Hyperlink network analysis: A new method for the study of social structure on the web

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Hyperlink Network Analysis: A New Method for the Study of Social Structure on the Web[1]

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This paper identifies hyperlink network analysis (HNA) as a newly emerging methodology. It suggests that social (or communication) structures on the web may be analyzed based on the hyperlinks among websites. Hyperlink network analysis has advantages in describing emerging structures among social actors on the web. In order to examine what constitutes hyperlink network analysis, this paper reviews prior research on the topic. Further, it describes the data-gathering techniques for those interested in hyperlink network analysis.

INTRODUCTION

The Internet represents a new channel for communication. As a result, we recently have witnessed a surprising growth of Internet studies across many disciplines.[3] Although researchers have conceptualized the Internet differently, it was originally characterized as the network of networks (Berners-Lee, 1999). The basic structural element of the Internet is the hyperlink. A hyperlink may be defined as a technological capability that enables one specific website (or webpage) to link with another.

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[3] The Association of Internet Researchers may be a good example. It was established with the advancement of the cross-disciplinary field of Internet studies. For more information, see the AoIR web site at: http://aoir.org

Hyperlinks let individuals or organizations running websites on the Internet expand their social or communication relations by making possible easy and direct contact among people or groups anywhere in the world. Using hyperlinks, people are able to have bilateral communication and coordination that crosses and/or strengthens off-line boundaries within and between organizations. In a hyperlink system, they can be linked together, exchange information, and maintain cooperative relationships by means of hyperlinks around a common background, interest, or project. This new form of communication structure can be seen on the world wide web.

As a methodology to study hyperlinks among websites, Jackson (1997) suggested that the methods of social network analysis (SNA) are applicable.[4] A social network is a set of nodes (people, organizations or other social entities) connected by a set of relationships, such as friendship, affiliation or information exchange (Wasserman & Faust, 1994). SNA is a set of research procedures for identifying structures in social systems based on the relations among the system components (also referred to as nodes) rather than the attributes of individual cases (Rogers & Kincaid, 1981; Richards & Barnett, 1993). SNA may be useful for understanding the interplay between computer-mediated social processes (Garton, Haythornthwaite, & Wellman, 1997). In particular, Jackson argued that hyperlink-based network analysis is a strong approach for studying the representation and interpretation of the web communication structure. Recently, several researchers have taken a hyperlink-based approach to investigate the Internet. To these researchers, hyperlinks on the web are considered not simply as a technological tool but as a newly emerging social (or communicational) channel. The website is regarded as an actor and the hyperlink among sites represents a relational connection or link.

The purpose of this paper is to identify a new and growing area of interest: hyperlink network analysis (HNA). This paper reviews the past research that used HNA, examines the implications for the study of the social structure on the web, and describes data-collecting techniques for HNA.

DEVELOPMENT OF SOCIAL NETWORKS

From Social Network to CMC Network.   SNA focuses on patterns of relations among people, organizations, or nation states (Wasserman & Faust, 1994). This research approach has rapidly developed in the past twenty years, principally in sociology (Galaskiewicz & Wasserman, 1993; Wellman & Berkowitz, 1989), science studies (Ben-David & Collins, 1966; De Solla Price, 1986; Mullins, 1972), and communication science (Richards & Barnett, 1993; Rogers & Kincaid, 1981; Monge & Contractor, 2000). As presented in Table 1 and in Figure 1, a social network is composed of nodes (people, groups, organizations or other social entities such as nation-state) connected by a set of relationships (Wellman & Berkowitz, 1994). Compared to this, a communication network

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[4] Before moving onto further discussion, we should make a few things clear. Jackson (1997) argued that the methods of SNA are useful in studying the hyperlink-mediated web communication. A distinction must be made between those hyperlink researchers who adopted SNA as their methods and others who didn't (e.g., Henzinger, 2001; Kleinberg, 1999; Thelwall, 2001). The two groups of research appear similar but they differ in that some do or do not use the methods of SNA. We call the research which employed SNA hyperlink network analysis (HNA) research. Because both groups have contributed to shaping the new method, this paper artificially conflates the two somewhat in order to elicit the nature of HNA (Brunn and Dodge, 2001; Halavais, 2000; Palmer, Bailey, and Faraj, 2000).

