

Mapping the Intellectual Structure of Digital Divide

Cheng-Hua Wang, Yender McLee, and Jen-Hwa Kuo

Abstract—To explore the intellectual structure of digital divide research in the last decade, 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 and social network analysis techniques are used to investigate the intellectual pillars of the digital divide literature. By analyzing 26,966 citations of 852 articles published in SSCI journal in digital divide area between 2000 and 2009, this study maps a knowledge network of digital divide studies. The results of the mapping can help identify the research direction of digital divide research and provide a valuable tool for researchers to access the literature in this area.

Index Terms—digital divide; social network; ethnic bulling; diffusion innovation

I. INTRODUCTION

As the diffusion of information and communication technologies (ICT) has occupy a central position in both international and national forums [6][12][18]. The past decade has especially seen extensive research on digital divide. Yet even though digital divide 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 digital divide lies in the subject's unusually high degree of interaction with other disciplines. This overlapping blurs the boundaries of digital divide 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 digital divide, the cross-fertilization of ideas between scholars of digital divide will be much more difficult to obtain. Consequently, while there is no doubt that there is an area or field of digital divide, 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 aim of this study is to provide digital divide researchers with a unique map to better understand digital divide related publications and to provide a systematic and objective mapping of different themes and concepts in the development of digital divide 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 digital divide 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 digital divide literature.

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 [5] 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 [9].

Several studies have used the bibliometric techniques to study the literature of management research. For example, Ponzi [16] explored the intellectual structure and interdisciplinary breadth of digital divide in its early stage of development, using principle component analysis on an author co-citation frequency matrix; Etemad [7] identified the most influential authors and studies in electronic commerce field by using citation analysis; Ramos-Rodriguez and Ruiz-Navarro [17] examined the intellectual structure change of strategic management research by conducting a bibliometric study of the Strategic Management Journal; Acedo and Casillas [1] explored the research paradigms of international management research by applying factorial analysis techniques in an author co-citation study. Chan, Seow and Tam [4] used citations from accounting dissertations completed during 1999-2003 to provide a ranking of accounting journals. To the best of our knowledge, no similar study has been conducted on the current research of digital divide. Therefore this study aims to fill a gap in digital divide literature by applying citation and co-citation analysis to a representative sample of recent research on digital divide 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 digital divide between 2000 and 2009. This time period was chosen because contemporary digital divide studies of the last five

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years represent the most update and probably also the most important research on digital divide. Citation and co-citation analysis is the main method for this study. First, the databases were identified as the sources of digital divide publications. Then data collection and analysis techniques were designed to collect information about topics, authors, and journals on digital divide research.

In the second stage, the collected data were analyzed and systematized by sorting, screening, summing, sub-totalling, and ranking. After a series of operations, key nodes in the invisible network of knowledge in digital divide were identified and the structures developed. In the final stage, the co-citation analysis was used and the knowledge network of digital divide was mapped to describe the knowledge distribution process in digital divide 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 8000 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 digital divide publications.

Unlike other prior studies, the data used in this study were not drawn from journals chosen by peer researchers [20]. Instead, the entire databases of SCI and SSCI from 2000 to 2009 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 "Digital divide" as key word, this study collected 852 journal articles which further cited 26,966 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 digital divide research, citation data were tabulated for each of the 1,224 source documents and 67,723 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 digital divide area in the decade years, among which *Telecommunications Policy*, *Information Society*, and *Jama-Journal of the American Medical Association* are the top three most cited journals, followed by *New Media & Society* and *Communications of the ACM*. The general pattern of the most cited journals shows that digital divide research features strategic, management and finance specific journals.

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 digital divide publication between 2000 and 2004 (the first five years) was Hoffman's paper *Bridging the racial divide on the internet*, followed by Kraut's paper *Internet paradox: A social technology that reduces social involvement and psychological wellbeing*,

and Norris's book *Digital divide civic* (see Table 2).

TABLE1 THE MOST FREQUENTLY CITED JOURNALS: 2000-2009

Journals	Total Citations
Telecommunications Policy	318
Information Society	202
Jama-Journal of the American Medical Association	156
New Media & Society	143
Communications of the ACM	137
Communications Research	124
Journal of the American Medical Association	124
British Medical Journal	123
Journal Medical Internet Research	119
Computers in Human Behavior	108
MIS Quarterly	96
Digital Divide Civic	86
International Journal of Medical Informatics	84
American Behavioral Scientist	82
Social Science Computer Review	78
Health Affairs	76

For the second five years (2000-2009), the most cited digital divide publications were the same as in the first five years. The third most cited was Norris's book *Digital divide civic* and Warschauer's book *Technology and Social Inclusion: Rethinking the Social Divide* and Van dijk's paper *The digital divide as a complex and dynamic phenomenon* (See Table 3).

