Using "Cited by" Information to Find the Context of Research Papers

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Abstract. This paper proposes a novel method of analyzing data to find important information about the context of research papers. The proposed CCTVA (Collecting, Cleaning, Translating, Visualizing, and Analyzing) method helps researchers find the context of papers on topics of interest. Specifically, the method provides visualization information that maps a research topic's evolution and links to other papers based on the results of Google Scholar and CiteSeer. CCTVA provides two types of information: one type shows the paper's title and the author, while the other shows the paper's title and the reference. The goal of CCTVA is enable both novices and experts to gain insight into how a field's topics evolve over time. In addition, by using linkage analysis and visualization, we identify five special phenomena that can help researchers conduct literature reviews.

Keywords: Automatic meta-analysis, Human factors, Link mining.

1 Introduction

Scholars and students face several problems when they start a research project. The first problem is information overload. Compared with the traditional means of reviewing literature, the World Wide Web (WWW) has wrought enormous changes in the way information is provided. As a result, the sheer amount of information can be overwhelming at times. Thus, how to help researchers find information they need has become a critical research issue.

The second problem is information organization. Although search engines are easy to use, they do not provide tools to help filter, interpret, and organize individual items of information. Jacobson & Prusak [1] found that employees of business enterprises spend more than 80% of their time and effort eliciting, interpreting, and applying knowledge, while actually searching for knowledge only occupies 15% of their time. In academic work, information organization is also important in helping researchers find the context of a research topic. Scholar tools, such as Google Scholar provide a great deal of information; however, researchers do not have time to browse documents one by one.

Despite the rapid increase in the volume of conference and journal publications, the WWW makes accessing such documents relatively easy. In this paper, we propose a

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novel method that integrates information search tools for scholarly publications and identifies the dynamic relationships in a research domain. We focus on systems that map the evolution of a research topic using the condensed result sets from Google Scholar and CiteSeer.

The remainder of this paper is organized as follows. In Section 2, we review several related papers and systems, and discuss our data schema. In Section 3, we define our research questions and explain our methodology. In Section 4, we discuss five phenomena that can help researchers conduct literature reviews. We also detail the results of experiments on the dataset complied from Google Scholar and CiteSeer. Finally, in Section 5, we present our conclusions.

2 Literature Review

Bibliographic management, citation indexing/extraction, and co-authorship analysis are important research topics in many fields. To the best of our knowledge, the first paper to propose the use of citation indexing for historical research was published in 1955 [3]. Since then, many researchers have used 2D graphs to demonstrate the relationship between scholarly papers and the evolution of research fields, as shown by the example in Fig. 1. Citation analysis has also become an important research topic in the field of information extraction. Giles et al. [4] developed a tool called CiteSeer [2], which can parse citations, identify citations of the same paper in different formats, and identify the context of citations in the body of an article. Lin et al. [6] used novel network paths to find information of interest. For example, they used bibliographic citation data from the Open Task of the 2003 KDD Cup to analyze and answer questions like: "Which people are connected to C.N. Pope?"

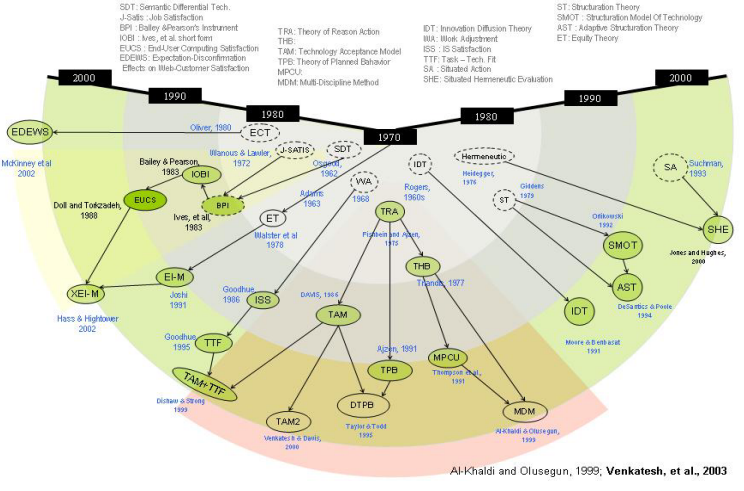


Fig. 1. Historical overview of Information System Evaluation (ISE) research streams