Table 1. Comparison between Hyperlink Network and Other Networks

Type of Network	Conceptual Definition	Operational Measure	Content of Relation/Link
Social Network	A set of people (or organizations or other social entities) connected by a set of relationships	Individual, Group, Organization, Nation-State	Any Kind of Social Relation
Communication Network	A network composed of interconnected individuals linked by patterned flows of information	Same as above, but generally focuses on individual people	Communication and Information
Computer-mediated Network	A specific type of communication network in which individuals are interconnected by computer systems	Same as above, but also includes computer systems	Same as above, but restricted to computer as channel of information flow
Internet Network	A communication network connected by the Internet among computer systems	Same as above, but focuses on Internet users	Same as above, but restricted to Internet as channel of information flow
Hyperlink Network	An extension of traditional communication networks in that it focuses on the structure of a social system based on the shared hyperlinks among websites	Same as above, but focuses on websites which represent Individuals, Groups, Organizations, Nation-States	Same as above, but restricted to hyperlink as channel of information flow

* Examples of each network can be readily found from the following references: Garton, Haythornthwaite, & Wellman (1997), Monge & Contractor (2000), Rice (1994), Richards & Barnett (1993), Rogers & Kincaid (1981), Wasserman & Faust (1994), and Wellman & Berkowitz (1989).

is a network composed of "interconnected individuals who are linked by patterned flows of information" (Rogers & Kincaid, 1981, p.346). The nodes in a communication network are the same as those in a traditional social network (generally individual people); the contents of the social relation (or link) are communication exchanges or information transfers. With the development of communication/information technologies, the approaches scholars have developed to analyse communication networks have becoming increasingly diverse: computer-mediated communication (CMC) networks, Internet networks, and hyperlink networks.

CMC network analysis places its focuses on a specific type of communication network in which individuals are interconnected by computer systems including computer conferencing, computer bulletin boards, facsimile, and group decision support systems (Rice, 1994). Scholars studying CMC networks (or networking) emphasize computer systems as the channels of information flow. With the emergence of the Internet, a communication network among computer systems connected by the Internet forms an important CMC network. The following section reviews recent studies that use SNA in the CMC environment.

In the past, several researchers have examined communication networks among computer conference users (Danowski & Edison-Swift, 1985; Rice, 1982; Rice & Barnett, 1986). Following this approach, Paccagnella (1998) used SNA to examine the structural communication pattern of Italian

cyber_punk computer conferences. In addition to network analysis, he has applied content analysis to find how different types of language are used according to a participant's position in the network. He found that an actor's centrality is positively correlated with the use of computer network slang and terms which show a collective identity.
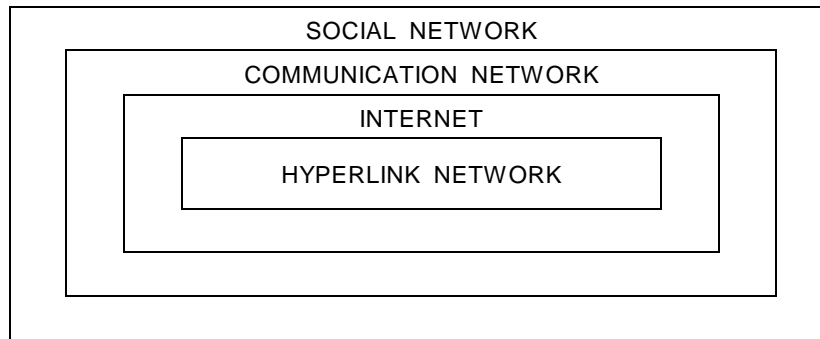
HYPERLINK NETWORK ANALYSIS

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│                  SOCIAL  NETWORK                      │
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│   │            COMMUNICATION  NETWORK               │  │
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│   │     │               INTERNET               │     │  │
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│   │     │   │      HYPERLINK  NETWORK      │    │     │  │
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Figure 1. Relation between Hyprlink networks and other Social or Communication networks

Haythornwaite and Wellman (1998) used network analysis to examine the pattern of relations and media use among 25 computer scientists in a university research group based upon their working and friendship relations, the frequency of communication, the information exchange relationship, and the types of media used. They found that those who communicated more frequently were involved in more types of information exchange relationships and used different media. The amount of usage of each medium was also higher. The closeness of work ties and of friendship ties respectively had a positive impact on those relationships. The type of information being exchanged influenced the types of media used. For example, electronic mail was more often used in work-oriented relationships than in socializing and exchanging major emotional support.

Kang and Choi (1999) analyzed the network of message flows among usenet users. Looking at cross-posting patterns of international news on the Internet, they analyzed the news content posted by users according to destination (country, region, or international organization). The results were consistent with the past world-system research on international communication: dominance of traditional core countries like the United States, the United Kingdom, and Japan; and Chinese-dominated Asian countries' move toward the core (Barnett, 2001). Also, international organizations such as the United Nations and the World Bank were relatively central in the international news flow network.

