

Citation analysis of Ted Nelson's works and his influence on hypertext concept

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This study investigates Ted Nelson's works and the influence of his hypertext concept through citation analysis, including citation counting, characteristics of citing articles on language, document type, citing year, discipline, and citation content. The selection of the Nelson's works was based on searching Library Literature & Information Science, Library and Information Science Abstracts, Google and Yahoo search engines. The citation data were compiled from the database of Web of Science. The results of the study reveal that hypertext has directly great impact on information retrieval and world wide web; therefore, the concept has had profound influence on information, library and computer science disciplines. Moreover, the influence of Nelson's works spreads to other disciplines variously, especially on education, literature, business and economics, engineering, sociology, psychology, etc. The citation context analysis of citing articles on information and library science reveals that (1) definition, orientation and general introduction of hypertext; (2) relation of Vannevar Bush and Ted Nelson in terms of hypertext; (3) Nelson's Xanadu system and its component of hypertext; (4) the application of hypertext in information science and library science are four most citing purpose.

Introduction

Ted Nelson [1] also named as Theodor Holm Nelson proposed the terminology of hypertext in 1965 and is recognized as the father of the word "hypertext". In a series of papers, Nelson proposed the notion of hypertext as nonlinear text that could not conveniently be presented or represented on paper. He also described the hypertext as "a series of text chunks connected by links which offer the reader different pathways" [2]. In fact, hypertext may differ from ordinary text in "(1) its sequence – it may branch into trees and networks; (2) its organization – it may have multiple levels of summary and detail; and (3) its mode of presentation – it may contain moving or manipulable illustrations" [3]. The concept of hypertext has had profound influence on various disciplines, well beyond the traditional boundaries of the computer science. The strength of this influence originated primarily from Ted Nelson's works dealing with this concept.

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The following is a brief chronology of Ted Nelson's significant events related to the development of the hypertext [4]:

1. 1960, as a graduate student at Harvard University, Nelson took a course in computer programming and began to think about writing a document management system to index and organize his collection of notes.
2. 1967, Nelson first used the term "Xanadu" to refer to his hypertext vision.
3. 1979, Nelson formed the Xanadu Group to work on the design for a database and file system to implement a hypertext system.
4. 1983, Nelson established the Xanadu Operating Company, Inc.
5. 1988, the Xanadu project and the Xanadu trademark were sold to Autodesk.
6. 1993, Nelson licensed the system specification to Serious Cybernetics in Australia.
7. 1994, Nelson moved to Japan and founded the Sapporo HyperLab.

The purpose of this study is to examine the influence of hypertext concept by conducting a direct citation count, citation subject classification and citation context analysis of Nelson's works. The number of citations that an author or a document receives is an indication of the importance of that author or document. The citation subject classification helps identify the subject category of citing articles. The content of the citing text reflects the perceived content of the cited work. A cited paper can represent such things as theoretical statements, methodologies, or experimental findings. The citation context analysis reveals the specific concept of cited works. Based on these citation analysis techniques, the present study will be able to measure mainly quantitatively the impact of Ted Nelson's contribution on the evolution and application of the hypertext concept. The present study confirms that Nelson's works have received many citations from publications in various disciplines, indicating their significance. It is, therefore, very interesting and important to explore the extent and diversity of its impact through an analysis of how much his work has been cited and in what contexts.

Citation techniques

A role of citation is that they can be used as symbols of concepts or methods. This leads to the citing of works which embody an author's idea. The cited documents become, then, in a more general sense, symbols for these ideas. A citation represents a relationship between the cited and citing documents. Bibliographic citations in research papers have been used by a variety of researchers to establish relationships among documents. Three unique measures based on citations are direct citation counting, citation subject classification and citation context analysis.

Direct citation counting

Citation counting determines how many citations a given author, document, journal, etc. has received over a period of time. The rationale for this is that citations are objective indicators of use and, therefore, that an author, article, journal, etc. that is more frequently cited is more useful or productive than one that is less frequently cited. Gross and Gross [5] originated the concept of counting and analyzing references appearing in the literature in 1927. They were the first to treat citation frequency as a measure of journal significance. Since then, many studies have applied the techniques they suggested to evaluate the importance of an author, document, or journal. Cason and Lubotsky [6] recognized and described the use of citations to measure the interdisciplinary influence of and the dependency relationships between psychological journals. Wispe and Osborn's [7] study focused on four communication journals and found that communication journals cited journals of other fields frequently, but other non-communication journals cite rarely communication journals. Communication researcher has been influenced by other subject fields, among which psychology had the strongest impact. White and McCain [8] identified the 120 authors most frequently cited in 12 key information science journals from 1972 through 1995. Brooks [9] examined the 28 best papers published in *Journal of the American Society for Information Science* from 1969–1996 and found best papers are cited at a significantly higher rate than the average article. He also explored the five best papers ranked by absolute number of citation received and by mean number of citations received per year and found that "A Study of Information Seeking and Retrieving" by Saracevic, et al. was ranked number one by both two measurements.

