On Measuring the Contextual Relevance of Research Paper Recommendation Systems

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ABSTRACT

The contextual information present in scholarly papers plays a vital role in the implementation of research paper recommendation systems. However, the most critical concern is how to measure the contextual relevance of scholarly papers for better recommendations? In this paper, we present the most common approaches used to measure the contextual relevance of research paper recommendation systems. Based on the research outcome, content-link, citation relation, social network analyses, and their combinations are the most widely used. The paper also outlined the strengths and weaknesses of each approach.

Keywords: Content-link analysis, citation relation analysis, social network analysis, contextual relevance, recommendation systems.

I INTRODUCTION

Scholarly papers contained some essential information such as metadata, citations, algorithms, figures, and tables which are vital for the implementation of efficient management of scholarly documents (Xia, Wang, Bekele, & Liu, 2017). This useful information is utilised by the research paper recommendation systems to identify and recommend relevant papers to researchers concerning their demands (Liang, Li, & Qian, 2011).

Research paper recommendation is a proactive system that personalises scholarly documents to individual researchers by offering the relevant publications in the best way possible (Haruna & Ismail, 2016, 2017a, 2017b).

The systems leverage the value of recommendations by exploiting the contextual information that affects researchers' preferences and situations, with the aim of recommending scholarly documents that are relevant to their changing needs (Champiri, Shahamiri, & Salim, 2015; Haruna, Ismail, Suhendroyono, et al., 2017). This is achieved by accurately identifying the most relevant papers that best suits the researcher's situation (Haruna, Ismail, Damiasih, Sutopo, & Herawan, 2017).

The most common examples of such systems are the TechLens (Torres, McNee, Abel, Konstan, & Riedl, 2004), CiteSeer (Bollacker, Lawrence, & Giles, 1998), Claper (Gipp, Beel, & Hentschel, 2009), and Docear's research paper recommendation systems (Beel, Langer, Genzmehr, & Nürnberger, 2013), among others.

However, the most critical concern is that how best to measure the contextual relevance of scholarly papers for better recommendations? This is critical because the success of any research paper recommendation framework depends on how well its logical computations are performed. However, research paper recommendation developers compute the similarities between target papers in regards to other candidate recommending papers based on the papers' contextual relevancies for making recommendations.

In this paper, we have identified the different ways researchers employed in measuring the relevancies between research papers.

The remaining sections of this paper are organised as follows. Section II presents the different approaches utilised in measuring the contextual relevance of research paper recommendation systems. Outlines of strengths and weaknesses of content-link, citation relation, and social network analyses are presented in section III. A brief conclusion is then presented in section IV.

II MEASURING CONTEXTUAL RELEVANCE OF RESEARCH PAPERS

The contextual information present in scholarly papers plays a vital role in the implementation of research paper recommendation systems.

Based on the literature, how researchers measure the contextual relevance in research paper recommendation systems can be categorised into the content-link analysis, citation relation analysis and social network analysis. A more detailed explanation of each category is presented below.

A. Content-Link Analysis

The content-link analysis is an exciting research area that aimed at solving the problem of information overload using the techniques of machine learning, data mining, text categorisation, information extraction, visualisation and knowledge

discovery (Sriram & Mining, 2006). It is a process by which network of interconnected objects are build up with several relationships to uncover trends and patterns (Feldman, 2002).

Extracting, discovering, and linking together sparse evidence from the vast amount of data sources are the primary goals of content-link analysis, to learn patterns that can guide the extraction, discovery, and linkage of entities (Sriram & Mining, 2006). It involves the preprocessing of document corpus (text categorisation, term extraction, and information extraction), integration with structured information sources, the storage of the immediate representations, the techniques to analyse these intermediate representations (distribution analysis, clustering, trend analysis, and association rules) and visualisation of the results.

Content-link analysis plays a vital role in the hypertext domains; an outstanding example is Google that employs the link-based concept of page authority to rank search results (Popescul & Ungar, 2003). Other most popular applications include the Google's PageRank (Page, Brin, Motwani, & Winograd, 1999), and Hypertext Induced Topic Selection or commonly known as Hubs and Authorities (HITS) algorithms (Kleinberg, 1999).

Content-link information has been proven to be very useful for machine learning and data mining such as in recommender systems (Ma, Lyu, & King, 2009; Massa & Avesani, 2007), feature selection (Tang & Liu, 2012a, 2012b), and document classification/clustering (Angelova & Siersdorfer, 2006; Neville, Adler, & Jensen, 2003).

