these disciplices. Because references are already resolved to MAG IDs, the data set is readily usable for recommendation tasks and allows for the use of rich metadata on both the citing and cited document side. Lastly, the embedding of citation markers in the full plain text of papers instead of pre-extraction enables users of the data set to choose and compare citation context lenghts and variations at will.

5. Approach

In order to investigate the use of explicit semantic representations for the task of local citation recommendation we first need to decide which kinds of semantic constructs we want to model. As a starting point for this we looked into the field of citation context analysis [41]. A common task in this area is the classification of citation contexts by their polarity (positive/neutral/negative) and function (often based on the four dimensions identified by Moravcsik et al. [12], conceptual/operational, evolutionary/juxtapositional, organic/perfunctory, conformative/negational). Such approaches are primarily concerned with the *intent* of the author rather than the *content* of what is being cited. We can therefore not expect to derive types of semantic constructs directly from citation functions. Starting from an established typology of citation functions will, however, ensure that we consider a wide range of different citations rather than cherry picking those that fit our preconceptions.

Table 4 lists categories of citation functions along with the kinds of semantic constructs that can be found in such citation contexts. The list of citation functions is taken from [45] (and therein built upon [44]). This study was selected because it gives an overview of previous attempts to classify citations, presents their new typology with extensive explanation as well as example contexts, and does not mix polarity into its function categories. Examining contexts from each of the eight functions we identify two types of semantic constructs: named entities (NE) and claims (or statements). The rationale behind these two is as follows. Named entities can identify reference publications for a certain data set/tool/concept (see *Attribution*, *Statement of use* and *Application* in Table 4) as well as a method/field of study

Table 4.: Semantic constructs in citation contexts from a range of citation functions used in the field of citation context analysis.

Function	Construct	Examples (semantic construct *highlighted*)
Attribution	claim	"Berners-Lee et al. [11] argue that *structured collections of information and sets of inference rules are prerequesites for the semantic web to function*."
	NE	"A variation of this task is '*context-based co-citation recommendation*' [25]."
	-	"In [22] Duma et al. test the effectiveness of using a variety of document internal and external text inputs to a TF-IDF model."
Exemplification	NE	"We looked into approaches to *local citation recommendation* such as [19–26] for our investigation."
Further reference	-	"See [42] for a comprehensive overview."
Statement of use	NE	"We use *CiteSeerX* [18] for our evaluation."
Application	NE	"Using this mechanism we perform '*context-based co-citation recommendation*' [25]."
Evaluation	-	"The use of DBLP in [27] 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 *finding proper citations is a time consuming task* [10, 19, 24, 25]."
	-	"Lamers et al. [43] base their definition on the author's name whereas Thompson [44] focusses on the grammatical role of the citation marker."
Comparison of own work with sources	claim	"Like [27] we find that, albeit written in a structured language, *parsing LaTeX sources is a non trivial task*."

common to a selection of publications (see *Exemplification* in Table 4). Claims can identify publications that can be cited to back or support the very claim contained in a citation context. Note that the example contexts listed to have no construct ("-" in the *Construct* column) may contain named entities and claims as well (e.g. "DBLP" or "Lamers et al. base their definition of the author's name"), but these are (in the case of NEs) not representative of the cited work or (in the case of claims) just statements *about* a publication rather than statements being backed by the cited work. A third semantic construct that can be considered, but would require considering a larger citation context, is argumentative structures. To keep the scope of this thesis at a reasonable level we will, however, limit our investigation to named entities and claims.

The following sections will describe our investigation of entity based and claim based models for local citation recommendation.

5.1. Entity based recommendation

The intuition behind an entity based approach is, that there exists a reference publication for a named entity. Examples would be a data set ("CiteSeerX [18]"), a tool ("Neural ParsCit [39]") or a concept ("Semantic Web [11]"). In a more loose sense this can also include publications being referred to as examples ("approaches to local citation recommendation [19–26]"). For the identification of such named entities we take two approaches. A more strict one based on the fields of study given in the MAG, and a more loose one based on noun phrases.

5.1.1. Fields of study in the MAG

Along with papers, authors, venues etc. the MAG data schema also includes fields of study (FoS) that are associated with papers and interlinked in a child-parent manner. At the time of writing there are 229,716 FoS at 6 levels of granularity. They range from the most coarse level 0 (example entries being *mathematics*, *sociology*, *computer science*) to more and more fine grained entities (*information retrieval*$_{(1)}$→*search engine*$_{(2)}$→*web search query*$_{(3)}$→*ranking (information retrieval)*$_{(4)}$→*Okapi BM25*$_{(5)}$). The levels of granularity don't seem to follow a globally consistent pattern though. *WordNet*, for example, being a particular piece of data in the same way *Okapi BM25* is a particular function, is not at level 5 but level 2 (*computer science*$_{(0)}$→*artificial intelligence*$_{(1)}$→*WordNet*$_{(2)}$). Another noteworthy aspect is that a FoS can have multiple parents (*search engine* for example has a second parent in *World Wide Web*).