Computer conference participants, coworkers, usenet users, and online networks of learners are at the centre of network-oriented CMC studies. Haythornthwaite (2000), using survey and interview data from four computer-supported distance learning classes, investigated the communication networks among the students. She analyzed the individuals' ego networks in an online learning environment in terms of size, type and pattern of relationship. She found that the characteristics of online networks were similar to those of offline social networks. The student's network sizes were in proportion to class size but the strength of this relationship decreased as class size increased. Compared to the least frequent communicators, more frequent communicators had more social and emotional interactions that were more supportive of current and future relationships. Also strongly connected students tended to use more Internet Relay Chat (IRC) and email to maintain the relations.

In contrast to these studies, Hampton and Wellman (2000) extended the role of CMC to offline life. In a study of a high-technology village in Canada, they used four methods (ethnographic observation, computer-assisted surveys, monitoring an online community forum, and focus groups) to examine the residents' community ties online and offline after the introduction of a high-speed network. They found that the wired village's residents had more social interactions including conversation and visiting in comparison to their non-wired counterparts. They argued that online network served to make social ties among residents stronger and denser, as the Internet was used more for local social contacts than for global communication.

In the context of CMC, social network researchers have concentrated on how specific social or technical attributes of computer-based media influence how people communicate with others (Rice, 1994; Garton *et al.*, 1997). These scholars have focussed on how people use CMC to maintain relations or on what communication network structures online look like. This tendency still prevails. However, one body of research examines actors linked by the hyperlinks on their websites rather than the individuals themselves.

NEW CMC NETWORK: HYPERLINK NETWORK

Recent studies of CMC networks have tended to examine the structural relationship between people and how their positions in the network affect their behavior and attitudes. They have been interested in how individuals' lives, embedded in a CMC environment, affect their interpersonal relations with coworkers, friends, classmates, residents, computer conference users, and online group members. In this research, the nodes in the networks have been individual people.

Recently, a group of scholars have begun to describe websites as actors. From this perspective, an actor is a website belonging to a person, private company, public organization, city, or nation-state. These nodes are linked by their hyperlinks. Hyperlink network analysts argue that despite the Internet's brief existence, its increasing role in communication has been made possible by the continual change in the structure of the network of hyperlinks. Patterns of hyperlinks designed or modified by individuals or organizations who own websites reflect the communicative choices, agendas, or ends (Jackson, 1997) of the owners. Thus, the structural pattern of hyperlinks in their websites serves a particular social or communicative function.

The Internet is a communication network made up of intertwined connections through which a number of messages travel. In this process, a website functions as a node that passes messages and determines their paths according to a selection of hyperlinks.[5] In particular, through a hyperlink, an individual website plays the role of an actor who could influence other website's trust, prestige, authority, or credibility (Kleinberg, 1999; Palmer, Bailey, & Faraj, 2000; Park, Barnett, & Nam, 2001). Hyperlinks as connections represent networks among people, organizations, or nation-states. Thus, we can interpret the social or communication structure among those social actors based on the hyperlink structure.

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[5] While any individual or institution has complete freedom in choosing the direction of hyperlinks on their websites (or webpages), research by Albert, Jeong and Barabasi (1999) shows that the web has "the flocking nature." According to them, if you select two webpages at random, you can get from one page to the other by clicking on an average of 19 hyperlinks. This is not a geometric distance but one due to the pattern of connections, e.g., a topological distance (see Hayes, 2000). In fact, the probability that there is a hyperlink between two randomly chosen websites is nearly 0 (Terveen & Hill, 1998). The web as a whole is a very spare network.

A HYPERLINK NETWORK ANALYSIS: A REVIEW OF RESEARCH

This section reviews the prior research that conducted a HNA within the topics of international communication, e-commerce, interpersonal communication, and interorganizational communication. Also, it briefly describes how to collect hyperlink data for HNA.

International Communication. International information flow has been perceived as a primary topic in the study of international communication (Barnett & Salisbury, 1996; Barnett, 1999; Barnett *et al.*, 2001). In the "information society," drawing the information flows among nation-states based upon their hyperlinks may be a necessary first step in mapping the new structure of international communication (Brunn & Dodge, 2001; Halavais, 2000, Hargittai, 1999).