Citation subject classification and citation context analysis

Citation subject classification can show structure with a subject specificity and track how that subject matter changes over time. Bagby, Parker and Bury [10] studied attribution theory and the theory of cognitive dissonance. The citation pattern showed that anxiety disorder research was not widely disseminated across disciplines due to fewer citations found in the publications of other disciplines. Citation context analysis goes deeper and can interpret what they represent. Citation context analysis faces problems in making classification correctly, and would consume considerable amount of time. Lancaster, Bushur and Low [11] examined the influence of Manfred Kochen through a review of the various publications that have cited his work. They concluded that Kochen may well have been the most influential of all information scientists, because he owned citations in the literature of library science, information science, scientometrics, bibliometrics, computer science, artificial intelligence, social sciences, political science, psychology, education, economics, engineering, and other fields.

Spassar [12] explored the fate of Swanson's ideas, using citation context analysis both to determine which authors have utilized Swanson's ideas and to examine the uses to which they have been put. He found that while Swanson has received significant attention from the library and information science community, his ideas have not been widely cited in biomedical disciplines and these results are interpreted as a failed instance of interdisciplinary communication. His emphasis was not simply on retrieving individual sentences, but on combining them to form a synthesis of knowledge from multiple sources. Therefore, citation context analysis determines the most frequent pattern of usage by examining the passages where documents are cited and providing a representation of the collective state of knowledge in a field.

From the above brief review, it is clear that citation and citation context analysis are based on the assumption that a relationship exists between citing and cited documents, although the nature of this relationship is unclear. Cozzens [13] indicated "citation plays a rhetorical function in a literature as well as serving other functions." Citations can be used as measures of the quality or importance of research work. Refinements of citation counts appear to be motivated by the feeling that we do not know enough about why authors cite. Some citation studies augment citation counts by developing and applying classification schemes for references. However, very little attention has been given to the content of the citation context. Moravcsik and Murugesan [14] observed that while a number of sociologists of science examined citation passages in an attempt to classify the reasons why citations were made very few of these studies examined the precise concept relationship between cited and citing documents. The present study will also focus on examining passages in the body of citing papers in which the references to Nelson's works are embedded and on classifying and interpreting them according to concepts in different subject fields.

Methodology

The selection of the Nelson's works from 1965 to 2002 was based on searching two most important bibliographic databases of library and information science: Library Literature & Information Science (LLIS) and Library and Information Science Abstracts (LISA). In addition, search engines of Google and Yahoo on World Wide Web were also used. LISA [15] produced by Cambridge Scientific Abstracts from British Library Association, covers subjects including: bookselling, CD-ROMs databases, copyright, document delivery, electronic publishing, hypermedia, imaging and image databases, information storage and retrieval, internet, libraries of all types, library automation, networks and networking, etc. LLIS [16], a production of H.W. Wilson, covers a wide range of subjects: automation, care and restoration of books, cataloging, censorship, children's literature, circulation procedures, classification, copyright legislation, education for librarianship, electronic searching, government aid,

indexing, information brokers, internet software, library associations and conferences, library equipment and supplies, personal administration, preservation of materials, public relations, publishing, rare books, web sites.

On the other hand, the citation data, i.e. those articles that cite Nelson's works, for the present study were compiled from the database of Web of Science (including Science Citation Index (SCI), Social Sciences Citation Index (SSCI), Arts and Humanities Citation Index (A&HCI) for the period 1980 through 2002. The time period was not chosen entirely arbitrarily. At the time this study began the Web of Science database was available only from 1980. In this study, the search term with truncation function, i.e. Nelson T* or Nelson -T* was limited to the cited author field of Web of Science for retrieving all articles that cite any works of Ted Nelson or Theodor Holm Nelson. The truncation operator (*) was used to ensure that a comprehensive searching results would be obtained. The name Nelson T* or Nelson -T* has many homographs in the Web of Science. To separate the Ted Nelson's works from those of other Nelson's, each article retrieved was compared with the Ted Nelson's publication list to ensure it is really an article of Ted Nelson considered in the present study.