TABLE 2 HIGHLY CITED DOCUMENTS: 2000-2004

Total Citations	Full Citation Index For Document
18	Hoffman DL, 1998, Science, V280, P390
15	Kraut R, 1998, American Journal Psychology, V53, P1017
14	Norris P, 2001, Digital Divide Civic
12	Parker EB, 2000, Telecommunications Policy, V24, P281
10	Negroponte N, 1995, Being Digital
10	Rogers EM, 1995, Diffusion Innovation
9	Bolt D, 2000, Digital Divide : Computer and Our Children's Future
9	Castells M, 1996, The Rise of the Network Society, Massachusetts
8	Brodie M, 2000, Health Affairs, V19, P255
8	Bucy EP, 2000, The Harvard International Journal of Press/Politics, V5, P50
8	Graham S, 1996, Telecommunications and the City: Electronic Spaces, Urban Places
8	Putnam RD, 2000, Bowling alone: The Collapse and Revival of American Community
8	Warschauer M, 2003, Technology and Social Inclusion: Rethinking the Social Divide

Journal articles and books combined, the top five most cited scholar between 2000 and 2004 (the first five years) were Castells, Norris, Hoffman, Kraut and Katz (See Table 4). For the second five years, the status of the most important scholars changed. The top five most cited scholars were Hill, Hargittai, Norris, Warchauer, and Castells (See Table 5).

These scholars have the most influence in the development of digital divide 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 Digital divide topics as well as their historical values.

TABLE 3 HIGHLY CITED DOCUMENTS: 2005-2009

Total Citations	Full Citation Index For Document
75	Norris P, 2001, Digital Divide Civic
43	Warschauer M, 2003, Technology and Social Inclusion: Rethinking the Social Divide
34	Van dijk J, 2003, The information society, V19, P315
27	Mossberger K, 2003, Virtual Inequality: Beyond the Digital Divide
24	Hargittai E, 1999, Telecommunications Policy, V23, P701
23	Brodie M, 2000, Health Affairs, V19, P255
23	Compaine BM, 2001, The Digital Divide: Facing a Crisis or Creating a Myth?
22	Dimaggio P, 2001, Annual Review of Sociology, V27, P307
20	Castells M, 2001, Internet Galaxy: Reflections on the Internet, Business, and Society
20	Dimaggio P, 2004, Social Inequality, P355
20	Hoffman DL, 1998, Science, V280, P390
20	Lenhart A, 2003, The Ever-shifting Internet Population: A New Look at Internet Access and the Digital Divide
20	Rogers EM, 1995, Diffusion Innovation

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 Digital divide 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 digital divide as a distinct phenomenon. A comparison between Table 2 and 3 reveals some interesting patterns from the first five years (2000-2004) to the second five years (2005-2009). First, the top four most influential publications in the last five remain the same, indicating their dominant status for the past decade in digital divide studies. This is also true for the top five most influential scholars in the last five years. Second, on the one hand, the most cited publications in the first five years have relatively smaller number of citations, comparing with the publications in the second five years.

TABLE 4 HIGHLY CITED AUTHORS: 2000-2004

Author	Frequency	Author	Frequency
Castells M	39	Wellman B	23
Norris P	31	Parker EB	19
Hoffman DL	30	Bimber B	18
Kraut R	27	Eysenbach G	18
Katz JE	24	Warschauer M	18

The gradual increase in the total citations supports the evolving process of digital divide 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 five years and the second five years do not change much. This indicates the development in digital divide is slow and a few classical works and influential authors still dominate the digital divide research. More efforts and theoretical breakthrough are thus needed in order to further advance the development of digital divide research.

TABLE 5 HIGHLY CITED AUTHORS: 2005-2009

Author	Frequency	Author	Frequency
Hargittai E	102	Vandijk J	65
Norris P	96	Dimaggio P	61
Warschauer M	88	Selwyn N	60
Castells M	77	Livingstone S	59
Fox S	69	Lenhart A	52

B. Co-citation Analysis

In this stage, data mapping was conducted and an intellectual structure of current Digital divide 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 [19].