Halavais (2000) examined the role of geographic borders in cyberspace using the hyperlink pattern of websites. Specifically, he took a sample of 4,000 websites and analyzed their external hyperlinks and determined the total percentage of hyperlinks from the sites to various countries. Domains, which did not contain their geographic locations (for example, .com or .edu), were checked against the WhoIs registry to determine the country of origin.

In a study on the structure of global commerce on the web, Brunn and Dodge (2001) used a similar method to analyze the inter-domain hyperlinks among 174 geographic TLDs (top-level domains, such as .ca for Canada). They treated website's incoming and outgoing links separately, even though they did not perform a SNA. They developed a domains-by-domains matrix of inter-hyperlinks upon which they conducted descriptive statistics and cross-tabulation analysis by country and region (North America, Europe, Australia, South America, Central American & Caribbean, South America, North Africa, Sub-Saharan Africa, South Asia, Southeast Asia, and East Asia).

Barnett, Chon, Park, and Rosen's (2001) study differed from the above research in that it used network analysis. They used secondary data published by the Organization for Economic Co-operation and Development (OECD, 1998). The data included the number of hyperlinks embedded in websites between all TLDs among OECD member countries. Network analysis enabled them to determine how central (or peripheral) each country is and to identify groups of countries, and underlying dimensions in the hyperlink network. Further, they employed quadratic assignment procedure (QAP) to evaluate the strength of the relationship between the hyperlink network and other social and communication networks (international telecommunications, trade, air traffic, telephone rates, language, physical location, science citations, student, immigrant flows and structural asynchrony). The authors argued that the hyperlink network analysis addressed two aspects of global communication. First, it reveals the influence of national borders on the Internet and second, it indirectly reveals the structural pattern of international information flow among nation-states.

E-commerce. Palmer *et al.* (2000) used the hyperlink method to examine e-commerce. When purchasing a commodity online, a consumer's trust (or perceived credibility) of a website has been regarded as one of the most influential factors in transaction process (Gefen, 2000; Tseng & Fogg, 1999).[6] Based upon this theory, they used the number of inward hyperlinks to a website as an

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[6] One might ask whether trust and credibility are synonymous concepts. In other words, how different (or similar) are the two? According to Tseng and Fogg (1999), trust generally indicates a positive belief about the perceived dependability of a person, object, or process. It is different from credibility when involving the

indicator of the trust of Internet firms. They obtained the data from Alexa.com. The results revealed that the number of incoming links was strongly related with the use and prominence of TTPs (Trusted Third Parties) and privacy statements which are regarded as another trust indicator. Their research method was similar to a traditional network analysis that measures individual's prestige in terms of the number of friends who choose the person as their representative.

Krebs' (2000) study of Amazon.com indirectly revealed the role of hyperlinks in relation to homophilous attribute among online consumers. Amazon.com provides customers with information about *who bought this book also bought these books*. It has a hyperlink so that prospective customers can take a look at the hyperlinked books directly. Krebs argued that the fact that people with similar interest bought those books contributes to persuading prospective consumers to buy them. Choosing a specific book as a focal node, he built an "ego" and "alter" network among books. This enabled him to see how the hyperlinked books are inter-connected and what position they occupy in the networks. Also, the books were clustered according to a topic and he analysed the role of individual book within cluster and among clusters.

While analysing the affiliation network among Korea's 152 most frequently visited commercial websites, Park *et al.* (2001) regarded the number of hyperlinks incoming to a website (and the outgoing links originating from the site) as an indicator of the credibility of the site. They created a websites-by-websites relations matrix based on the existence of hyperlinks in a webpage titled "affiliation program." Websites that did not play a significant role in the network (e.g., isolates) were excluded. Finally, the 44 group websites identified by NEGOPY were used in the research. They measured centralities and found that the structure of the affiliation network was influenced by the financial websites with which others are affiliated.

Park *et al.* (2001) explained websites' hyperlink affiliation networks as a function of the credibility among websites and the desire to strengthen certain dimensions of credibility. A website perceived highly credible gets more links from others. The strength of links, in this case, the number of incoming hyperlinks, is an indicator of the website's credibility. Thus, website position relative to other commercial websites could be examined as a hyperlink network.[7] They argued that hyperlink network analysis has an advantage to answer important questions: What does the associational structure among websites look like? What element makes websites form networks with others on the Internet? Their research provided a useful theoretical basis for applying HNA to a web-based system. Their perspective recognized individual websites as independent actors, which together comprise a system.

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effectiveness of technological capability, like, for example, a trust system frequently used in computer technology (Stefik, 1999). But it can be used synonymously with credibility when referring to the psychological attribute such as people's beliefs or expectations.