The Web of Science was searched to compile a bibliography of all papers published in all disciplines that cited at least one of the Nelson's works. From the bibliography, the number of citing articles from each subject field or discipline was determined. Thus the data compiled reflects not the number of individual citations to all Nelson's works, but the number of articles citing them. In other words, if one author cited another author more than once in one particular article, this was counted as only one citation. This is to prevent a few authors who might heavily cite a particular person from skewing the results. Thus, if an author received *n* citations, this means that his work has been cited by *n* different articles. Subject fields of citing article context were defined by the subject-classification assigned to journals in Ulrich's Plus database, 2004. For this study, the 'discipline' of the citing article was considered to be the same as that for the journal in which it was published.

Citation context analysis is a way of understanding the significance of highly cited documents. This approach stresses the content of the citation context rather than its function. The general steps in the procedure are (1) start with a group of highly citing papers by online searching of Web of Science database; (2) locate the original papers through various sources; (3) locate the passages in the text of the citing paper; (4) examine all the contexts individually, and determine the most frequent or prevalent concept associated with it; (5) finally, a 'synthetic' statement or phrase representing the most frequent mode of citation will be constructed. In this study, the brief citation context analysis was based on articles of four most citing fields, i.e. computer science, information science and library science, education and literary. Citing papers of information science and library science will be the focus of the citation context analysis

and, therefore, be explored more deeply. The results of the citation context analysis determine the nature of the influence of Nelson's works cited by authors in each discipline.

Each relevant record that retrieved from Web of Science was then downloaded to compact disk and analyzed and processed. Bibliometric study usually involves a large set of character string data with a uniform structure. In this study, Access database software, Excel and Perl programming language have been employed to sort and manipulate the data.

Results

Nelson's publications

There are 66 articles that Nelson published from 1965 to 2000. Table 1 summarizes the number of articles yearly. It indicates that his publications remain fairly uniform as measured by number of publications in the last three and half decades. In average, Nelson published approximately two papers each year. The most productive year is 1997, with five articles, followed by four works for the year of 1965, 1987, 1988, 1990 and 1994. Detail bibliography is shown in the Appendix.

Table 1. Distribution of Nelson's publications by year, from 1965–2000

Year	Articles	Year	Articles
1965	4	1984	1
1966	2	1986	2
1967	1	1987	4
1969	2	1988	4
1970	2	1990	4
1971	2	1991	3
1973	2	1992	2
1974	3	1993	3
1975	1	1994	4
1977	2	1995	2
1978	1	1997	5
1980	2	1998	1
1981	2	1999	3
1982	1	2000	1
		Total	66

Direct citation count

Table 2 summarizes the number of articles citing Nelson's works from 1981 to 2002 in SCI, SSCI and A&HCI. The total number of citations of these three databases is 582. To eliminate 117 double or triple counts, the number of identical citations is 465. It should be noted that citing articles included in SCI may also be covered by SSCI and

A&HCI. The same situation may also happen to SSCI and A&HCI. This will be further discussed below. Table 2 reveals that the journals in SSCI cited Nelson's works most, the SCI journals come next and the journals in A&HCI follow. Moreover, the number of citations included in SSCI is significantly higher than the number in the other two citation index databases. This suggests that Nelson's works have the greatest impact on the fields of social sciences as one may expect. Table 2 also demonstrates that the remarkable period for each citation index database is 1996 to 2000 for SCI (79 citations), 1991 to 1995 for SSCI (92 citations) and A&HCI (33 citations), respectively. This may indicate that the science researchers are interested in Nelson's concepts later than the researchers of social sciences and humanities are.

Table 2. Number of articles citing Nelson's works in SCI, SSCI and A&HCI

SCI		SSCI		A&HCI	
Year	Articles	Year	Articles	Year	Articles
1981–1985	15	1981–1985	24	1980–1984	0
1986–1990	36	1986–1990	81	1985–1990	9
1991–1995	58	1991–1995	92	1991–1995	33
1996–2000	79	1996–2000	63	1996–2000	25
2001	13	2001	11	2001	12
2002	12	2002	12	2002	7
Total	213	Total	283	Total	86

Citation date

Table 3 shows the distribution of 465 articles in the three databases that cited Nelson's works from 1981 to 2002. Before 1988, the number of citations Nelson received each year was no more than ten times. Subsequently, the number of citations each year rose from 21 to 43. In 1994, Nelson's ideas were cited most frequently by 43 articles. There are three years, i.e., 1990, 1996, 1999 Nelson possessed more than 30 citations. The reasons for the significant rise of cited rate for Nelson's work after 1988 is given below.

Most of "hypertext" definitions, concepts, ideas and applications were described in Nelson's famous work, namely *Literary Machines*, which initially published in 1981 and followed by 1987, 1988, 1991 and 1993 four updating versions (including another electronic edition in 1987). Many versions of *Literary Machines* published after 1987, illustrated its popularity and may suggest a big jump of citations from 8 to citations greater than 20. As indicated by its subtitle, i.e., *the report on Project of the Xanadu that concerning word processing, electronic publishing, hypertext, thinker toys, tomorrow's intellectual revolution, and certain other topics including knowledge education and freedom* [17], the coverage of this book is exhaustive and, therefore, makes influence on various disciplines and received the most citations. Moreover,

the World Wide Web has been responsible for rapidly bringing hypertext into wide spread use during 1990s. The above two reasons may explain that why Nelson receives most citations after 1988.