Model The entity based representation of a citation context is the set of FoS that appear within the context. Formally, let $\mathcal{F}$ denote the set of FoS; then the entity based representation of a citation context c is the set of terms t defined as $R_{\text{FoS}}(c) = \{t | t \text{ appears in } c \wedge t \in \mathcal{F}\}$. Because of the hierarchical structure of FoS we experiment with augmenting the set by including the set members' parents into the representation. We find that his leads to worse results, presumably because a context's description becomes more vague which is detrimental to identifying reference publications or exemplifications. We furthermore look into only using a FoS when it directly precedes the citation marker—as it might be more relevant to the citation then—, but notice that such cases are too rare. In a preliminary test with 900k citation contexts, only 0.14% of our 180k test set items have a FoS in the required position matching any of the representations learned from the training set.

Recommendation For recommending documents based on R_{FoS} we use the Jaccard similarity between the input citation context and the aggregrated citation contexts describing each candidate document. Formally, let c_i denote the input citation context and $\mathcal{D}$ be a set of documents with members $d \in \mathcal{D}$. Furthermore let $\varrho(d)$ be the set of citation contexts referencing d; $\varrho(d) = \{c | c \text{ references } d\}$. The Jaccard similarity then is defined as $J(A, B) = \frac{|A \cap B|}{|A \cup B|}$, where $A = R_{\text{FoS}}(c_i)$ and $B = \bigcup_{c \in \varrho(d)} R_{\text{FoS}}(c)$.

5.1.2. Noun phrases

For our second entity based model we take a more loose approach and treat noun phrases extracted from the arXiv data set as named entities. By filtering out items that appear only once we end up with 2,835,929 noun phrases (NPs).

Model Similar to the FoS representation, we look at the NPs appearing within a citation context. To ensure a high descriptiveness, we only take into account maximally long matches. A context *"This has been done for language model training [27]"*, for example, would have "language model training" in its representation, but not "language model". Formally we can define $R_{\text{NP}}(c) = \{t|t \text{ appears in } c \wedge t \in \mathcal{P} \wedge t^{+pre} \notin \mathcal{P} \wedge t^{+suc} \notin \mathcal{P}\}$ where $\mathcal{P}$ is our set of NPs while t^{+pre} and t^{+suc} denote an extension of t using its preceding or succeeding word respectively. As an alternative representation we furthermore define $R^{2+}_{\text{NPmrk}}(c)$ as a subset of $R_{\text{NP}}(c)$ containing, if present, the NP of minimum word length 2 directly preceding the citation marker in c that a prediction is to be made for. Formally, $R^{2+}_{\text{NPmrk}}(c) = \{t|t \in R_{\text{NP}}(c) \wedge len(t) \geq 2 \wedge t \text{ directly precedes } m\}$ where m is the citation marker in c that a prediction is to be made for.

Recommendation Recommending documents based on R_{NP} and R^{2+}_{NPmrk} is done using a vector space model (VSM) in which NP representations, treated as a bag of word (BoW), are compared by their cosine similarities. Representations of candidate documents are, likewise to the FoS based model, aggregrates over all contexts referencing the document. Formally, the vector representation of a context is given by $V(R(c)) = (t_{1,j}, t_{2,j}, ..., t_{|\mathcal{P}|,j})$ where $\mathcal{P}$ is the set of all NPs and $t_{i,j}$ is a non-negative integer representing a quantity with regards to the ith term in $\mathcal{P}$. Aggregated context representations for candidate documents are caluclated by adding up all vector representations of the contexts referring to a document. I.e., let $\varrho(d)$ be the set of citation contexts referencing d, then d's vector representation is $\sum_{c \in \varrho(d)} V(R(c))$. The similarity between an input context c_i and a candidate document $d \in \mathcal{D}$ can then be calculated as the cosine θ between the two vector representations $\cos(\theta) = \frac{A \cdot B}{\|A\|\|B\|}$ where $A = V(R(c_i))$ and $B = \sum_{c \in \varrho(d)} V(R(c))$