[7] Past studies support this hypothesis. Terveen and Hill (1998) studied the use of the number of hyperlinks between websites as an indicator of the quality of sites and found that hyperlink connectivity had a significant relationship to the expert quality judgments of sites. Also, the indegree connectivity of a site (the number of sites that are linked to a given site) was positively correlated with judgments. Further evidence can be found in more recent studies. A series of studies conducted by Persuasive Technology Laboratory at Stanford University have found that having a partner website hyperlinked may influence people perceived credibility of certain sites (Fogg *et al.*, 2001). Thus, a website that intends to increase its credibility adds hyperlinks to credible websites. A website perceived as highly credible receives many links from others.

Vedres and Stark's (2001) approach is similar to that of Park *et al.* (2001). In order to find the most prestigious Hungarian websites, they traced out the hyperlinks originating from 170 sites selected in terms of their presence in the most popular web directories. Measuring the most authoritative site based on the number of links on other sites may be more reliable (or valid or reasonable) than using the number of hits or visitors (Henzinger, 2001; Kleinberg, 1999; Terveen & Hill, 1998).

Interpersonal and Interorganizational Communication. The research described above shows that the structure of hyperlinks among websites may be used to measure the international communication flow and individual website's credibility. The following studies use a HNA to examine interpersonal and interorganizational communication.

Park, Barnett, and Kim (2000) analyzed a hyperlink network among Korea's political parties and assemblymen in which the nodes were their websites. They developed a sites-by-sites matrix of hyperlink existence upon which they conducted hierarchical cluster analysis. In addition to describing the hyperlink network of politicians, they examined the relationship between the structure of the hyperlink network and shared party membership. They found that the structure of their hyperlink network is significantly related to party membership.

Adamic and Adar (2001) focused on university students' (Stanford University and the Massachusetts Institute of Technology) homepages and described hyperlink connections between them. They found that some students had more than 30 incoming and/or outgoing hyperlinks while some of their schoolmates did not have any links. In order to find a connector who plays a key role in linking other homepages in the university, they measured the average shortest path between any two homepages (9.2 for the Stanford network and 6.4 for the MIT). They concluded that these results may reflect the existence of a small world network online as well as in the offline world (Milgram, 1967; Watts & Strogatz, 1998). Besides, they examined what two students hyperlinked have in common using the content analysis of homepages. At the interorganizational level, Bae and Choi (2000) employed bilateral hyperlink networks among websites, to capture the structure of hyperlink communication between 402 human rights non-governmental organizations (NGOs). They found that many NGOs form a hyperlink network with others according to the similar aim or activities rather than geographic location. This certainly warrants further research: How similar is the clustering of organizations based upon the content analysis of mission statements to that of HNA?

In order to describe the coordinational forms of the Hungarian Internet market, Vedres and Stark (2001) conducted a multiple network approach comparing hyperlink network with other networks such as the backbone and webhosting networks. They were able to estimate the overall structural similarity among major organizations supporting the Internet economy.

In the context of interpersonal and interorganizational communication, HNA is certainly a worthwhile method. Thanks to HNA, a researcher is able to identify an invisible network in the field of human and/or organization communication. HNA rendered visible a latent network among people or organizations that did not appear when only focusing on the organizations and their members' relationships. Also, hyperlink analysis has the advantage of being unobtrusive (Garton, *et al.*, 1997; Webb, 1966). Hyperlink data can be gathered naturally without intruding in the research context. This can avoid sensitive issues that result from obtrusive observation in the Internet: monitoring, physical fatigue, and privacy.

DATA GATHERING METHODS

Data on hyperlink networks between websites can be obtained in two ways: 1) observation and 2) computer-assisted measurement.

First, a researcher is able to gather hyperlink data through direct observation. Park *et al.* navigated 152 websites which are the most frequently visited sites among Korean web users (Park *et al.*, 2001) and 273 assemblymen websites and 5 political party's sites in Korea (Park *et al.*, 2000). Based on the result of these observations, they measured who was linked to whom, in this case, which website linked to which other site.

There is no doubt that direct observation has been a central measurement tool for gathering network data. Nevertheless, the use of human coders has limitations. It requires a researcher to surf websites and many webpages within each site carefully. When it is used for large number of sites, there is a high labor cost and the possibility of coding errors.