Table 3. Distribution, by year, of articles citing Nelson's works from 1981–2002

Citation Year	Articles	Citation Year	Articles
1981	10	1992	27
1982	8	1993	28
1983	4	1994	43
1984	5	1995	26
1985	6	1996	35
1986	6	1997	27
1987	8	1998	21
1988	23	1999	32
1989	26	2000	24
1990	33	2001	25
1991	27	2002	21
		Total	465

Document type of citation

Table 4 shows the distribution of document type of the 465 citing literature on Nelson's works. The most common document type is research article which constitutes 85.3% of the total citing literature. Review articles, the second most frequent type, account for 8.2%. Judging by the fact that research and review articles constitute 93.5% of the total citing literature from 1981 to 2002, one can conclude that Nelson's ideas were most applied to original researches and secondary on review studies.

Table 4. Document type distribution of citing literature, 1981–2002

Document type	Articles	%
Article	397	85.3
Review	38	8.2
Editorial	15	3.2
Book Review	5	1.1
Letter	5	1.1
Software Review	4	0.9
Note	1	0.2
Total	465	100.0

Subject classification analysis

Table 5 shows in more detail the pattern of the influence of Nelson's works on various disciplines, which are categorized by the subject of citing journals from 1981–2002. Among 465 citing works, 29 can not be found in Ulrich Plus database; consequently, the valid articles for analyzing the subject category are 436 in this study. As expected, for Nelson's works, the largest category is computer science, in which

there are 101 out of 436 (23.2%) citations as grouped by discipline of the citing journal. Information science and library science with 96 articles (22%) of citations is the second largest category. Education comes third with 48 articles (11%). Further next are five categories; including literature (5%), business and economics (3.7%), engineering (3.4%), sociology (3.4%), and psychology (3.2%). Other disciplines that contribute five to ten citations are: linguistics, communication, law and medical sciences. The miscellaneous journal category (86 articles, 19.7%) is a catchall for journals covering fields too small to be included as separate entries. Among them, there are 30 disciplines cite Nelson's works only once. The miscellaneous journal category includes lots of areas for each one constitutes less than five articles. They are art, humanities, literary and political reviews, health facilities and administration, sciences: comprehensive works, social sciences: comprehensive works, anthropology, physics, public administration, publishing and book trade, social services and welfare, technology: comprehensive works, agriculture: computer applications, biology, children and youth, ergonomics, geography, history, housing and urban planning, multidisciplinary sciences, music, philosophy. The broad diversity of this category is a further indication of the wide range of the impact of Nelson's concept, especially the idea of hypertext. The impact of Nelson's works on hypertext may be broader and deeper than that reflected by the citations collected in the present study. There may be many other studies using hypertext without even referring to Nelson as the hypertext has now become a common sense in many subjects listed in Table 5.

As shown in Table 5, for the computer category, the largest sub-category is computers-general, accounting for 36.6% (37 out of 101) of citations as grouped by discipline of the citing journal. Computer network, data communications and data transmission systems, two sub-categories come next and constitutes 11.9% each (12 out of 101). Other subcategories include information systems, information science and information theory, software, artificial intelligence, electronic data processing, Internet.

ACM Computing Surveys and *Communications of the ACM* (both are publications of the Association of Computing Machinery) are two most frequently citing journals on computer science. According to the analysis of this study, these two journals constitute 27 articles, (15 and 12, respectively). The remaining 74 articles distributed to 45 journals of computer science, each with no more than six articles. There are 22 journals published only one article relating to Nelson's concept. *ACM Computing Surveys* [18] publishes surveys, tutorials, and special reports on all areas of computing research. It covers image understanding, software reusability, object and relational database topics and would be valuable for professionals to develop perspective on, and identify trends in complex technologies. *Communications of the ACM* [19] is one of the often cited magazines in the computing field. The feature articles cover the latest technical subjects and implementations of computing and information technology. The columns provide such topics as legal issues, business strategies, professional growth, programming

acumen, safety risks, and political matters. Clearly, these two citing core journals are computer science orientation including resources that emphasize experimental computer processing methods or programming techniques. The implementation of hypertext technology highlights the area of computer science recently of greatest relevance to the wide spread usage of Internet.