5.2. Claim based recommendation

For the introduction of a claim based model we first need to make a few observations on how citations interact with the text they're placed in. By convention, citations are constructed by placing a type of marker, which identifies an entry in the document's reference section, in the text. These markers can, depending on discipline, journal, etc. take different forms. Some examples are numbers in square brackets ("In [27] ..."), alphanumeric identifiers in square brackets ("In [Bol98] ..."), a year in parentheses succeeding an author's name ("Swales (1990) has argued ...") and an author's name with a year in parentheses ("It has been argued (Swaled, 1990) ..."). Named entities can stand in a grammatical relation to such a marker. In "By using CiteSeer, [Bol98], we ...", for example, the named entitiy *CiteSeer* and the citation marker *[Bol98]* are in a grammatical relation called *apposition*. A citation marker can, however, reasonably assumend to never be *part of* the named entity. This is different in the case of the statements within a citaiton context. Looking at the sentence "In [9] Bollacker et al. introduce Citeseer." we can see that the marker itself is part of what is being said, while this is not the case in for example "Bollacker et al. introduced Citeseer in 1998 [9].". This distiction will briefly be explained in the following section.

5.2.1. Integral and non-integral citations

The term "integral"—in the adjectival sense close in meaning to "essential" or "inherent", not what we denote in caluclus with $\int$—is used to describe citation markers that are part of a sentence. There seems to be no consensus on the exact definition of *"part of"* though. While some [] others []

how citations are embedded in sentences (integral/non-integral [43, 44, 46–48])

Table 5.: Differences in definition of integral and non-integral citations. i=integral, n=non integral.

Citation type	Swales [46]	Hyland [47]	Thompson [44]	Okamura [48]	Whidby et al. [49]	Abujbara et al. [50]	Lamers et al. [43]
“Swales has argued that ... [42].”	x	x	?	x	x	x	x
“Swales (1990) has argued that ...”	x	x	i	x	x	x	x
“It has been argued (Swales 1990) that ...”	x	x	n	x	x	x	x
“[42] argues that ...”	x	x	i	x	x	x	x
“foo [42]”	x	x	x	x	x	x	x

actually look into automatic classification [49, 50]

5.2.2. Tools for extracting claims

tools tools

also: Survey on open information extraction [42]

context specific claim detection [51]

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

5.2.3. A predicate-argument model

predpatt [52, 53]

unfeasibility of use of PredPatt output as is

loosened predicate:parameter model

predicates could be grouped/clustered to represent functions as in [54]

alternative view: model gives a selective citation context derived from claim structure (cf. concept of reference scope as sub part of citation context sentence [50, 55]

6. Evaluation

evaluate evaluate

implemetation pain and bad evaluation scores [56]

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 [57, 58]

relevance of time [59]

candidates are only citations within current paper [22]

6.2. Offline evaluation

pre-filtering experiments (knn [34], lsi, lda, fos, ...)

different evaluation settings (all, CSonly, comparison to MAG, ACL (data from [60])...)

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

PP model alone, combined, ...

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

also mention [25] here b/c they specifically target cases where more than one citation is applicable (could be interpreted as either *multiple (simultaneously)* for one context or *several options that are all valid by themselves but in the end a single one is to be chosen* for one contexts)

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 [61])

Argumentative structures. (Argumentation mining [62–64])

also data set is already extended with 2018 data

for data where no precise citation marker can be guaraneed (and so far NPmarker was not tested) look into heuristically identifying marker position

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Appendices

A. Evaluation of reference resolution

The sample of 300 matched reference items was acquired from the reference data base as shown in Listing A.1. The table `bibitem` holds most of the information on reference items. The table `bibitemmagidmap` contains per row the UUID of a reference item and the MAG ID it was matched to.

Listing A.1: SQL query used to acquire the sample

```
select b.bibitem_string, m.mag_id
    from bibitem as b
        join
         (select *
            from bibitemmagidmap
                order by random()
                limit 300
         ) as m
        on b.uuid = m.uuid;
```

Table 6 shows the full evaluation. Wrongly matched items are highlited in red. Note that there are seven cases where the reference item refers to more than one publication. In such cases our method only captures the first one and is cosequetually evaluated on the first one. Note further that in one case a reference item named a PhD thesis while the match was for the very same thesis published two years later. This was deemed a correct match. Lastly, there was one case where a book was cited with the date indicating its second edition while the matched record in the MAG has a date indiciating the books thrid edition. This also was deemed a correct match.