For these reasons, computer-assisted measurement is recommended. Past research in the field of CMC has used computer-assisted tools to gather social network data (Hampton, 1999). The ideal method is to use a computer program that has been developed for HNA. However, to our knowledge, no program provides exactly what a social network analyst is looking for. In response to this situation, some researchers have written programs (Bae & Choi, 2000; Halavais, 2000; Terveen & Hill, 1998). Although this process seems to be more effective than traditional observation methods, it is also problematic. The program used varies according to a researcher. In other words, measurement tool may be idiosyncratic answering only the research question being investigated. Also, access to these programs is limited, preventing other researchers from replicating their results. Different ways of gathering data may cause different research results.

In fact, the difficulty in deciding on data-gathering tools is a common issue for the Internet research community (Jones, 1999; Mann & Stewart, 2000). In order to determine the validity and reliability of a research method, a data-collecting tool needs to be reliable and accessible at an affordable price. The measurement tool should be available to the researcher without any serious barriers. Alternatively, a search engine has been proposed as a proper tool to trace the hyperlinks among websites (Adamic & Adar, 2001; Brunn & Dodge, 2001).[8] The AltaVista may be good example; they are able to record in-going and outgoing link separately.[9] It should be noted that none of the search engines commonly used among web users produces outcomes tailored for a network analysis. The network researcher needs to transform the results generated by search engines into sociomatrices.

CONCLUSIONS

This paper has focused on HNA as new methodological tool and provided some techniques for collecting hyperlink data. HNA is an extension of traditional network analysis in that it focuses on the structure of a social system based on the shared links among communication partners. The

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[8] However, there is a criticism about the academic use of search engine for hyperlink analysis. Snyder & Rosenbaum (1999) cast a question about the reliability of the results from search engine.

[9] For the detailed search command of AltaVista, refer to the advanced query of altavita.com.

difference between hyperlink and traditional network analysis is the use of hyperlink data which can be obtained only from websites. In other words, two nodes, in this case, two websites, are connected in a hyperlink network to the extent that there are hyperlinks between them. Thus, HNA requires a content analysis of HTML (Hyper Text Markup Language) data to determine if there is bilateral hyperlink between two websites or how many hyperlinks they share throughout webpages. Hyperlink network analysts based their theoretical framework on the assumption that the relations among a set of those actors on the web may be analyzed in terms of the connections on their websites. They argued that hyperlink analysis not only reveals the social structure of the Internet, but also can be used to examine the communication among actors.

But HNA research has not addressed the following questions fully: First, are meaningful communication relations being maintained or transmitted via hyperlinks? Is there structural information flow through hyperlinks, connecting individuals, organizations, or countries? How are hyperlinks, as the channel of information flow, related (or unrelated) to offline (or online) other channels? Secondly, as Barnett *et al.* (2001) put it, new communication networks are in the process of evolution incorporating other elements from within the existing social system. Hyperlink networks among websites and social networks in the physical world may be seen as co-constructing each other, such that offline relationships can influence how online relationships are developed and established. Similar questions arise: How do hyperlink relationships articulate wide-ranging offline (or other online) ties? Do they really reflect social networks in the physical world? Or do they contribute to building online relationships across offline boundaries? Thirdly, the wider the Internet's global reach, the greater the number of regional and national preferences (or cultures). Do cultural differences influence the hyperlink network structure among websites? Fourthly, what does the location of websites in the hyperlink networks mean? In other words, what do centrality measures (such as in/out degree, betweenness, and closeness) tell us? Are they reliable indicators of credibility, reputation, or quality contents? Lastly, researchers have argued why a website chooses to hyperlink with a certain site. What leads to an increase (or decrease) in a website's current and future links? When deciding to hyperlink with other websites, what elements are involved? Several important questions seem unanswered from the prior research. Future research needs to elaborate the questions unanswered in relation to the nature of hyperlinks. In addition, in order to overcome certain limitations of HNA, several methods need to be employed to examine the reasons developers of websites form a network with other sites via hyperlinks: survey, in-depth interviews, observation, comparative analysis of website contents and other network data would contribute to an understanding of the social relationships among the network's components, in this case, the websites (Lievrouw,   *et al.*, 1987). In other words, this methodological strategy has strength in identifying hyperlink networks among websites, examining why and how websites are interconnected.

REFERENCES

Adamic, L.A. and E. Adar. 2001. You are what you link. Presented to the 10th annual International World Wide Web Conference, Hong Kong. Retrieved June 19, 2001 from: http://www10.org /program/society/yawyl/YouAreWhatYouLink.htm.

Albert, R., H. Jeong, and A.L. Barabasi. 1999. Diameter of the world wide web. *Nature, 401*(9): 130-131.