Table 5. Distribution, by subject, of articles cite Nelson's works from 1981–2002

Rank	Subject of citing journals	Articles
1	Computers	101
	Computers – General	37
	Computers – Computer Network	12
	Computers – Data Communications and Data Transmission Systems	12
	Computers – Information Systems	8
	Computers – Information Science and Information Theory	7
	Computers – Software	7
	Computers – Artificial Intelligence	6
	Computers – Electronic Data Processing	6
	Computers science – Internet	6
2	Information Science and Library Science	96
	Information Science and Library Science – General	82
	Information Science and Library Science – Computer Applications	14
3	Education	48
	Education – General	22
	Education – Higher Education	12
	Education – Computer Applications	7
	Education – Teaching Methods and Curriculum	7
4	Literature	22
5	Business and Economics	16
	Business and Economics – Computer Applications	4
	Business and Economics – General	8
	Business and Economics – Management	4
6	Engineering	15
	Engineering – Electrical Engineering	7
	Engineering – General	4
	Engineering – Computer Applications	4
7	Sociology	15
	Sociology – Computer Applications	9
	Sociology – General	6
8	Psychology	14
9	Linguistics	7
10	Communication	6
11	Law	5
12	Medical Sciences	5
13	Miscellaneous	86
	Total	436

As indicated earlier, there were 96 articles in information science and library science citing Nelson's works. Among them, 14 are pertinent to the applications of computer and 82 articles belong to general studies that providing a broad overview of information science and library science or their foundations. For the latter, seventy-three citing articles were written in English. Other non-English articles' language includes German

(4 articles), Russian (4 articles) and French (1 article). Two of the most citing journals are *Journal of the American Society for Information Science and Technology (JASIST)* and *Annual Review of Information Science and Technology (ARIST)*, each contains 18 and 9 articles, respectively. The remaining 55 articles are dispersing to 26 journals. *JASIST* [20] covers the area of generation, recording, distribution, storage representation, retrieval and dissemination of information, as well as its social impact and management of information agencies, and new information technologies in text analysis, retrieval systems. It has a strong emphasis on new information technologies and methodologies in text analysis, computer based retrieval systems as indicating by the new title (changed in 2002) that has an addition of the word of "technology". On the other hand, *ARIST* [21] is produced for ASIST. It is an annual publication that reviews a wide range of key topics varies considerably reflecting the dynamism of the discipline and the diversity of theoretical and applied perspectives of information science and technology. Lots of hypertext related papers published in these two prominent journals. The citation context analysis of 60 citing papers on information science and library science will be discussed in the next section.

The education category comes third citing Nelson's works, as stated previously, and includes subcategory of higher education, computer applications, courses and teaching methods. The application of hypertext and hypermedia has various influences on teaching and learning especially on the higher education environment. Nelson has suggested that information organized by associative webs or links is superior to information organized sequentially, therefore, hypertext and hypermedia, are two innovations which offer students an opportunity to create their own meaningful learning environment [22]. In general, using the technology of electronic networks to create an online classroom is a challenge for teaching in the digital age. Ted Nelson suggested that "such an object and system, properly designed and administered, could have great potential for education, increasing the student's range of choice, his sense of freedom, his motivation, and his intellectual grasp" [23]. However, hypertext, and the related concept of hypermedia, is indeed, a key element of teaching instruction in this environment.

Literature is another major discipline that cites many of Nelson's concepts on hypertext. The advent of hypertext, or electronic non-sequential writing, poses significant challenges for literary writers. In 1960s and 1970s, Nelson foresaw electronic publishing as the key technology of a de-centered information culture [24]. In his *Literary Machines*, Nelson indicated that "hypertext, from the document as we have long known it, the author, as we have long known him or her, and an extended form of writing as we have long done it and read it, is an ongoing system of interconnecting documents and writings" [25]. Internet, or WWW, is a cybertextual system and hypertext is one of the key features of the system. The impact of cybertext on

intellectual life has altered the conditions of writing and publishing. Hypertext has also made influence on the traditional writing habit and publishing pattern and change the reader's reading behavior for a certain long time.

Citation distribution of cited works

As mentioned previously, Nelson's sixty six articles were cited 582 times on Web of Science database. On average, each article was cited 8.8 times. Table 6 summarizes the citation frequency and corresponding percentage of leading works of Nelson that was cited at least four times. As indicated by Table 6, *Literary Machines* is the most cited book receiving 151 citations (25% of the total citations). *Literary Machines* [26] is Ted Nelson's original and definitive exploration of Project Xanadu that explored the original hypertext system. First published in 1982, *Literary Machines* remains essential reading for anyone deeply interested in hypertext, digital libraries, and the World Wide Web. In this book, Nelson describes his dream project Xanadu as a "universal open hypermedia environment". It also deals with programming of microcomputer, data processing of self publishing. Covering a lot of prospective views on hypertext and hypermedia, it can be understood that *Literary Machines* possessed many citations.