Table 1. Comparison of information provided by Google Scholar & Citeseer

	Citeseer	Google Scholar
Domain	Focus on computer science	General (Web, Digital Library, Publisher)
Items	Title name Paper Link Author name Journal/conference name Abstract Cited by Similar documents Active bibliography Similar documents based on text Related documents from co-citations BibTeX entry Citations Years of citations(Graph)	Title name Paper Link Author name Journal/conference name Snippet Cited by Links to British Library Direct, where the paper can be purchased Links to Web search Related articles
Characteristics of Information Provided	Provides rich historical information	Provides information about what happened after a paper was published
Constraint	N/A	Constrained at 1,000 entries

Smeaton et al. [7] analyzed the content of papers published in SIGIR proceedings to identify research trends. Their objective was to determine the topics that appear most frequently; however, they did not visualize the results or include any citation analysis. Nascimento et al. [8] constructed a co-authorship graph of all the papers published by SIGMOD between 1975 and 2002. Lee et al. [9] developed a visualization tool called PaperLens, which allows researchers to identify the trends and topics in a field.

Fortuna et al. [10] found that extracting the main concepts from documents using techniques like the Latent Semantic Index (LSI) yields more useful visualization results. For example, given a set of descriptions of European Research projects (6FP), one can find the main areas that these projects cover, e.g., the Semantic Web, e-learning, and information security.

In this section, we discuss the use of scholar tools to find information of interest and compare various tools. Scholar tools are programs that enable users to search the Web for articles in academic journals and databases. The following are some of the most popular tools: Google Scholar [1], OAIster [11], Windows Live Academic Search [12], Citeseer [2], and DBLP [13]. There are also several digital libraries, such as the ACM Digital Library [14], IEEE Xplore [15], Arxiv.org [16] and PubMed [17]. These libraries provide various kinds of information, e.g., article names, author names, papers linked to journals and conference proceedings, references, abstracts, and keywords. We conduct a data analysis of "Google Scholar" and CiteSeer, as shown in Fig. 2 and Fig. 3. We compare the information provided by "Google Scholar" and CiteSeer in Table 1. The most widely used features are author, paper

Fig. 2. Data Analysis of Google Scholar

Fig. 3. Data Analysis of CiteSeer

title, and publisher's information. To trace a theory's evolution and data convergence, we determine the relationships between an original paper and papers that have cited it and use the result to form our data schema.

3 Empirical Study and Research Method

We use research publications for our empirical study. Before the advent of the WWW, researchers had to expend a great deal of effort searching for papers to learn about developments in their field. When they started a research topic, they had to depend on one or two journals and review all the papers to find relevant information. In contrast, the WWW enables researchers to access e-journals, personal publication

lists, and other important information with relative ease. However, the availability of large volumes of information has caused an "information explosion", which poses tremendous challenges in terms of the intelligent organization of data and visualization.

3.1 Research Questions

We use Teece at al.'s "Dynamic Capabilities" theory [18] as the basis of our empirical investigation. As with any field of study, we need to address the following research questions:

RQ1: "How can we determine which papers we should review?"
RQ2: "How can we discover the evolution of a specific domain?"
RQ3: "Does the "cited by" number mean a highly cited paper is very important?"
RQ4: "Is there a tool that can locate the information we require?"

3.2 The Proposed Method - CCTVA

To address the above questions, we have developed a method called CCTVA (Collecting, Cleaning, Translating, Visualizing, and Analyzing), which is comprised of the following five processes.

