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Effects of Three Hypermedia Topologies on Users' Navigational Performance

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Abstract: This study examined the effects of two different hypermedia topologies (hierarchy and network) on users' navigation performance compared to a linear version of the same document. Eighteen participants were allowed 10 min to interact with as much of the document as they chose. After a 2 min rest, participants returned to the document to locate seven specific nodes. The mean times for locating specific nodes and the number of opened nodes were measured and counted and the participant's own evaluation of their performances was assessed by using a questionnaire. The results showed that participants performed significantly better with the network topology than with the hierarchical and linear topologies. Analysis of the questionnaire data confirmed these differences. The results are discussed in terms of their implications for the design of hypermedia systems.

Key words: Hierarchy, hypermedia, linear, navigation, network, topology

INTRODUCTION

Hypermedia is an interactive, nonlinear medium where data are represented by nodes and links. It is an elaborated form of hypertext. The terms hypertext and hypermedia were coined by Ted Nelson in the early 1970's. He envisioned a system called Xanadu (Nelson, 1974), where all the literature of the world would be linked together in a gigantic world-wide distributed database. Annotations and cross-references would make it possible to browse through the literature quickly and easily. The difference between hypertext and hypermedia is that hypermedia in addition to text makes use of other forms of representations, like pictures, animations and sound. Hypermedia provides a mechanism that allows users to store, manipulate and communicate information as interactive documents and has become an essential element in a wide variety of computer applications, such as the World Wide Web (WWW), electronic commerce systems, computer-based learning systems and so forth (Lin, 2003a).

The characteristics of the non-linear form of hypermedia are indeed different from printed media. Hypermedia allows users to access the material in many different ways and to jump to different information items, since the user has been provided with the necessary links. Although, hypermedia allows rapid nonlinear access to large amounts of information and extends the users' control by giving them the freedom to explore documents according to their information needs (Conklin, 1987), there is little evidence to suggest that users can in practice, benefit from the degree of freedom that hypermedia provides in searching for information. Indeed, researchers have indicated that the major limiting factor of hypermedia has been that users often get lost or disoriented due to the topological complexity (McDonald and Stevenson, 1998; Kim, 1999).

The disorientation problem in the use of hypermedia can be characterized as the Art Museum Phenomena (Foss, 1989). The Art Museum Phenomena refers to the problems associated with hypermedia browsing, an open information-seeking activity in a nondirective manner. During this activity, users may be unable to recognize which nodes have been visited or which parts remain to be seen, as a result of nonspecific wandering in the hyperlink-based environments.

Kim (1999) stated that in order to solve the disorientation problem in hypermedia systems, the structure of hypermedia topology should be considered. Two common structures of topology in the use of hypermedia are hierarchical and network topologies (Shin *et al*., 1994). As the names suggest, hierarchical structures allow the nodes to be connected to form a strict hierarchy, where a node at one level can only access nodes directly above or below.

These structures contain organizational links (Locatis *et al*., 1989). Nonetheless, network structures allow a node to be connected to any other node in the hypertext to form a complex structure with many links, often referred to as referential links (Locatis *et al*., 1989). McDonald and Stevenson (1998) examined the effects of hierarchical and network topologies on users' navigation performance compared to a linear version of the same document. The results of the study showed that there was

no significant difference between the hierarchical and network topologies. However, a nonlinear topology, which took the form of multiple data linkage was more likely to result in disorientation than its organizational counterpart's data connection built on linear topology. In two other studies (Lin, 2003a, b) researchers examined the effects of hierarchical and network topologies on older users' navigation performance. The results showed that for older adults, hypertext with a hierarchical topology was superior to its referential counterpart in terms of browsing and navigation efficiency.

According the results generated from the previous studies mentioned above (McDonald and Stevenson, 1998; Lin, 2003a, b), the position is unclear as to which structure is more likely to be easy to use and to enhance navigation. Furthermore, while scrutinizing the nonlinear topology of their studies, it was found that different forms of network topology were used in their studies. In the study of McDonald and Stevenson (1998), the nodes in the document were linked to form a network based on a number of cross-referential links in which any node could be connected to any other node.

A link was established, via keywords or text buttons in the text of each node to other related nodes; the positions and arrangements of the links within each node were placed according to the content of the text itself. Therefore, the different text contents produced different positions and arrangements of the links. In contrast, the studies of Lin (2003a, b) integrated all the links in the same position and order for each node. However, the links of a node can only connect to some nodes instead of to any other node.

Combining the above mentioned points, a hypothesis was generated: If a network topology could be constructed with links that connect to all the other nodes and all the links were arranged in the same position and order for each node, the users' navigation performance be better. Consequently, a different form of network topology, which was inspired by past research was examined to discover its effect on users' navigation performance in comparison to both traditional linear and hierarchical topologies in the present study.

MATERIALS AND METHODS

Participants: Eighteen undergraduates at a local university, who had >1 year of constant web browsing experience, participated in the experiment. Their ages ranged from 18-36 years old (M = 21.6, SD = 3.7), respectively.