The second often-cited work is *Computer Lib/Dream Machines*. It was cited 145 times for two versions, 107 times for 1974 version and 38 times for 1987 version, and constituted 24% of the total citations. The book is actually two books. It starts from *Computer Lib* (copyright 1974, 1975, 1987) and ended with *Dream Machines* that bound up-side-down. The subtitle of *Computer Lib* [27] is "You can and must understand computers now". The subtitle of *Dream Machines* [27] is "New freedoms through computer screens". The *Computer Lib* predicted that personal computers were coming, and the *Dream Machines*, had greater importance in the development of new media. Nelson [27] proposed that computers would generate new media and these new media would be placed in an open publishing network. For Ted Nelson, computers were "All-Purpose Machines" that could control almost any other machine. Their use should be limited only by our own imagination [28]. Nelson envisioned in 1974, an affordable computer service that would deliver information and entertainment into people's homes.

The above two books received approximately 50% of total citations. Other work that was cited more than 20 times including "Getting It Out of Our System", "Replacing the Printed Word: A Complete Literary System", "A File Structure for the Complex, the Changing and the Indeterminate", and "Managing Immense Storage".

Table 6. Citation data of Nelson's most cited works

Rank	Cited work	Times	%
1	Literary Machines, volume version 87.1., self-published, 1987.	151	25.95
2	Computer Lib / Dream Machines, Mindful Press, 1974.	107	18.38
3	"Getting It Out of Our System". In: George Schlechter (ed), Information Retrieval: A Critical Review. Washington D.C.: Thompson Books, 1967, pp. 191–210.	56	9.62
4	Computer Lib / Dream Machines, 2nd edition, Washington: Microsoft Press, 1987.	38	6.53
5	"Replacing the Printed Word: A Complete Literary System". In: Simon H. Lavington (ed), Information Processing: Proceedings of the 1980 IFIP World Computer Congress, 8, North-Holland, Amsterdam, 1980, pp. 1013–1023.	35	6.01
6	"A File Structure for the Complex, the Changing and the Indeterminate". ACM 20th National Conference, 1965, pp. 84–100.	26	4.47
7	"Managing Immense Storage". Byte, 13(1):225–233, 1988.	26	4.47
8	"The Right Way to Think about Software Design". In: Brenda Laurel (ed), The Art of Human-Computer Interface Design, Reading, MA.: Addison-Wesley, 1990, pp. 235–243.	19	3.26
9	"Interactive Systems and the Design of Virtuality". Creative Computer, 6:11–12, 1980.	12	2.06
10	"Opening Hypertext: A Memoir". In: Tuman, M.C. (ed), Literacy Online. The Promise (and Peril) of Reading and Writing with Computer,. Pittsburgh: University of Pittsburgh, 1992, pp. 43–57.	10	1.72
11	"As We Will Think". Proceedings of the Online '72 International Conference on Online Interactive Computing, Uxbridge England: Brunel University, 1973. Reprinted in: Nyce, James/Kahn, Paul (ed), From Memex to Hypertext: Vannevar Bush and Mind's Machine, Boston, MA: Academic Press, 1991, p.245.	8	1.37
12	The Home Computer Revolution, (self-published) 1977.	7	1.20
13	"All for One and One for All". Proceedings of the Hypertext '87 conference, November 1987.	7	1.20
14	"A New Home for the Mind". Datamation, March 1982, pp. 168–180.	6	1.03
15	"The Tyranny of the File", Datamation, December 1986, p.15.	6	1.03
16	"The Heart of Connection: Hypermedia Unified by Transclusion". Communications of the ACM, 38(8):31–33, 1995.	6	1.03
17	"Electronic Publishing and Electronic Literature". In: Edward DeLand (ed), Information Technology in Health Science Education, Plenum Press, 1978.	5	0.86
18	"The Unfinished Revolution and Xanadu". ACM Computing Surveys, 31(4es), 1999.	4	0.69
19	"On the Xanadu Project". Byte, 15(9):298–299, September 1990.	4	0.69
20	"The Call of the Ocean: Hypertext Universal and Open". HyperAge, May-June, 1988.	4	0.69
21	"Embedded Markup Considered Harmful". In: XML: Principles, Tools, and Techniques (World Wide Web Journal 2(4), Fall, 1997).	4	0.69
22	Others	41	7.04
Total		582	100