Collecting: To obtain "cited by" information, we used two scholar search tools, Google Scholar and Citeseer. We developed a focused spider to crawl Google Scholar's data and translated CiteSeer OAI Compliance (http://citeseer.csail.mit.edu/oai.html) into our repository with our schema, as shown in Fig. 4. As a result, we obtained 15,717 records from Google Scholar.

id	Paper	PaperTitle	PaperTit	paperC	pape	paperCites	pape	Authors	Source	Location
132	17952	Dynamic capabilities: what are they?	/url?sa=l	9 個群	/sch	被引用 865 次	/scl	KM Eisenhardt, JA Ma	Strategic Management Journal, 2000	doi.wiley.com
133	17952	企業核心能力: 理論溯源與課輯結構剖析	/url?sa=l	2 個群	/sch	被引用 110 次	/scl	王毅, 陳勁…	管理科學學報, 2000	萬方資料資源
134	17952	Knowledge of the firm and the evolutio	/url?sa=l	9 個群	/sch	被引用 613 次	/scl	B Kogut, U Zander	Journal of International Business St	palgravejourr
135	17952	Creating and Managing a High-Performan	/url?sa=l	9 個群	/sch	被引用 461 次	/scl	JH Dyer, K Nobeoka	Strategic Management Journal, 2000	doi.wiley.com
136	17952	Value creation in e-business	/url?sa=l	18 個群	/sch	被引用 405 次	/scl	R Amit, C Zott	2000	doi.wiley.com
137	17952	Strategy Research: Governance and Comp	/url?sa=l	5 個群	/sch	被引用 391 次	/scl	OE Williamson	Strategic Management Journal, 1999	doi.wiley.com
138	17952	企業的競爭優勢來源及其戰略選擇	/url?sa=l	2 個群	/sch	被引用 41 次	/scl	李海艦, 盖耀華	中國工業經濟, 2002	維普資訊
139	17952	Deliberate Learning and the Evolution	/url?sa=l	14 個群	/sch	被引用 317 次	/scl	M Zollo, SG Winter	Organization Science, 2002	atyponlink.co
140	17952	公司治理, 內部控制, 組織結構互動關係研	/url?sa=l	none	none	被引用 33 次	/scl	程新生	會計研究, 2004	維普資訊
141	17952	我國企業核心能力實證研究	/url?sa=l	3 個群	/sch	被引用 38 次	/scl	王毅	管理科學學報, 2002	萬方資料資源
151	17952	Knowledge transfer: A basis for compet	/url?sa=l	4 個群	/sch	被引用 267 次	/scl	L Argote, P Ingram	Organizational Behavior and Human De	dxslab.mis.cc
152	17952	Bridging Ties: A Source of Firm Hetero	/url?sa=l	6 個群	/sch	被引用 217 次	/scl	B McEvily, A Zaheer	Strategic Management Journal, 1999	doi.wiley.com
153	17952	Toward a synthesis of the resource-bas	/url?sa=l	4 個群	/sch	被引用 199 次	/scl	R Makadok	Strategic Management Journal, 2001	doi.wiley.com
154	17952	Research partnerships	/url?sa=l	4 個群	/sch	被引用 195 次	/scl	J Hagedoorn, AN Link	Research Policy, 2000	arno.unimaas.
155	17952	International Expansion by New Venture	/url?sa=l	2 個群	/sch	被引用 176 次	/scl	SA Zahra, RD Ireland	The Academy of Management Journal, 2(	JSTOR
156	17952	Integration and Dynamic Capability: Ev	/url?sa=l	none	none	被引用 176 次	/scl	M IANSITI, KIMB CLAR	Industrial and Corporate Change	Oxford Univ P
157	17952	Towards a competence theory of the reg	/url?sa=l	5 個群	/sch	被引用 171 次	/scl	C Lawson	Cambridge Journal of Economics, 1999	cje.oupjourna
158	17952	Direct and moderating effects of human	/url?sa=l	none	none	被引用 168 次	/scl	MA Hitt, L Bierman,	Academy of Management Journal, 2001	aom.pace.edu
159	17952	Theory and research in strategic manag	/url?sa=l	5 個群	/sch	被引用 146 次	/scl	RE Hoskisson, MA Hit	Journal of Management, 1999	jom.sagepub.c
