Web Services: Themes, Concepts and Relationships

Chiu-Chuan Lin, Yender McLee, Jen-Hwa Kuo

***Abstract*—To explore the intellectual structure of web services research in the last eight years, this study identified the most important publications and the most influential scholars as well as the correlations among these scholar's publications. In this study, bibliometric, social network and tag clouds analysis techniques are used to investigate the intellectual pillars of the web services literature. By analyzing 22,785 citations of 1,510 articles published in SCI and SSCI journal in web services area between 2001 and 2008, this study maps a knowledge network of web services studies. The results of the mapping can help identify the research direction of web services research and provide a valuable tool for researchers to access the literature in this area.**

***Index Terms*—web services; business process; web service composition; tag cloud.**

I. Introduction

With the upcoming of semantic web services, business process and web service composition has gradually developed into an independent academic field and scholars from different fields have joined the studies of Web services. The past eight years has especially seen extensive research on web services. Yet even though web services has established itself as an academic discipline, its establishment has been a slow process because researchers in this area prefer to publish their best work in more established journals. Another major obstacle to the development of web services lies in the subject's unusually high degree of interaction with other disciplines. This overlapping blurs the boundaries of web services and as a result its distinct theoretical model and analytical tools are unjustly attributed to other competing fields. With limited resources contributing to the development of Web services, the cross-fertilization of ideas between scholars of web services will be much more difficult to obtain. Consequently, while there is no doubt that there is an area or field of web services, the question remains somehow unclear on what it is, how good its work is, and what are its prospects and needs for future development.

The objective of this study is to provide web services researchers with a unique map to better understand Web services related publications and to provide a systematic and objective mapping of different themes and concepts in the development of web services field. This study also attempts to help identify the linkage among different publications and confirm their status and positions in their contribution to the development of web services field. The principal methods used are citation and co-citation analysis, social network analysis, plus a factor analysis which is performed to identify the invisible network of knowledge generation underlying the web services literature.

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II. Studies of Academic Literature

There are a number of techniques that can be used to study a body of literature. Most frequent is the simple literature review where a highly subjective approach is used to structure the earlier work. Objective and quantitative techniques have recently become popular with more databases available online for use. These techniques adopt author citations, co-citations, and systematic review [1] to examine the invisible knowledge network in the communication process by means of written and published works of a given field. These techniques are attractive because they are objective and unobtrusive [2].

Several studies have used the bibliometric techniques to study the literature of management research. For example, Ponzi [3] explored the intellectual structure and interdisciplinary breadth of knowledge management in its early stage of development, using principle component analysis on an author co-citation frequency matrix; Etemad [4] identified the most influential authors and studies in electronic commerce field by using citation analysis; Ramos-Rodriguez and Ruiz-Navarro [5] examined the intellectual structure change of strategic management research by conducting a bibliometric study of the Strategic Management Journal; Acedo and Casillas [6] explored the research paradigms of international management research by applying factorial analysis techniques in an author co-citation study. To the best of our knowledge, no similar study has been conducted on the current research of knowledge management. Therefore this study aims to fill a gap in knowledge management literature by applying citation and co-citation analysis to a representative sample of recent research on knowledge management collected by the Science Citation Index and Social Sciences Citation Index

III. Methodology

The citation data used in this study included journal articles, authors, publication outlets, publication dates, and cited references. Based on the objective of this study, the authors explored the intellectual structure of web services between 2001 and 2008. This time period was chosen because contemporary web services studies of the last four years represent the most update and probably also the most important research on web services. Citation and co-citation

analysis is the main method for this study.. First, the databases were identified as the sources of web services publications. Then data collection and analysis techniques were designed to collect information about topics, authors, and journals on web services research.

In the second stage, the collected data were analyzed and systematized by sorting, screening, summing, sub-totaling, and ranking. After a series of operations, key nodes in the invisible network of knowledge in web services were identified and the structures developed. In the final stage, the co-citation analysis was used and the knowledge network of web services was mapped to describe the knowledge distribution process in web services area.