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 ten years and 30 in the second five 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].

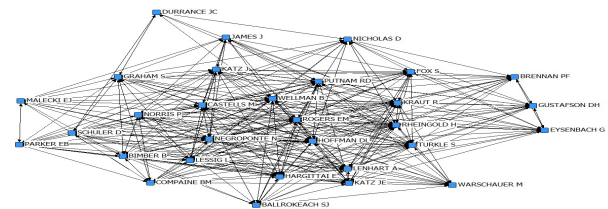


Figure 1 Key Research Themes in Digital divide (2000-2004)

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 digital divide [15]. Figure 1 and Figure 2 show the core research themes in Digital divide 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 [2] 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 digital divide area is concentrating on the interactions of essential of technological diffusion, ethnic bullying, different cultural practices, diffusion innovation and technology adoption. The few scholars in Figure 1 and 2 with the most links (co-citation) are the super stars in digital divide research. Their heavy citations and intensive interlinks with each other undoubtedly indicate their prestigious status in digital divide research and their publications and research work collectively define the future research directions of digital divide studies.

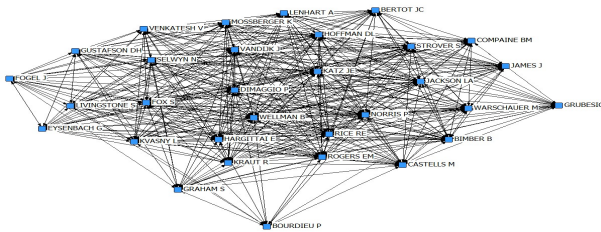


Figure 2 Key Research Themes in Digital divide (2005-2009)

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 [22].

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 [13].

Six factors were extracted from the data in the first five years (2000-2004) and together they explained over 79.6% of the variance in the correlation matrix. Table 6 lists the six 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 [21]. 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 digital divide research in this period is composed of at least three different sub-fields: racial divide, urban digital divide and digital service (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.

Similarly, studies on digital divide also clustered on different research themes between 2005 and 2009 and together they explained over 79.2% of the variance in the

correlation matrix of the second five years, as pictured in Figure 2. Table 7 lists the eight 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 digital divide research at this stage is also composed of at least four key subfields: technological diffusion, ethnic bullying, different cultural practices and diffusion innovation.

Figure 1 and Table 6 clearly indicated that the most influential authors in digital divide studies between 2000 and 2004 clustered together. The first factor in Table 6 appears to define racial divide by Hoffman, Katz and Schuler. Hoffman and Novak [11] use Americans collected data on race and ethnicity, from December 1996 through January 1997. Whites and African Americans student also different habit of where they had ever used the Web. Whites were significantly more likely to have ever used the Web at home; Whereas African Americans more likely used the Web at School. Because 73% of white students owned a home computer, only 32% of African American students owned one.

TABLE 6 AUTHOR FACTOR LOADINGS: 2000-2004

Factor 1: Racial divide	variance	Factor 2: Urban digital divide	variance
Hoffman DL	0.830	Graham S	0.930
Katz JE	0.798	Malecki EJ	0.925
Schuler D	0.787	Negroponete N	0.757
Turkle S	0.777	Hargittai E	0.658
Katz J	0.751	Lessig L	0.537
Wellman B	0.731		
Kraut R	0.592		
Rheingold H	0.534		
James J	0.526		
Factor3: Digital service	variance	Factor4: Ethical issues	variance
Nicholas D	0.941	Eysenbach G	0.904
Fox S	0.924	Lenhart A	0.697
Gustafson DH	0.641	Brennan PF	0.668
Factor 5: Social Divide	variance	Factor 6: Digital divide civic	variance
Putnam RD	0.648	Norris P	0.813
Warschauer M	0.585	Lessig L	0.604
Rheningold H	0.569	Bimber B	0.592
Kraut R	0.564		
Rogers EM	0.532		

Factor 2 is defined by Graham, Malecki and Negroponete, and appears to represent urban digital divide research. Information and communications technologies (ICTs) allow specialist urban centre extend their powers, market and control over ever-more distant regional, national,

international and even global hinterlands [10].

Factor 3 represents digital service is defined by Nicholas, Fox and Gustafson. A digital service, like a web site, may contain a lot of information but we often do not know if it is used, relevant or valuable. Even for digital services of the same organization, to adopt different page naming conventions for each service. This is even truer about digital services run by different organizations [14]. Factor 4 represents Ethical issues is defined by Eysenbach, Lenhart and Brennan.