160	17952	Beyond local search: boundary-spanning,	/url?sa=l	6 個群	/sch	被引用 144 次	/scl	L Rosenkopf, A Nerka	Strategic Management Journal, 2001	doi.wiley.com
161	17952	Human resources and the resource based	/url?sa=l	4 個群	/sch	被引用 144 次	/scl	PM Wright, BB Dunfor	Journal of Management, 2001	jom.sagepub.c
162	17952	The Satisficing Principle in Capabilit	/url?sa=l	4 個群	/sch	被引用 143 次	/scl	SG Winter	Strategic Management Journal, 2000	doi.wiley.com
163	17952	Product sequencing: co-evolution of kn	/url?sa=l	10 個群	/sch	被引用 138 次	/scl	CE Helfat, RS Raubit	Strategic Management Journal, 2000	doi.wiley.com
164	17952	Transaction Cost Economics: How It Wor	/url?sa=l	13 個群	/sch	被引用 134 次	/scl	OE Williamson	De Economist, 1998	Springer
165	17952	Capabilities, cognition, and inertia:	/url?sa=l	5 個群	/sch	被引用 134 次	/scl	M Tripsas, G Gavetti	Strategic Management Journal, 2000	doi.wiley.com
166	17952	Managing organisational knowledge by d	/url?sa=l	7 個群	/sch	被引用 130 次	/scl	N Bontis	International Journal of Technology M	Inderscience
167	17952	Resource-based theories of competitive	/url?sa=l	3 個群	/sch	被引用 131 次	/scl	JB Barney	Journal of Management, 2001	jom.sagepub.c
168	17952	Understanding dynamic capabilities	/url?sa=l	4 個群	/sch	被引用 130 次	/scl	SG Winter	Strategic Management Journal, 2003	doi.wiley.com
169	17952	Alliance capability, stock market resp	/url?sa=l	4 個群	/sch	被引用 127 次	/scl	P Kale, JH Dyer, H S	Strategic Management Journal, 2002	doi.wiley.com
170	17952	Avoiding Complexity Catastrophe in Coe	/url?sa=l	4 個群	/sch	被引用 123 次	/scl	B McKelvey	Organization Science, 1999	JSTOR
3645	17952	基於知識的動態能力演化模型研究	/url?sa=l	2 個群	/sch	被引用 11 次	/scl	董俊武, 黃江圳, 陳	中國工業經濟, 2004	維普資訊
3646	17952	NEBIC: A Dynamic Capabilities Theory f	/url?sa=l	14 個群	/sch	被引用 47 次	/scl	BC Wheeler	Information Systems Research, 2003	atyponlink.co
3647	17952	The organizational impact of technolog	/url?sa=l	8 個群	/sch	被引用 46 次	/scl	M Chesbrough	Industrial and Corporate Change, 199	bbk.ac.uk
3648	17952	Competence-building, technology fusion	/url?sa=l	none	none	被引用 45 次	/scl	DT Lei	International Journal of Technology M	Inderscience
3649	17952	International Entrepreneurship: The Cu	/url?sa=l	none	none	被引用 46 次	/scl	SA Zahra, G George	Strategic Entrepreneurship: Creating	instruction.b

Fig. 4. Raw data in the repository

Cleaning: The purpose is to construct a temporal matrix from the cleaned bibliographic dataset. In this stage, our hypothesis is that there must be a paper that is particularly important in each research field. Most researchers cite an important paper in their published works. We call that paper the *root paper*. In our empirical study, we found that Teece's "Dynamic capabilities and strategic management" paper [18] had the highest citation rate (2,928). Hence, we adopted it as the root and used the 2,928 papers that cited it as correlation elements to find the relations.