In this study, the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) were used for analysis. The SCI and SSCI are widely used databases, which include citations published in over 9000 world's leading scholarly journals. While there are arguments that other online databases might also be used for such analysis, using SCI and SSCI provided the most comprehensive and the most accepted databases of web services publications.

Unlike other prior studies, the data used in this study were not drawn from journals chosen by peer researchers [7]. Instead, the entire databases of SCI and SSCI from 2001 to 2008 served as the universe for analysis. In order to collect the data, we used "key word" method which utilizes the SCI and SSCI databases key word search in article's title and abstract. Using "web services and web service" as key word, this study collected 1,510 journal articles which further cited 22,785 publications as references. The cited references in these papers included both books and journal articles.

IV. Results

A. Citation Analysis

To identify the key publications and scholars that have laid down the ground work of knowledge management research, citation data were tabulated for each of the 1,510 source documents and 22,785 references using the *Excel* package. The citation analysis produced interesting background statistics, as shown in the following tables. Table 1 lists the most cited journals in Web services area in the last four years, among which *IEEE Internet Computing, Communications of the ACM*, and *IEEE Intelligent Systems & Their Applications* are the top three most cited journals, followed by *IEEE Transactions on Software Engineering* and *Bioinformatics*. The web services specific journal, Journal of Web services, is only ranked No. 7 in web services area. Such a result indicates the majority of web services research is still published in other, non-web services specific journals and that there is still a long way before Web services develops into a fully-fledged field that can support its own knowledge generation and dissemination. The general pattern of the most cited journals shows that web services research features organization and general management specific journals prominently, alongside the web services specific journals; with a cluster of information systems focused titles also evident.

TABLE 1 THE MOST FREQUENTLY CITED JOURNALS: 2001-2008

Journals	Total Citations
IEEE Internet Computing	393
Communications of the ACM	365
IEEE Intelligent Systems & Their Applications	161
IEEE Transactions on Software Engineering	122
Bioinformatics	110
Vldb Journal	107
Nucleic Acids Research	105
IBM Systems Journal	95
Scientific American	92
IEEE Intelligent Systems	91

The most influential documents with the most citation and the most influential scholars were then identified by their total counts of citation within the selected journal articles. As shown in Table 2, the most cited web service publication between 2001 and 2004 (the first four years) was Christensen's book *Web services description language(WSDL)1.1,* followed by Mcilraith's paper *Semantic Web Services,* and Berners-Lee and James and Lassila's paper *The Semantic Web* (see Table 2). For the second four years (2005-2008), the first two most cited web services publications were the same as in the first four years. The third most cited was Anderws's book *Business process execution language for web services* (See Table 3).

TABLE 2 HIGHLY CITED DOCUMENTS: 2001-2004

Total Citations	Full Citation Index For Document
36	Christensen E, 2001, Web services description language(WSDL)1.1
33	Mcilraith SA, 2001, IEEE intelligent systems & their applications, V16, P46
31	Berners-Lee T, 2001, Scientific American, V284, P34
24	Box D, 2000, Simple object access protocol(SOAP) 1.1
22	Leymann F, 2001, Web services flow language(WSFL 1.0)
19	Thatte S, 2001, XLANG web services for business process design
19	Curbera F, 2002, IEEE internet computing, V6, P86
18	Ccrbera F, 2002, Business process execution language for web services
13	Fensel D, 2002, Electronic commerce research and application, V1, P11
12	Hendler J, 2001, IEEE intelligent systems & their applications, V16, P30

Journal articles and books combined, the top five most cited scholar between 2001 and 2004 (the first four years) were Curbera, Fensel, Paoulcci, Christensen, and Leymann (See Table 4). For the second four years, the status of the most important scholars changed. The top five most cited scholars were Paoulcci, Benatallah, Foster, Curbera, and Berners-Lee (See Table 5). These scholars have the most influence in the development of Web services area and thus collectively define this field. Their contributions represent the focus of the main research in the field and thus give us an indication of the popularity of certain Web services topics as well as their historical values.