Wang, Tang, Aggarwal, and Liu (2016) provide a principled way by which link and label information can be captured mathematically. The approach combines link and label information with content information to discover words and document embedding for classification.

B. **Citation Relation Analysis**

As defined by Smith (1981), a citation is "the acknowledgement that one document receives from another" and citation context is the piece of text that the citation is placed inside. In other words, a citation context is an explicit description of the cited work from the point-of-view of the citing author (Small, 1982). Citations play significant roles in revealing the impact of scientific works, and to understand scientific knowledge diffusion, and for identifying the emerging research topics (Kuhn, Perc, & Helbing, 2014). It is also a key input in building co-citation networks, and in studying the intellectual structure of a given domain (Zhao & Strotmann, 2014).

A citation analysis concerns with the analysis of relations between a citing document and the document it cites (Zarrinkalam & Kahani, 2013). Citation recommendation is becoming an exciting research area that aims at solving the problem of information overload in academia by suggesting relevant citations to a research paper (Liu et al., 2015).

Wu, Hua, Li, and Pei (2012) proposed a model which treat citation recommendation as a special retrieval task to address the challenge of meeting the information need of researchers by automatically suggesting citations from the pool of citations available over the digital libraries. The users provide the target papers of their interest with some metadata, and the system automatically retrieves relevant candidate citation papers.

Similarly, a research paper recommendation algorithm has been proposed in (Gori & Pucci, 2006), based on the citation graph and random-walker properties. The approach assigns preference scores to the set of documents contained in a digital library and linked each other using bibliographical references. Also, some previous work has tackled the task of mining semantics in citation relations, such as classifying citation relations (Nanba & Okumura, 1999), influence and importance among different citations (Huang & Qiu, 2010).

There are several concepts in the citation analysis, which include the following:

(a) Bibliographic Coupling

Two documents are said to be bibliographically coupled if both have at least a reference in common (Kessler, 1963). This approach is considered to be the first citation-based technique for a paper recommendation (Pan, Dai, Huang, & Chen, 2015), in which citations are analysed to establish the similarities between papers. The strengths of two bibliographically coupled papers are higher if both refer to more common papers, and the larger the value of co-coupling strength between them, the larger the probability of them shared a common topic.

Bibliographic coupling network has been widely used to identify research specialities, examine interdisciplinarity, and map the backbone of science (Yan & Ding, 2012). One essential property of bibliographical coupling networks is that there is no delay in the calculation of the links between articles because all data needed are present in publications (Xia et al., 2017). However, the primary drawback of this approach is that it is static, which means it never changes over time as scientific papers never change their sets of references after publication.

Therefore it cannot reflect the dynamic changes of the community (Steinert & Hoppe, 2016).

(b) Co-citation Analysis

Two documents are said to be co-cited if there is a third document that cites both of them (Small, 1973). It is a popular similarity measure that is used to establish a subject similarity between two publications (Wu et al., 2012). Similar to co-coupling, co-citation is also a paper recommendation approach that makes use of the citation information (Pan et al., 2015). The underlying assumption of this approach is that two papers are highly relevant if are both cited by many other papers.

Co-citation analysis has been further categorised into two methods namely author co-citation analysis and document co-citation analysis (Chen, Ibekwe-SanJuan, & Hou, 2010). The primary goal of co-citation network analysis is to identify the intellectual structure of a given domain (Zhao & Strotmann, 2014) as well as to reveal scientific topics (Kuhn et al., 2014).

(c) Direct Citation Analysis

The direct citation also called inter-citation is said to exist between two documents if one references another (Boyack & Klavans, 2010). In a direct citation network, the network nodes are papers and a directed edge runs from paper A to paper B if A cites B in its bibliography (Bornmann & Leydesdorff, 2015).

Different from the co-citation and co-coupling analyses, direct citation analysis although employed from time to time (Shibata, Kajikawa, Takeda, & Matsushima, 2008), has not been widely used because of the need to use very long time windows to obtain a sufficient linking signal for clustering (Boyack & Klavans, 2010). However, one advantage of direct citation is that documents are clustered more evenly across time windows, and the clustering tends to be more substantial than either co-citation or bibliographic coupling processes.

Shibata, Kajikawa, Takeda, & Matsushima (Shibata, Kajikawa, Takeda, & Matsushima, 2009) discovered that direct citation performs better than co-citation in detecting research themes. Also, papers connected by direct citations had the most active clustering tendency than those connected by co-citation or shared references. However, assuming that a direct citation is a good enough measure of similarity is perhaps too simplistic.