Translating: To form an *N***N* correlation matrix, the correlation matrix can be reduced to a *Partially Ordered Set* (or poset) that contains a partially order relation. The relation formalizes the intuitive concept of the ordering, sequencing, or arrangement of the set's elements.

Visualizing: The objective is to translate a matrix into a network. We use AT&T's Graphviz (http://www.research.att.com/sw/tools/graphviz) format to visualize the result. In the operation, we provide two functions to facilitate the analysis. The first function allows users to scale the number of papers. Users can specify a number (*n*) (Top *n*), which represents the most frequently cited papers. The system will then analyze the percentages of each paper's "cited by" number among the Top *n* papers. The other function is called grouping. When a user moves the mouse on to any node or inputs a search query, the system will group the related papers by changing the color of the font. This function helps researchers find the context of papers more easily. Fig. 5 and Fig. 6 show the network topology of the top 100 and 200 papers respectively.

Analyzing and Weighting: This function allows users to sort papers by the year of publication, or "cited by number" information, or specify some conditions like "select

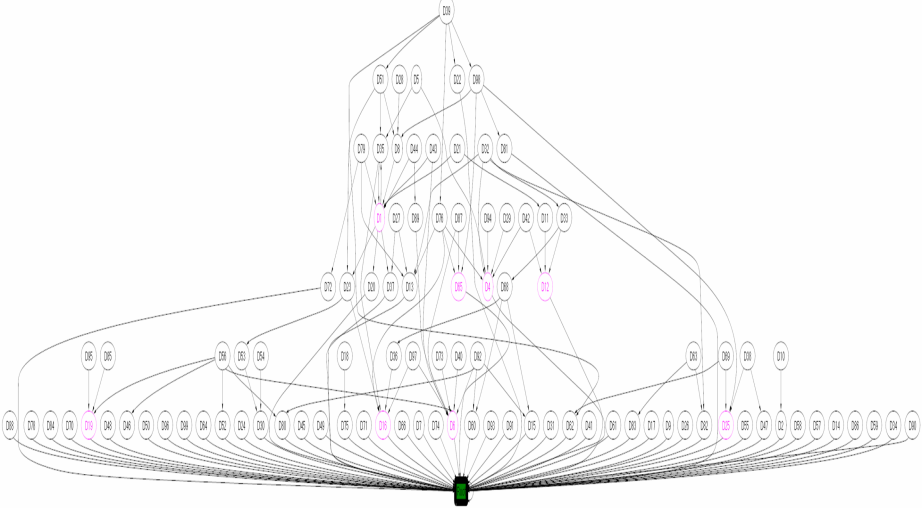


Fig. 5. The network topology of the top 100 papers

top *M* cited by number” papers or find papers with more than *N* links. For example, Fig. 5 shows the results for the case of the “Top 100 papers with more than three links”. We found that D1, D4, D6, D12, D16, D19, D25, and D65 are more important than the other papers.

4 Result Analysis and Discussion

We use the theory of Social Network Analysis (SNA) to analyze the cited-by graph. The theory views social relationships in terms of nodes and ties. By using the number of links as the condition, we observed several phenomena in the visualization results, as shown in Fig. 5 and Fig. 6.

4.1 Cited-by Data Analysis: Social Network Analysis

By changing the scale of the correlation matrix and linkage, we observed the following five phenomena.

Phenomenon 1: If paper A is cited by different groups, it means this node has several branches; that is, it is not a single node. No matter whether A’s “cited by” number is high or low, the paper is very important, as shown in Fig. 7(a). If A is widely quoted by researchers in different areas, we call this phenomenon a *diffusion model*. The real cases are shown in Fig. 5 and Fig. 6, i.e., D0, D1, D8, etc. Specifically, D0 is the original paper written by Teece et al. [18]. We find that if a node has more branches, extending from it, then it is more important than the other nodes.