TABLE 3 HIGHLY CITED DOCUMENTS: 2005-2008

Total Citations	Full Citation Index For Document
49	Berners-Lee T, 2001, Scientific American, V284, P34
45	Christensen E, 2001, Web services description language
44	Andrews T, 2003, Business process execution language for web services
44	Mcilraith SA, 2001, IEEE intelligent systems & their applications, V16, P46
40	Alonso G, 2004, Web services: concepts, architectures and applications
33	Papazoglou MP, 2003, Communications of the ACM, V46, P25
30	Zeng LZ, 2004, IEEE Transactions on software engineering, V30, P31
29	Curbera F, 2003, Communications of the ACM, V46, P29
28	Menasce DA, 2002, IEEE internet computing, V6,
27	Fensel D, 2002, Electronic commerce research and application, V1, P11

Although the citation analysis does not eliminate the bias against younger scholars, a paper-based ranking (as in Table 2 & 3) places more emphasis on the quality (as opposed to the quantity) of the documents produced by a given scholar than a ranking of authors based on the frequencies with which a particular author has been cited (as in Table 4 & 5). In addition, Table 2 and 3 represent the key research themes in a field and give us an indication of the popularity of certain Web services topics. The readers can find high citations are associated to what can be termed field-defining titles and they lay down the ground work for the understanding of Web services as a distinct phenomenon. A comparison between Table 2 and 3 reveals some interesting patterns from the first four years (2001-2004) to the second four years (2005-2008). First, the top two most influential publications in the last four years remain the same, indicating their dominant status for the past four years in web services studies.

TABLE 4 HIGHLY CITED AUTHORS: 2001-2004

Author	Frequency	Author	Frequency
Curbera F	65	Foster I	50
Fensel D	62	Berners-Lee T	45
Paolucci M	57	Benatallah B	39
Christensen E	53	Casati F	39
Leymann F	53	Box D	37

The gradual increase in the total citations supports the evolving process of web services research as an academic field and the process of gaining more and more recognition in the literature. On the other hand, the most influential papers in the first four years and the second four years do not change much. For example, among the top five most cited publications, only two of them were the same, even though the rankings were slightly different. In particular, the publications of Berners-Lee and Christensen took four spots in the top five most cited publications in the first four years; and similarly they took three spots in the top five most cited publications in the second four years. This indicates the development in web services is fast and a few classical works and influential authors still dominate the web services research. More efforts and theoretical breakthrough are thus needed in order to further advance the development of web services research.

TABLE 5 HIGHLY CITED AUTHORS: 2005-2008

Author	Frequency	Author	Frequency
Paolucci M	147	Fensel D	77
Benatallah B	123	Vanderaalst WMP	74
Foster I	95	Andrews T	69
Curbera F	86	Alonso G	66
Berners-Lee T	83	Papazoglou MP	66

B. Co-citation Analysis

In this stage, data mapping was conducted and an intellectual structure of current Web services studies was revealed. Co-citation analysis is a bibliometric technique that information scientists use to map the intellectual structure of an academic field. It involves counting documents from a chosen field - paired or co-cited documents. Co-citation analysis compiles co-citation counts in matrix form and statistically scales them to capture a snapshot at a distinct point in time of what is actually a changing and evolving structure of knowledge [8].

Co-citations were tabulated for each source documents by using the *Excel* package. Many of the authors had very few co-citations that were either unlikely to have had a significant impact on the development of the field or were too new to have had time to impact on the literature. To facilitate analyses and improve the probability of its success, it was made sure that all authors in the final set had at least 30 citations in the first four years and 30 in the second four years. Based on the total number of citations in the selected journals, the top scholars were identified, and then a co-citation matrix was built before a pictorial map was drawn to describe the correlations among different scholars. In doing so, we were following the procedures recommended by White and Griffith [9].