Table 6.: Evaluation

Reference item	MAG ID	
V. N. Senoguz and Q. Shafi, “Reheat temperature in supersymmetric hybrid inflation models,” Phys. Rev. D 71, 043514 (2005) [hep-ph/0412102].	2075392245	✓
Keiding, N. and Nielsen, J.E. (1975) Branching processes with varying and random geometric offspring distributions. J. Appl. Prob. 12, 135–141.	2332540167	✓
H. Izeki and S. Nayatani, Combinatorial harmonic maps and discrete-group actions on Hadamard spaces, Geom. Dedicata 114 (2005), 147–188.	2017711173	✓
T. Adamo, M. Bullimore, L. Mason and D. Skinner, “Scattering Amplitudes and Wilson Loops in Twistor Space,” J. Phys. A 44 (2011) 454008 [arXiv:1104.2890 [hep-th]].	2002091616	✓
Eren Mehmet Kıral and Matthew Young, The fifth moment of modular FORMULA -functions, arXiv preprint arXiv:1701.07507 (2017).	2582886839	✓
T. Baumgarte and S. Shapiro, Numerical Relativity: Solving Einstein’s Equations on the Computer. Cambridge University Press, 2010. http://books.google.co.uk/books?id=dxU1OEinvRUC.	2566410267	✓
R.E. Renfordt, D. Schall, R. Bock, R. Brockmann, J.W. Harris, A. Sandoval, R. Stock, H. Ströbele, D. Bangert, W. Rauch, G. Odyniec, H.G. Pugh, and L.S. Schroeder, Phys. Rev. Lett. 53 (1984) 763.	2001418221	✓
T. A. Porter, I. V. Moskalenko, A. W. Strong, E. Orlando and L. Bouchet, arXiv:0804.1774 [astro-ph].	2129746122	✓
Jon Kleinberg, Sendhil Mullainathan, and Manish Raghavan. Inherent trade-offs in the fair determination of risk scores. arXiv preprint arXiv:1609.05807, 2016.	2522104760	✓
R.M. Fernandes, L. H. VanBebber, S. Bhattacharya, P. Chandra, V. Keppens, D. Mandrus, M.A. McGuire, B.C. Sales, A.S. Sefat, and J. Schmalian, Phys. Rev. Lett. 105, 157003 (2010)	2143202785	✓
Fomin, S., Wei, P., Chugunov, V., 1995. Contact melting by a non-isothermal heating surface of arbitrary shape. Int. J. Heat Mass Transfer 38 (17), 3275–3284.	2030656707	✓
R.F. Lebed, arXiv:1507.05867v1 [hep-ph].	1844403609	✓
R. Billinton, R. Karki, Y. Gao, D. Huang, P. Hu, and W. Wangdee, “Adequacy Assessment Considerations in Wind Integrated Power Systems,” IEEE Trans. Power Syst., vol. 27, no. 4, pp. 2297–2305, 2012.	2024825567	✓
C. Morningstar and M. Peardon, Phys. Rev. D 56, 4043 (1997).	2109255696	✓
I. B. S. Passi, M. Singh and M. K. Yadav, Automorphisms of abelian group extensions, J. Algebra 324 (2010), 820–830.	2051680489	✓
S. Dimopoulos, P. W. Graham, J. M. Hogan, M. A. Kasevich, and S. Rajendran, Phys. Rev. D 78, 122002 (2008).	2749889157	✓
P.Jaworski, Value at Risk in the presence of the power laws, Acta Physica Polonica B 36 (2005) 2575-2587.	2566822874	✓
L. L. Chau, M. L. Ge and Y. S. Wu, Phys. Rev. D 25, 1086 (1982); L. L. Chau and Wu Yong-Shi, Phys. Rev. D 26, 3581 (1982); L. L. Chau, M. L. Ge, A. Sinha and Y. S. Wu, Phys. Lett. B 121, 391 (1983).	2075757391	✓
E. C. Blomberg, M. a. Tanatar, R. M. Fernandes, I. I. Mazin, B. Shen, H.-H. Wen, M. D. Johannes, J. Schmalian, and R. Prozorov, Nat. Commun. 4, 1914 (2013).	2081425933	✓
A. Arenas, A. Díaz-Guilera, C. J. Pérez-Vicente, Synchronization reveals topological scales in complex networks, Phys. Rev. Lett. 96 (11) (2006) 114102.	2100240966	✓
M. Alizadeh, A. Greenberg, D. A. Maltz, J. Padhye, P. Patel, B. Prabhakar, S. Sengupta, and M. Sridharan. Data Center TCP (DCTCP). ACM SIGCOMM, 2010.	2164740236	✓
M. Nishiyama, T. Okabe, Y. Sato, and I. Sato. Sensation-based photo cropping. In ACM Multimedia, pages 669–672, 2009.	2013339738	✓
L. Landau and E. Lifchitz, Classical theory of fields, Butterworth-Heinemann, Oxford, 1994, p. 87.	119088996	✓
Peregrine, D., 2003. Water-wave impact on walls. Annu. Rev. Fluid Mech. 35, 23–43.	2118259172	✓