Phenomenon 2: If paper A is cited by Paper B, and both papers have high “cited by” numbers, then A and B are both important, as shown in Fig. 7(b). This model is very

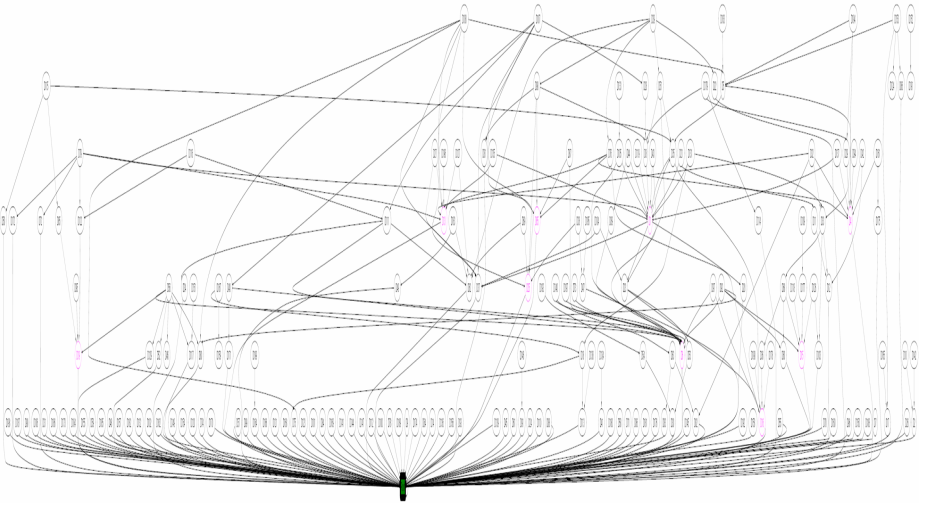
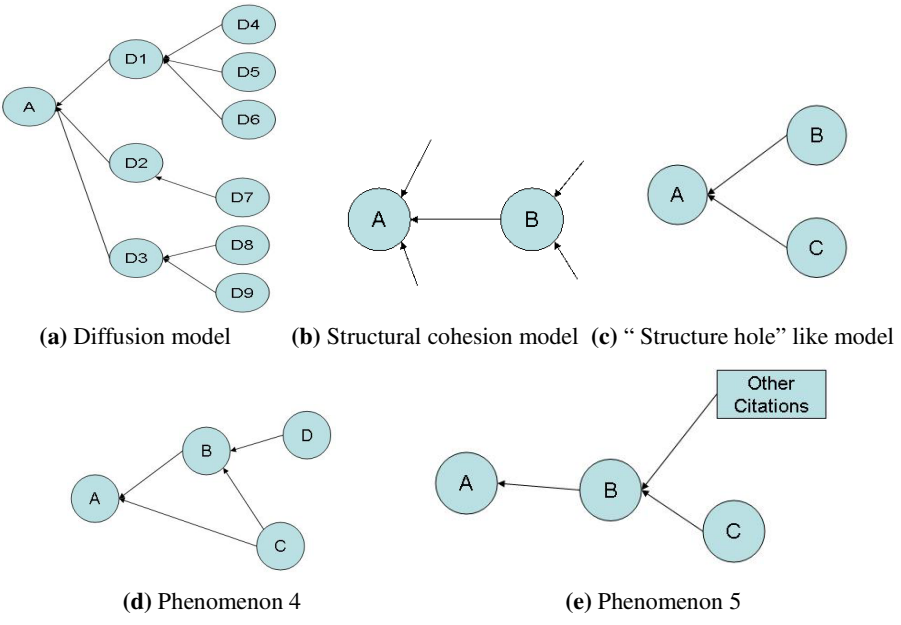