Social network analysis techniques were used to graph the relationships in the co-citation matrix and identify the strongest links and the core areas of interest in web services [1]. Figure 1 and Figure 2 show the core research themes in web services studies, based on sampled articles with links of greater than or equal to ten co-citations shown in the network. This is produced using UCINET software [3] and shows graphically the core areas of interest. Different shapes of the nodes result from performing a faction study of these authors. This method seeks to group elements in a network based on the sharing of common links to each other. The diagrams show that current research in web services area is concentrating on the interactions of essential of Business Process, Semantic Web Services, Web Services Composition and Internet Technology. The few scholars in Figure 1 and 2 with the most links (co-citation) are the super stars in web services research. Their heavy citations and intensive interlinks with each other undoubtedly indicate their prestigious status in web services research and their publications and research work collectively define the future

research directions of web services studies.

While the diagrams in Figure 1 and Figure 2 provide a clear picture, their foci are only on the very core areas and only a limited amount of information is revealed. By taking the co-citation matrix and grouping the authors using factor analysis of the correlations between the entries, we can determine which authors are grouped together and therefore share a common element. According to this, the closeness of author points on such maps is algorithmically related to their similarity as perceived by citers. We use r-Pearson as a measure of similarity between author pairs, because it registers the likeness in shape of their co-citation count profiles over all other authors in the set [10].

The co-citation correlation matrix was factor analyzed using varimax rotation, a commonly used procedure, which attempts to fit (or load) the maximum number of authors on the minimum number of factors. The diagonals were considered missing data and were applied the criterion of omitting the two cases [5].

Four factors were extracted from the data in the first four years (2001-2004) and together they explained over 86% of the variance in the correlation matrix. Table 6 lists the four most important factors along with the authors that had a factor loading of at least 0.5. As is usual in this type of analysis, authors with less than a 0.5 loading or with cross-loadings were dropped from the final results [9]. We tentatively assigned names to the factors on the basis of our own interpretation of the authors with high loadings. Our interpretation of the analysis results is that web services research in this period is composed of at least three different sub-fields: Semantic Web Services, Business Process, Web Services composition and Internet Technology (Please see Figure 1). We made no attempts to interpret the remaining factors due to their small eigenvalues. They have also been excluded from Table 6.

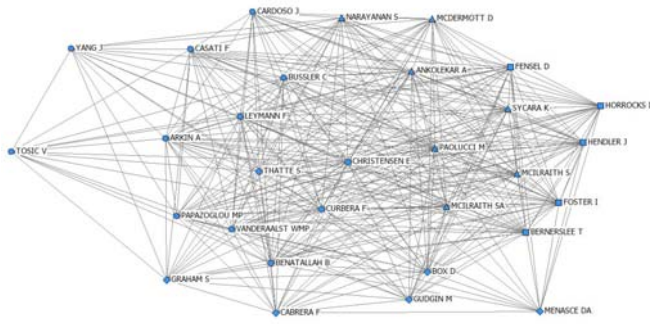

Figure 1 Key Research Themes in Web Services (2001-2004)

Similarly, studies on Web services also clustered on different research themes between 2005 and 2008 and together they explained over 89% of the variance in the correlation matrix of the second four years, as pictured in Table 7 lists the four most important factors along with the authors that had a factor loading of at least 0.5. We also tentatively assigned names to the factors on the basis of our own interpretation of the authors with high associated loadings. Our interpretation of the analysis results is that web services research at this stage is also composed of at least four key sub-fields: Business Process, Semantic Web Services, Web Service Composition and Internet Technology.