Citation context analysis of citing articles on information and library science

Citation context analysis deals with the semantic content of the text to which the key paper citation is linked. It requires that the citing papers be read to determine the contexts in which the cited papers were used, and the semantic content of the text surrounding the citations. It is interesting to examine the specific hypertext concept, as proposed by Nelson, has been cited in the field of information and library science. The online searching of Web of Science database (as shown in Table 5) resulted in eighty-two highly citing articles of general information science and library science. Twenty-two of them were unable to locate and therefore excluded in this study. All of the remaining 60 citing paper are journal articles presenting primary research or reviews of the literature. To provide the greatest possible contrast among individual papers, while keeping the task of analysis to some reasonable size, these 60 papers were read thoroughly. In other words, these 60 papers were the focus of the context analysis. This analysis will survey the literature that cited Nelson's work. The survey is intended to show the range of hypertext influence rather than to be a comprehensive review, therefore, not every citation is described in the following section.

After citation context analysis, the passages of hypertext or its corresponding information can be grouped into four categories, i.e. (1) definition, orientation and general introduction of hypertext; (2) relation of Vannevar Bush and Ted Nelson in terms of hypertext; (3) Nelson's Xanadu system and its component of hypertext; (4) the application of hypertext in information science and library science.

The largest category of citation context is Nelson's definition and interpretation on hypertext. The following are examples of citation contexts, which may reveal how these issues were treated by the authors in their citing papers. The term hypertext was originally created by Ted Nelson in 1965 as he believed that text systems should reflect the hyperspace of concepts implicit in the text [29]. His philosophy of "everything for any user" inspired vast application of links by every hypertext user [30]. Then, in his book *Literary Machines*, Nelson developed the concept and introduced the definition of hypertext as *non-sequential writing* – "text that branches and allows choices to be made, [and] is best read at an interactive screen" [31]. Nelson's ideas about hypertext, was to "create a shared information space through which large number of people and machines could communicate via associative links" [32]. His objective was "a coherent stable world for a unified, lasting literature...a reasonably static landscape that can be seen through any of the new, dynamic electronic windows" [33]. Nelson introduced that hypertext "is a body of written or pictorial material interconnected in such a way that it could not conveniently be presented or reproduced on paper. It may contain summaries, or maps, of its contents and their interrelations"[23]. Nelson interpreted that Hypertext was a text presentation system of "making rapid, arbitrary jumps, where material stored

in one place may offer a link, much like a footnote, to material stored in another, in either the same or a different document" [34]. In other words, hypertext allows users to structure, access, and manipulate information within a spatial network of nodes and links [35]. In addition to hypertext, Nelson also presented the facts and ideas of "hypermedia" (also known as "interactive-multimedia") [31]. Hypermedia refers to computerized systems that incorporate multiple linkages between items of information within a variety of media [36]. Hypermedia systems have emphasized means by which text or media fragments may be organized or structured through the addition of links [37].

Historically, many of the concepts underlying hypertext were outlined by Vannevar Bush in 1945 [38]. Many citing papers link Nelson's hypertext to Bush's Memex. These citations constitute the second largest group of citing papers. The followings are some examples showing how the authors of citing papers interpreting the link between Nelson's hypertext and Bush's Memex. The "hypertext" was first appearing as Bush's MEMEX and proposed in much its present form by Theodor Nelson [39]. "Vannevar Bush is often cited as the 'founder' of the concept of hypertext. The term itself was coined by Ted Nelson"[40]. Hypertext is a term invented by Ted Nelson to describe "a system that would index and link very large numbers of documents building on the 'MEMEX' notion of Vannevar Bush" [41]. "The idea of linking knowledge was first advanced in 1945 by Vannevar Bush, computer scientist (e.g. Ted Nelson) attempted to realize some of Bush's ideas with electronically interconnected text and multimedia information" [42]. Bush's original notion of an associative structure for organizing one's own storehouse of information has been extended by visions of an international and universal archival system such as Xanadu [43]. "We have essentially achieved the Memex and Xanadu system dreams of Vannevar Bush and Ted Nelson, envisioned 50 and 20 years ago respectively" [44]. "We are now in the midst of a "seismic" shift of digital content and context from the global repository (i.e., Bush's *memex* through Nelson's *docuverse* to the global resource" [45]. "The opportunities created by the electronic manipulation of text have prompted futurists to propose "hypertext" be equivalent to Memex" [46].