Bae, S. and J.H. Choi. 2000. Cyberlinks between human rights NGOs: A network analysis. Paper presented to the 58th annual national meeting of the Midwest Political Science Association, Chicago.

Barnett, G.A. 2001. A longitudinal analysis of the international telecommunication network, 1978-1996. *American Behavioral Scientist, 44*(10): 1638-1655.

Barnett, G.A. 1999. The social structure of international telecommunications. In Sawhney, H. and G.A. Barnett. (Eds.) *Progress in communication sciences, Volume XV: Advances in telecommunications* , 151-186. Stanford, CT: Ablex.

Barnett, G.A., and J.G.T. Salisbury. 1996. Communication and globalization: A longitudinal analysis of the international telecommunication network. *Journal of World System Research, 2*(16): 1-17.

Barnett, G.A., B.S. Chon, H.W Park, and D. Rosen. 2001. Network analysis of international Internet flows. Presented to the International Sunbelt Social Network Conference, Budapest, Hungary.

Ben-David, J. and R. Collins. 1966. Social factors in the origins of a new science: The case of psychology. *American Sociological Review, 31*: 451-465.

Berners-Lee, T. 1999. *Weaving the web: The original design and ultimate destiny of the World Wide Web by its inventor.* New York: Harper Collins Publishers.

Brunn, S.D. and M. Dodge. 2001. Mapping the 'Worlds' of the world wide web: (Re)Structuring global commerce through hyperlinks. *American Behavioral Scientist, 44*(10): 1717-1739.

Danowski, J. and P. Edison-Swift. 1985. Crisis effects on intraorganizational, computer-based communication. *Communication Research, 12*(2): 251-270.

De Solla Price, D.J. 1986. *Little science, big science...and beyond.* New York: Columbia University Press.

Fogg, B.J., J. Marshall, O. Laraki, A. Osipovich, C. Varma, N. Fang, J. Paul, A. Rangnekar, J. Shon, P. Swani, and M. Treinen. 2001. What makes web sites credible? A report on a large quantitative study. Presented to the Computer-Human Interaction Conference, Seattle, Washington.

Galaskiewicz, J. and S. Wasserman. 1993. Social network analysis: Concepts, methodology, and directions for the 1990s. *Sociological Methods & Research, 22* (1): 3-22.

Garton, L., C. Haythornthwaite, and B. Wellman. 1997. Studying online social networks. *Journal of Computer-Mediated Communication, 3*(1). Retrieved September 19, 2000 from: http://www. ascusc.org/jcmc/vol3/issue1/garton.htm.

Gefen,D. 2000. E-commerce: The role of familiarity and trust. *OMEGA-International Journal of Management Science, 28*(6): 725-737.

Halavais, A. 2000. National borders on the world wide web. *New Media & Society, 2*(1): 7-28.

Hampton, K.N. 1999. Computer assisted interviewing: The design and application of survey software to the wired suburb project. *Bulletin de Methode Sociologique (BMS), 62*: 49-68.

Hampton, K.N. and B. Wellman. 2000. Examining community in the digital neighborhood: Early results from Canada wired suburb. In Ishida, T. & Isbister, K. (Eds.), *Digital cities: Technologies, experiences, and future perspectives*, 194-208. Heidelberg, Germany: Springer-Verlag.

Hargittai, E. 1999. Weaving the Western Web: Explaining differences in Internet connectivity among OECD countries. *Telecommunications Policy, 23*: 701-718.

Hayes, B. 2000. Computing science graph theory in practice: Part 1. *American Scientist, 88*(1): 9-13.

Haythornthwaite, C. 2000. Online personal networks: Size, composition and media use among distance learners. *New Media & Society, 2*(2): 195-226.

Haythornthwaite, C. and B. Wellman. 1998. Work, friendship and media use for information exchange in a networked organization. *Journal of the American Society for Information Science, 46*(12): 1101-1114.

Henzinger, M.R. 2001, Hyperlink analysis for the web. *IEEE Internet Computing 5*(1): 45-50.

Jackson, M.H. 1997. Assessing the structure of communication on the world wide web. *Journal of Computer-Mediated Communication, 3*(1). Retrieved September 19, 2000 from:
http://www.ascusc. org/jcmc/vol3/issue1/jackson.htm

Jones, S. 1999. *Doing internet research: Critical issues and methods for examining the net.* Thousand Oaks, CA: Sage.