M. S. Khalil, S. Gladchenko, M. J. A. Stoutimore, F. C. Wellstood, A. L. Burin, and K. D. Osborn, Phys. Rev. B 90, 100201 (2014).	1998393159	✓
F. Gabbiani, E. Gabrielli, A. Masiero and L. Silvestrini, Nucl. Phys. B 477, 321 (1996) [arXiv:hep-ph/9604387].	2133327165	✓
Abramowitz, M. and Stegun, I. A., Handbook of Mathematical Functions, (Dover, New York, 1965).	2120062331	✓
N. V. Chawla, K. W. Bowyer, L. O. Hall, and W. P. Kegelmeyer. Smote: synthetic minority over-sampling technique. Journal of artificial intelligence research, 16(1):321–357, 2002.	2148143831	✓
B. H. Lee, W. Lee, R. MacKenzie, M. B. Paranjape, U. A. Yajnik and D. h. Yeom, Phys. Rev. D 88, 085031 (2013).	2074315988	✓
D. Nishiguchi, K. H. Nagai, H. Chaté, and M. Sano, Long-range nematic order and anomalous fluctuations in suspensions of swimming filamentous bacteria. arXiv preprint arXiv:1604.04247 (2016).	2336881770	✓
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M. L. Skoge & T. W. Baumgarte, Phys. Rev. D 66 107501 (2002).	2016175541	✓
A. Lozano, A. M. Tulino, and S. Verdú, "Optimum power allocation for parallel Gaussian channels with arbitrary input distributions," IEEE Trans. Inf. Theory, vol. 52, no. 7, pp. 3033–3051, Jul. 2006.	2097695636	✓
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Movassaghi, Samaneh and Abolhasan, Mehran and Smith, David, Smart spectrum allocation for interference mitigation in Wireless Body Area Networks, IEEE International Conference on Communications (ICC), pages 5688-5693, 2014	2083602816	✓
M. Apollonio et al. [CHOOZ Collaboration], Phys. Lett. B 466, 415 (1999) [arXiv:hep-ex/9907037].	1571701324	✓
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Kováčik R. and Ederer C., Phys. Rev. B 80 (2009) 140411; Kim M. et al., Phys. Rev. B 81 (2010) 100409.	1758648405	✓
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Arata, I., Y. Ohno, F. Matsukura, and H. Ohno, 2001, "Temperature dependence of electroluminescence and I-V characteristics of ferromagnetic/non-magnetic semiconductor pn junctions," Physica E 10, 288–291.	1987870048	✓
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R. Killip, S. Kwon, S. Shao, and M. Visan. On the mass-critical generalized KdV equation. Discrete Contin. Dyn. Syst., 32(1):191–221, 2012.	1975802612	✓
Danilo Jimenez Rezende and Shakir Mohamed. Variational inference with normalizing flows. arXiv preprint arXiv:1505.05770, 2015.	299440670	✓
D. Rossi and G. Rossini, "On sizing CCN content stores by exploiting topological information," in Proc. IEEE NOMEN, 2012.	1985355206	✓
F. Bezrukov, A. Magnin, M. Shaposhnikov and S. Sibiryakov, JHEP 1101 (2011) 016 [arXiv:1008.5157].	2064410211	✓
M. Horodecki, P. Horodecki, and R. Horodecki. Separability of mixed quantum states: linear contractions approach. preprint archiv quant-ph/0206008.	1668368460	✓
S. White, Phys. Rev. B 48, 10345 (1993).	2016407890	✓
A. Brandt et al., [UA8 Collaboration], Evidence for a Super-Hard Pomeron Structure, submitted to Phys. Lett. 1992.	1983143801	✓
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S. Ryu, J. E. Moore, and A. W. W. Ludwig, Phys. Rev. B 85, 045104 (2012), arXiv:1010.0936.	2083123179	✓
P. Balaz, V. K. Dugaev, and J. Barnaś Phys. Rev. B 85, 024416 (2012)	2322343165	✓
T. Giamarchi and A. Tsvelik, Phys. Rev. B 59, 11398 (1999).	2069018114	✓
M. Molloy and B. Reed. The size of the giant component of a random graph with a given degree sequence. Combin. Probab. Comput., 7(3):295–305, (1998).	2129918926	✓
D. W. Sivers, Phys. Rev. D 41, 83 (1990); Phys. Rev. D 43, 261 (1991).	2174029682	✓
J. Boronat and J. Casulleras, Phys. Rev. B 49, 8920 (1994).	1982967539	✓
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