C. **Social Network Analysis**

The increasing number of social networking sites and research communities have brought new opportunities for paper recommendations. The advantage of social networking sites indicates that it can provide values to several types of users in various ways (Van Noorden, 2014). It can also serve as an avenue for scientific collaborations, promoting institution impact in education and research, and enabling scholars to share their research works and expertise (Xia et al., 2017).

The primary task of social network analysis is to mine the significance of relationships between interacting units (Sriram & Mining, 2006). The perspective of social network analysis includes theories, models, and applications conveyed in relational concepts. The unit of analysis is not based on the individuals, instead, the entity consisting the whole collection of individuals and the linkages between them. Network focusing on two actors and their ties is called *dyads*, and *triads* for three actors and their ties. Others comprise more extensive systems, subgroups of the individual, or entire networks.

Researchers discovered that users in online social networks tend to form knit groups (Girvan & Newman, 2002), with vigorously large connected components (Kumar, Novak, & Tomkins, 2010). Several works consider the use of social group formation and community membership in recommender systems (Asabere, Xia, Meng, Li, & Liu, 2015; Backstrom, Huttenlocher, Kleinberg, & Lan, 2006; Chua, Lauw, & Lim, 2011; Konstas, Stathopoulos, & Jose, 2009; Liu et al., 2017; Ma, King, & Lyu, 2009; Ma, Zhou, Liu, Lyu, & King, 2011; Xia, Liu, Lee, & Cao, 2016). These researchers utilized the influence of social properties to suggest relevant information to individual or group of users based on social ties, which can either be strong or weak depending on the tie strength that represents the closeness and interaction frequency between the information source and recipient (Granovetter, 1973; Song, Yi, & Huang, 2017).

Recommendations from strong ties are believed to be more persuasive than those from weak ties (Aral & Walker, 2014; Krackhardt, Nohria, & Eccles, 2003; Steffes & Burgee, 2009) because information transferred by strong ties is likely to be perceived as more relevant and reliable. To be specific, the authors of (Asabere et al., 2015; Xia, Asabere, Liu, Deonauth, & Li, 2014) proposed a novel algorithm called socially aware recommendation of scholarly papers (SARSP) that utilises the aspect of social learning and networking for conference participants through the construction of relations in folksonomies and social ties. The algorithm recommends research papers issued by an active participant to other conference participants based on the computation of their social ties. This approach

has been extended in (Asabere, Acakpovi, & Michael, 2017), to include personality behaviour in addition to social relations among smart conference attendees. A more detail survey of scholarly data is presented in (Xia et al., 2017) for more exploration.

III STRENGTHS AND WEAKNESSES OF CONTENT-LINK, CITATION RELATION, AND SOCIAL NETWORK ANALYSES

The strengths and weaknesses of each of the content-link, citation relation, and social network analyses are presented in Table 1.

Table 1. Strengths and Weaknesses of Content-Link, Citation Relation, and Social Network Analyses

S/N	Relevance Measurement	Strengths	Weaknesses
1	Content-Link Analysis	The content-link analysis is a readily-understood, inexpensive research method, which does not require contact with people (Stemler, 2001). Of all the research methods, content analysis scores highest about ease of replication, as establishing reliability is easy and straightforward (Neuendorf, 2016).	The content-link analysis is a purely descriptive method, which describes what is there, but may not reveal the underlying motives for the observed pattern ('what' but not 'why'), and the analysis is limited by the availability of material (Stemler, 2001).
2	Citation Relation Analysis	A crucial advantage of citation relation analysis is that it measures the trends in science, as reflected in a formal publication, and for tracking these changes, connections and development over time (Moed, 2006).	There is a high possibility of biased citing (Smith, 1981), and citations are not all of the same types; some are affirmative while others are negative (MacRoberts & MacRoberts, 1989).
3	Social Network Analysis	The advantage of social network analysis is that, unlike many other methods, it focuses on interaction rather than on individual perception (Scott, 2017; Wasserman & Faust, 1994). The focus is on the relations between actors rather than attributes of actors, and actors are assumed to be interdependent rather than independent autonomous units.	The primary limitation of social network analysis is that the actors must be reachable with either direct or indirect connections, and the probability declines as the distance between actors increases (Scott, 2017).

IV CONCLUSION

The contextual information present in scholarly papers plays a vital role in the implementation of research paper recommendation systems. Researchers calculate the similarities between target papers in regards to other candidate recommending papers based on this information for making recommendations. In this paper, we present the most common approaches to measuring the contextual relevance of research paper recommendation systems. Based on the research outcome, content-link, citation relation, social network analyses, and their combinations are the most widely used. The paper also outlined the strengths and weaknesses of each approach.

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