Fig. 6. The network topology of the top 200 papers



(a) Diffusion model **(b)** Structural cohesion model **(c)** " Structure hole" like model

(d) Phenomenon 4 **(e)** Phenomenon 5

Fig. 7. Cited-by data analysis: Social Network Analysis

similar to the "Structural Cohesion" model. The real cases shown in Fig. 6 are D1-D8, D4-D5, D16-D35. We observe several trends starting from the root, which means the research topic of "dynamic capabilities" has evolved into several subgroups. D1-D8 focus on *organization learning*; D4-D5 focus on the relationship between *dynamic capabilities* and *performance of a firm*; and D16-D35 focus on the relationship between *dynamic capabilities* and *innovation*.

Phenomenon 3: If paper A is cited by papers B and C, and both B and C have high "cited by" numbers, it does not matter whether A's "cited by" number is high or low because it is very important, as shown in Fig. 7(c). This phenomenon is similar to the "Structure Hole" theory in social network analysis. The cases shown in Fig. 6 are D1, D23, and D51. Note that D23 is Helfat & Raubitschek's paper [19], which addresses the relationship between knowledge, capabilities, and products.

Phenomenon 4: In Fig. 7(a), paper A is cited by papers B, C, and D, and papers A and C have high "cited by" numbers. This means that some papers cited A and C, but not B. Meanwhile, if paper D has a small "cited by" number, but it cites A and B, then paper B is important in some cases.

Phenomenon 5: We add more information, such as the value of the original paper's "cited by number," or we subtract the paper cited in the root paper, as shown in Fig. 7(e). If paper B has a high citation rate, but it does not have a high linkage in our results (shown in Fig. 5 and Fig. 6), then B may be important in another domain. Papers D11, D14, and D17 are the real cases, as shown in Fig. 6.

4.2 Discussion

By applying visualization to the different scales of the matrix elements and the linkage frequencies, some of which are shown in Figs. 5 and 6, we obtain the statistical results listed in Table 2. The results, which are based on "keyword search" and "cited by number" queries, provide a different view of the original correlation table described in Section 2. We find that the "cited by" number is not the only important evaluation criterion for deciding whether a paper is important. Some papers with high citation rates, such as D11 (cited 267 times), D14 (Cited 195 times), and D17 (cited 171 times) are not important in the visualization result. This answers the question: Does "cited by number" mean a paper is very important?

In addition, if we consider the "Structural cohesion" phenomenon, we find that several groups, e.g., D1-D8, D1-D105, D4-D5, D6-D40, D16-D35, and D30-D52-D23 are independent of the other papers. This answers the question: How can we discover the evolution of this domain?

By using linkage frequency analysis, we find that some nodes in Figs. 5 and 6 and some items in Table 2 are important in this domain. This answers the question: How can we determine which papers we should review?

Finally, we provide a user interface (shown in Fig. 8) to help researchers conduct literature reviews using CCTVA. The researcher can use the "search for a paper", "select a paper from the list", "move the mouse to select a node" functions to find the context of a research field. When a node in the panel is selected, the system will show related nodes and information.