Kleinberg, J.M. 1999. Hubs, authorities, and communities. *ACM Computing Surveys, 31*(4). Retrieved March 2, 2001 from:
http://www.cs.brown.edu/memex/ACM_HypertextTestbed/papers/10.html

Krebs, V. 2000. Working in the connected world book network. *IHRIM (International Association for Human Resource Information Management) Journal, 4*(1): 87-90.

Lievrouw, L.A., E.M. Rogers, C.U. Lowe, and E. Nadel. 1987. Triangulation as a research strategy for identifying invisible colleges among biomedical scientists. *Social Networks, 9*: 217-248.

Mann, C. and F. Stewart. 2000. *Internet communication and qualitative research: A handbook for researching online.* Thousand Oaks, CA: Sage.

Milgram, S. 1967. The small world problem. *Psychology Today, 1*(1): 60-67.

Monge, P. and N.S. Contractor. 2000. Emergence of communication networks. In Jablin, F.M., & Putnam, L.L. (Eds.), *The new handbook of organizational communication: advances in theory, research, and methods*, 440-502. Thousand Oaks, CA: Sage.

Mullins, N. 1972. The development of a scientific specialty: The phage group and the origins of molecular biology. *Minerva, 19*: 52-82.

OECD 1998. *Working paper on telecommunication and information service policies: Internet infrastructure indicators.* Paris: OECD.

Paccagnella, L. 1998. Language, network centrality, and response to crisis in on-line life: A case study on the Italian *cyber_punk* computer confernce. *The Information Society, 14*: 117-135.

Palmer J.W., J.P. Bailey, and S. Faraj. 2000. The role of intermediaries in the development of trust on the WWW: The use and prominence of trusted third parties and privacy statements. *Journal of Computer-Mediated Communication, 5*(3). Retrieved Jun 22, 2000 from:
http://www .a sc us c. or g/ jcmc/vol5/issue3/palmer.htm

Park, H.W., G.A. Barnett, and I.Y. Nam. 2001. Affiliation network structure of top websites: Examining affiliates with hyperlink in Korea. Presented to the International Sunbelt Social Network Conference, Budapest, Hungary.

Park, H.W., G.A. Barnett, andC.S. Kim. 2000. Political communication structure in Internet networks: A Korean case. *Sungkok Journalism Review, 11*: 67-89.

Richards, W.D. and G.A. Barnett (Eds). 1993. *Progress in communication science, 12.* Norwood, NJ: Ablex.

Rice, R.E. 1994. Network analysis and computer-mediated communication systems. In Wasserman, S., & Galaskiewicz, J. (Eds.), *Advances in social network analysis*, 167-203. Thousand Oaks: Sage.

Rice, R.E. and G.A. Barnett. 1986. Group communication networking in an information environment: Applying metric multidimensional scaling. In McLaughlin, M. (Ed.) *Communication Yearbook, 9*: 315-338. Beverly Hills, CA: Sage.

Rice, R.E. 1982. Communication networking in computer-conferencing systems: A longitudinal study of group roles and system structure. In Burgoon, M. (Ed.), *Communication Yearbook, 6*: 925-944. Beverly Hills, CA: Sage.

Rogers, E.M. and D.L. Kincaid. 1981. *Communication networks: Toward a new paradigm for research.* New York: Free Press.

Snyder, H. and H. Rosenbaum. 1999. Can search engines be used as tools for web link analysis?: A critical review. *Journal of Documentation, 55*(4): 375-384.

Stefik, M. 1999. *The internet edge: Social, technical and legal challenges in a networked world.* Cambridge: The MIT Press.

Terveen, L. and W. Hill. 1998. Evaluating emergent collaboration on the web. Presented to the Conference of Computer Supported Cooperative Work, Seattle, Washington.

Thelwall, M. 2001. Commercial web site links. *Internet Research: Electronic Networking Applications and Policy, 11*(2): 114-124.

Tseng, S. and B.J. Fogg. 1999. Credibility and computing technology.   *Communications of The ACM, 42*(5): 39-44.

Vedres, B. and D. Stark. 2001. The [Hungarian] Internet economy – A network approach. Presented to the International Sunbelt Social Network Conference, Budapest, Hungary.

Wasserman, S. and K. Faust. 1994. *Social network analysis: Methods and applications.* Cambridge, NY: Cambridge University Press.

Watts, D. J. and S.H. Strogatz. 1998. Collective dynamics of `small-world' networks. *Nature, 393*: 440-442.

Web, E.J. 1966. *Unobtrusive measures: Nonreactive research in the social sciences.* Chicago: Rand McNally.

Wellman, B. and S.D. Berkowitz. 1989.   *Social structures: A network approach.* New York: Cambridge University Press.

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