The third category of citation context concerns about Nelson's Xanadu system. Examples of how authors of the citing papers viewed the Xanadu system are given below. Nelson suggested that "parts of books and articles could be stored in dispersed computer systems and linked electronically in various ways by different readers. This approach with each reader a potential linker and creator, would be supported by Xanadu system of providing contributions to the document base and trails of links" [47]. Xanadu system, has no support for hierarchical structures [48], was designed to be the principal publishing utility, i.e. hypertext publishing, of the future [49]. The development of Xanadu system led to the concept of hypermedia [47]. Xanadu system provided for "the deposit, delivery, and continual revision of linked electronic documents, servicing hundreds of millions of simultaneous users with hypertext,

graphic, audio and movies" [50]. "The early emphasis on distributed, and thus collaborative, text is one of the distinguishing features of Xanadu TM system"[51]. In Nelson's Public Access Xanadu (PAX) system, documents were encoded with accounting software, which would be tally royalty payments and bill patrons' accounts accordingly [52]. "The Xanadu architecture is instantiated in part in the Hyper-G and HyperWave systems. A key idea in this body of work is transclusion, the including of virtual copies of passages from diverse sources into a single document"[53].

The application of hypertext to information science and library science is the fourth category of citation context. Some significant applications showing the view of citing authors are given as follows. A review of the literature on personal information systems would have shown that several individuals and a few institutions had recognized the value of supporting the scientists by hypertext in this area [54]. Nelson "envisioned a system that would allow everyone access to all published material: the documentary universe, or 'docuverse' of information". According to Nelson, all texts should be treated equally and with no censorship. In his opinion, "the purpose of computers is human freedom" [55]. Nelson stated that "one of the greatest problems on libraries application of the year 2000 is how to make the reader feel comfortable and oriented". The incidental cues in books and magazines that Nelson mentioned may be important stimuli in an OPAC [56]. Nelson's technoids began to appear in force in libraries after 1970. Their appearance coincided with the beginnings of widespread automation of libraries. Thereafter, "if we go with the implications of Nelson's analysis, librarianship became an arena of struggle between the technoids and the humanists"[57]. Ted Nelson's idea of the Xanadu Docuverse was becoming reality as a worldwide virtual library would be established by means of virtual electronic documents which were linked together by Hypertext and Hypermedia features [58]. Nelson's Xanadu project was intended "to provide online libraries to which people can add their own links and annotations on others' work as well as their own new papers" [59]. In information retrieval, database refers to a collection of documents, where a document following Nelson's definition, is "a package of information created by someone" [60]. Nelson in a series of papers criticized the approach taken in most computer-based information retrieval systems, asserting that of Bush's "associative trail" has been largely ignored [3]. Nelson described hypertext systems in which "associations (links) between parts of text files are easily built and followed"; at the same time he predicted that "computers would become nearly universal tools with hypertext systems profoundly affecting the way we record, disseminate, and access information" [61]. Roughly the XANADU is "a system whereby one person thinks of something, communicates it via computer, and others add glosses to it, while still others add glosses to the glosses, and son on". This feature is one kind of user friendliness in online searching system [62]. Nelson's proposal for hypertext is "suggestive of how such links between citing and cited documents could be followed, moving from citing to cited document and back again

when the full text of documents is available for display" [63]. Nelson predicted the actualization of hypertext in the new environment of electronic media. He called on people to "imagine a new libertarian literature with alternative explanations so that anyone can choose the pathway or approach that best suits him or her" [2].

Summary and conclusion

This work explores Ted Nelson's works and the impact of his hypertext concept through citation analysis including citation counting, characteristics of citing articles including language, document type, citing year, subject, and citation context analysis. The following conclusions may be drawn from the results of this study.

1. The journals in SSCI cited Nelson's works most and the citation is significantly higher than that for SCI and A&HCI journals, which rank second and third, respectively. This suggests that Nelson's works have the greatest impact on the fields of social sciences. It is also found that the science researchers are influenced by Nelson's concept later than the researchers of social sciences and humanities are.
2. Most of the citations to Nelson's works appear after 1988, after the updating and electronic editions of *Literary Machines*, which is Nelson's famous work illustrating the "hypertext" definitions, concepts, ideas and applications.
3. Research article is the most common type citing Nelson's works which constitutes 85.3% of the total citing literature. Review article, the second most frequent type, accounts for 8.2%.
4. The largest category of citing literature on Nelson's works is computer science, as expected, which contributes 23.2%. The second largest group (22%) is information and library science. On the other hand, 19.7% of citing journal category constitutes less than five articles indicating the broad diversity of the impact of Nelson's concept.
5. On average, each of Nelson's sixty six articles was cited 8.8 times. *Computer Lib/Dream Machines* and *Literary Machines* are the most and second often-cited works of Nelson.
6. The citation context analysis of citing articles on the subject of information and library sciences reveals that
 - (1) The largest category of citation context is Nelson's definition and interpretation of hypertext.
 - (2) Many citing papers link Nelson's hypertext to Vannevar Bush's Memex.
 - (3) The third category of citation context concerns about Nelson's Xanadu System.
 - (4) The application of hypertext to information science and library science is the fourth category of citation context.

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Appendix

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