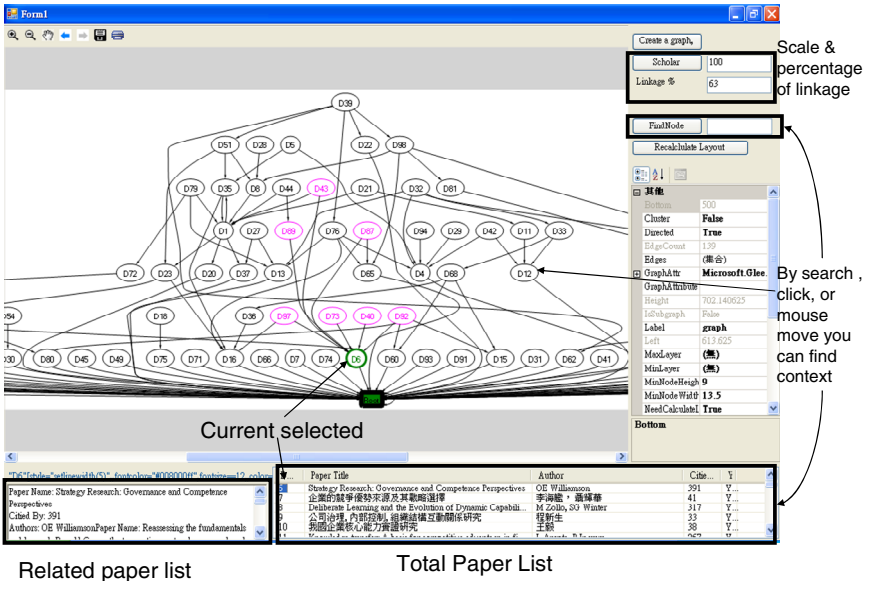


Fig. 8. The CCTVA system

Table 2. The query results

ID	Author	Title	Cited by number	Top 100, Links >3	Top 200, Links > 4	Top 300, Links> 5
D1	KM Eisenhardt, JA Martin	Dynamic Capabilities: What are they?	865	1	1	1
D4	JH Dyer, K Nobeoka	Creating and Managing a High-Performance Knowledge-Sharing Network: The Toyota Case	461	1	1	1
D5	R Amit, C Zott	Value creation in e-business	405		1	1
D6	OE Williamson	Strategy Research: Governance and Competence Perspectives	391	1	1	1
D8	M Zollo, SG Winter	Deliberate Learning and the Evolution of Dynamic Capabilities	317		1	1
D12	B McEvily, A Zaheer	Bridging Ties: A Source of Firm Heterogeneity in Competitive Capabilities	217	1		1
D13	R Makadok	Toward a synthesis of the resource-based and dynamic-capability views of rent creation	199		1	1
D15	SA Zahra, RD Ireland, MA Hitt	International Expansion by New Venture Firms: International Diversity, Mode of Market Entry, …			1	
D16	M IANSITI, KIMB CLARK	Integration and Dynamic Capability: Evidence from Product Development in Automobiles and Mainframe …	176	1	1	1
D19	RE Hoskisson, MA Hitt, WP Wan, D Yiu	Theory and research in strategic management: Swings of a pendulum …	146	1	1	
D22	SG Winter	The Satisficing Principle in Capability Learning	143			1
D25	M Tripsas, G Gavetti	Capabilities, cognition, and inertia: evidence from digital imaging	134	1	1	1
D37	S Karim, W Mitchell	Path-Dependent and Path-Breaking Change: Reconfiguring Business Resources Following Acquisitions in …	97			1
D65	D Holbrook, WM Cohen, DA Hounshell, S Klepper	The nature, sources, and consequences of firm differences in the early history of the semiconductor …	63	1	1	1
D75	TH Brush, KW Artz	Toward a Contingent Resource-Based Theory: The Impact of Information Asymmetry on the Value of …	53			1

5 Conclusion

In this paper, we propose a novel method called CCTVA (Collecting, Cleaning, Translating, Visualizing, and Analyzing) to help researchers find the context of papers on topics of interest. The method also enables users to gain insight into how a field's topics have evolved over time.

The contribution of this paper is three fold. First, the proposed CCTVA method helps researchers find the context of a research field and reduces the complexity of citations. Second, we generalize five phenomena to help researchers find important papers. The observed phenomena can help users explore the evolution of a research field, and find the most frequently referenced papers and the most published authors in that field. Finally, we provide an interface to help researchers find a topic's branches in a research field and select the branch of interest.

In our future work, we will add some algorithms to help users find more information like co-authorship, keywords, and key phrases in papers. We will also use text mining techniques to analyze papers in order to extract more information about the contexts of the papers.

Acknowledgments

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