For the second five years, Figure 2 and Table 7 clearly indicated that the most influential authors in digital divide studies between 2005 and 2009 also clustered together.

The first factor in Table appears to define the Technological Diffusion of digital divide is defined by Compaine, Mossberger and Bimber. The digital divide is closing among various ethnic, racial, and geographical groups in access to the Internet. At least two factors account for the rapid diffusion of internet technology; steadily decreasing costs of use, and steadily increasing ease of us [5].

TABLE 7 AUTHOR FACTOR LOADINGS: 2005-2009

Factor 1: Technological Diffusion	variance	Factor 2: Ethnic Bulling	variance
Compaine BM	0.929	Fox S	0.954
Mossberger K	0.821	Gustafson DH	0.861
Bimber B	0.805	Fogel J	0.837
Van Dijk J	0.795		
Bertot JC	0.778		
Kvasny L	0.776		
Warschauer M	0.711		
James J	0.604		
Selwyn N	0.551		
Livingstone S	0.537		
Factor 3: Different cultural practices	variance	Factor 4: Diffusion innovation	variance
Bourdieu P	0.856	Rogers EM	0.956
Hargittai E	0.826	Hoffman DL	0.871
Factor 5: Racial divide	variance	Factor 6: Interactive information network	variance
Jackson LA	0.889	Castells M	0.862
Wellman B	0.742	Kraut R	0.776
Lenhart A	0.643	Dimaggio P	0.569
Norris P	0.601		
Factor 7: Technology adoption	variance	Factor 8: Rural internet connective	variance
Venkatesh V	0.770	Strover S	0.676
Rice RE	0.573	Grubestic TH	0.664

Factor 2 is defined by Fox and Gustafson, and appears to represent ethnic bulling on digital divide. Fox [8] study examined relations between the incidence of workplace

bullying and the everyday experiences of members of ethnic and racial minorities in the American workplace. The most striking finding of this study was the ubiquity of bullying among the survey participants nearly all (97%) had experienced some form of general bullying over the past five years at work.

Factor 3 represents different cultural practices of digital divide are defined by Bourdieu and Hargittai. The different cultural practices are recognized and taught by the educational system, and the influence of social origin is strongest. The socially recognized hierarchy of the arts, and within each of them, of genres, schools or periods, correspond a social hierarchy of the consumers. Culture also has its titles of nobility - awarded by the educational system- and its pedigrees, measured by seniority in admission to the nobility [3]. Factor 4 represents diffusion innovation that is defined by Rogers and Hoffman. Factor 5 represents racial divide that is defined by Jackson, Wellman and Lenhart.



Figure 3 Tag clouds in key word of Web Services (2000-2004)

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 [23][24]. 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 digital divide 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 digital, divide, information, internet, technology, social, computer and health.

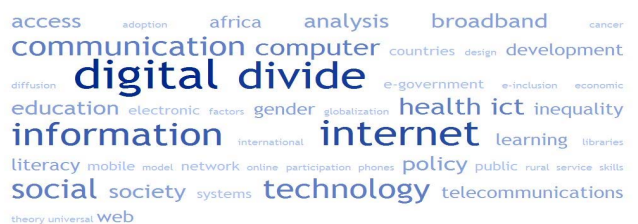


Figure 4 Tag clouds in key word of Web Services (2005-2009)

V. CONCLUSION

The past decade years have seen extensive research on digital divide. This study investigates digital divide research using citation and co-citation data published in SCI and SSCI between 2000 and 2009. With a factor analysis of the co-citation data, this study maps the intellectual structure of digital divide research, which suggests that the contemporary digital divide research is organized along different concentrations of interests: essential of technological diffusion, ethnic bullying and different cultural practices.

The mapping of the intellectual structure of digital divide studies indicates that digital divide has somehow created its own literature and that it has gained the reputation as a legitimate academic field, with digital divide specific journals gaining the status required for an independent research field, such as the Telecommunications Policy and Information Society. Given that the digital divide is still young and our analysis has shown that it has an evolving structure, it is believed that digital divide 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 digital divide studies, how they relate, and what they stand for. With more scholars and more resources contributing to the digital divide area, a better academic environment conducive for research ideas' cross-fertilizing will be formed and digital divide, as a field, will gain more momentum for further development.

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