TABLE 6 AUTHOR FACTOR LOADINGS: 2001-2004

Factor 1: Semantic Web Services	Variance	Factor 2: Business Process	Variance
Mcdermott D	0.965	Vanderaalst WMP	0.922
Mcilraith S	0.928	Casati F	0.846
Narayanan S	0.909	Papazoglou MP	0.829
Ankolekar A	0.882	Benatallah B	0.811
Paolucci M	0.865	Bussler C	0.806
Sycara K	0.819	Leymann F	0.805
Mcilraith SA	0.747	Tosic V	0.693
Cardoso J	0.588	Cardoso J	0.642
		Thatte S	0.578
		Arkin A	0.568
		Curbera F	0.554
Factor3: Web Service Composition	Variance	Factor4: Internet technology	Variance
Gudgin M	0.936	Hendler J	0.958
Box D	0.865	Fensel D	0.932
Christensen E	0.858	Horrocks I	0.915
Cabrera F	0.766	Berners-Lee T	0.838
Graham S	0.653	Foster I	0.641
Curbera F	0.645	Mcilraith SA	0.602
Foster I	0.597		
Menasce DA	0.590		
Thatte S	0.589		

Table 6 clearly indicated that the most influential authors in Web services studies between 2001 and 2004 clustered together. The main research focused on the semantic web services with an attempt to define this emerging field and help distinguish this new area from other related yet distinct fields. The Semantic Web will bring structure to the meaningful content of Web pages, creating an environment where software agents roaming from page to page can readily carry out sophisticated tasks for users. The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation. The first steps in weaving the Semantic Web into the structure of the existing Web are already under way [11].

Web services are unanimously supported by major suppliers of middleware technology. Standards in this area, such as SOAP (Simple Object Access Protocol), WSDL (Web Services Description Language), and UDDI (Universal Description, Discovery, and Integration), are being proposed or agreed on serve as a basis for implementing product features [12].The WSDL description is used to power a

service oriented architecture enabling the likes of enterprise application integration (EAI), business-to-business application integration (B2B), and grid computing. The provider creates a WSDL service description that details the interface, that is, the operations of the service and the input and output messages for each operation. The WSDL now contains all the information needed to invoke the service. The service provider now publishes the WSDL service description to one or more discovery agencies

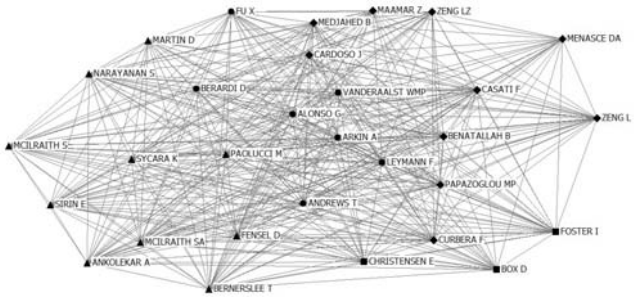

Figure 2 Key Research Themes in Web Services (2005-2008)

.As shown in Table 6, the business process attracts authors in the second group. New technologies, notably service-oriented architectures and web services, are enabling a third wave of business process management (BPM). Supporters claim that BPM is informed by complexity theory and that business processes can evolve and adapt to changing business circumstances.

The web Service Composition permeates the authors in the third group. Current web services standards and techniques support these parts and enable many important use cases, but the particular set of basic standards they employ are incidental to the key concepts underlying service-oriented computing (SOC). Indeed, although Web services provide a ready source of practical examples, they are unnecessarily limited. The architecture for Web services provides a framework that can be fleshed out with more powerful representations and techniques taken from established computer science approaches. SOC's emphasis falls on the architecture, because many of the key techniques for its components databases, transactions, software design are already well understood in isolation. Practical success depends on how well we can place these techniques into a cohesive framework, so that we can apply them in production software development. Recent progress on standards and tools is extremely encouraging in this regard [13].

For the second four years, Table 7 clearly indicated that the most influential authors in web services studies between 2005 and 2008 also clustered together. The main research focused on the Business process. Business process and Semantic Web Services are believed to be key contributors to process and product for the second four years, Table 7 clearly indicated that the most influential authors in web services studies between 2005 and 2008 also clustered together. The main research focused on the business process.

TABLE 7 AUTHOR FACTOR LOADINGS: 2005-2008

Factor 1: Business Process	Variance	Factor 2: Semantic Web Services	Variance
Leymann F	0.913	Mcilraith SA	0.953
Andrews T	0.880	Ankolekar A	0.938
Alonso G	0.875	Sirin E	0.923
Arkin A	0.862	Mcilraith S	0.893
Fu X	0.862	Sycara K	0.872
Vanderaalst WMP	0.784	Martin D	0.814
Berardi D	0.553	Paolucci M	0.806
Papazoglou MP	0.541	Narayanan S	0.603
Narayanan S	0.504	Fensel D	0.693
		Medjahed B	0.544
		Berners-Lee T	0.516
Factor3: Web Service Composition	Variance	Factor4: Internet technology	Variance
Zeng LZ	0.886	Foster I	0.841
Maamar Z	0.868	Box D	0.808
Menasce DA	0.853	Christensen E	0.644
Zeng L	0.799		
Benatallah B	0.754		
Cardoso J	0.727		
Papazoglou MP	0.699		
Medjahed B	0.688		
Curbera F	0.627		
Casati F	0.567		

With this increasing dynamism and the emergence of a continuously consolidating paradigm to lead both the academic inquiry and industrial practice, and through such an evolving process, the web services field is growing and its invisible network of knowledge production is developing.

C. Tag Cloud Analysis

Tag clouds have proliferated over the web in the past decade. One of the most exciting recent developments in web science is social network that enables users to easily annotate web content using free form keywords [14][15]. They provide a visualization of a collection of simple texts by visually depicting the tag frequency by font size. In use, tag clouds can evolve into the associated data source over time. tag clouds are not only used to display tag sets but are also increasingly applied in other contexts and for various data sets, for instance, in the areas of information visualization or text summarization. Figure 3 and Figure 4 show the core research themes web service studies, based on sampled article with links of key word than show in the tag clouds. . This is produced using software of TagCrowd web and shows graphically the core areas of interest. The diagrams show that current research in web service area is concentrating on the keyword of essential of web, service,

semantic, systems, composition, business, process and management.

Figure 3 Tag clouds in key word of Web Services (2001-2004)

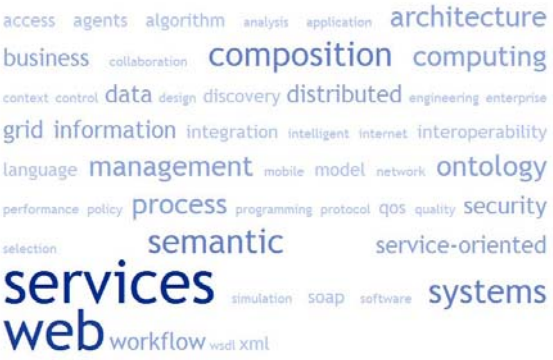

Figure 4 Tag clouds in key word of Web Services (2005-2008)

V. Conclusion

The past eight years have seen extensive research on Web services. This study investigates Web services research using citation and co-citation data published in SCI and SSCI between 2001 and 2008. With a factor analysis of the co-citation data, this study maps the intellectual structure of web services research, which suggests that the contemporary web services research is organized along different concentrations of interests: essential of business process, semantic web services and web service composition.

The mapping of the intellectual structure of web services studies indicates that Web services has somehow created its own literature and that it has gained the reputation as a legitimate academic field, with web services specific journals gaining the status required for an independent research field, such as the IEEE Internet Computing. Given that the web services is still young and our analysis has shown that it has an evolving structure, it is believed that web services publication outlets will gain more popularity and prestige that is required to become a more prominent academic field when we learn more about current paradigms and the key research themes in web services studies, how they relate, and what they stand for. With more scholars and more resources contributing to the Web services area, a better academic environment conducive for research ideas' cross-fertilizing will be formed and web services, as a field, will gain more momentum for further development.

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