Materials: The experimental materials were three sets of car-show web pages. The three web pages were programmed by Hypertext Markup Language (HTML) based on three different hypermedia topologies: linear, hierarchical and network. Each of the three sets of documents provided 15 different car-show web pages. Each web page represented one node in the hypermedia systems and the contents for every node comprised two car pictures, one animation between the two pictures and a 100 words description on average of 14-point traditional Chinese Ming characters. The linear document had a sequential structure of the 15 nodes with 14 links (Fig. 1); each node appeared in a fixed linear sequence. Movement through the document was achieved by means of clicking on Next and Previous buttons on the bottom of the web pages, which caused the next or previous web page to be displayed.

The links of the web pages in the hierarchical document were based on one parent node for two child nodes, resulting in the 15 nodes with 14 links (Fig. 2). Participants moved through the document by clicking on the text buttons on the bottom of the web pages. Clicking on the text button caused a web page bearing the same name as the button to be displayed. The document included a backtrack facility. The web pages in the network document were based on 210 cross-referential links in which each web page could be connected to every other web page. The links were established via text buttons shown on the bottom of the web pages (Fig. 3). The document also included a backtrack facility. All of the three sets of documents were run on the Microsoft's IE browser 6.0 and were displayed with a 17-in. LCD color monitor. Participants' activities were monitored throughout the experiment.

Experimental design: A between subjects single factor experimental design was adopted in this study. The independent variable was hypermedia topology, i.e., hierarchical, network and linear. The dependent variables were the mean time of locating specific nodes and the mean number of nodes opened during browsing (Shin *et al*., 1994). Participants were randomly assigned to one of the three experimental conditions.

Procedure: At the beginning of the experiment, each participant was asked to complete a questionnaire regarding his or her computer experience. To ensure an equivalent level of interaction, each participant was then provided with an explanation on how to use the hypermedia document. Any questions the participant had were answered before the experiment. Participants were also asked to browse through the web pages as much as possible during a period of 10 min. After 2 min rest, participants were then required to use the hypermedia document to answer seven questions. Each participant

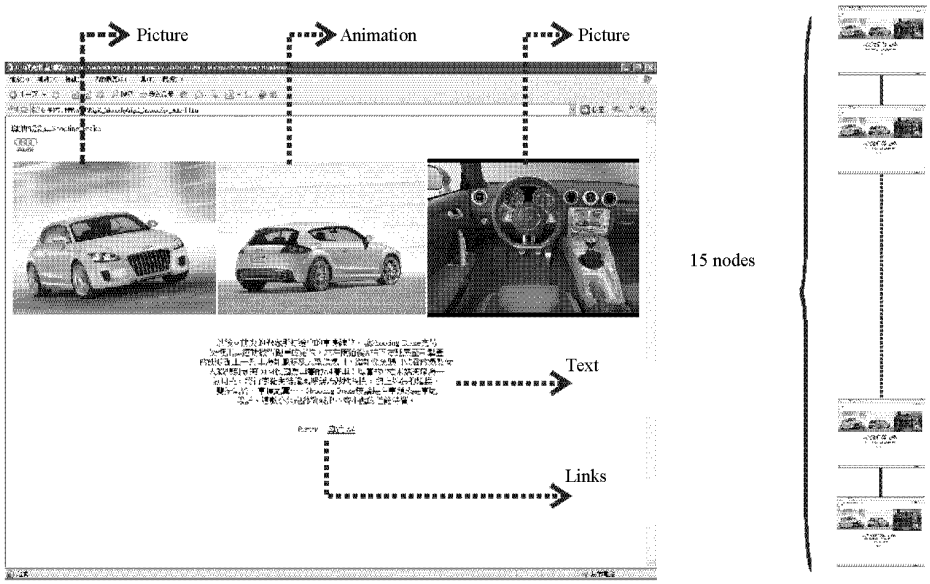


Fig. 1: The linear type of hypermedia topology

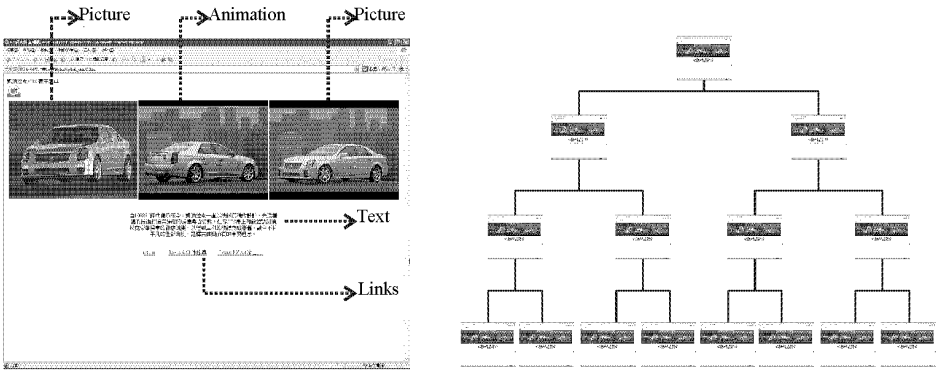


Fig. 2: The hierarchical type of hypermedia topology

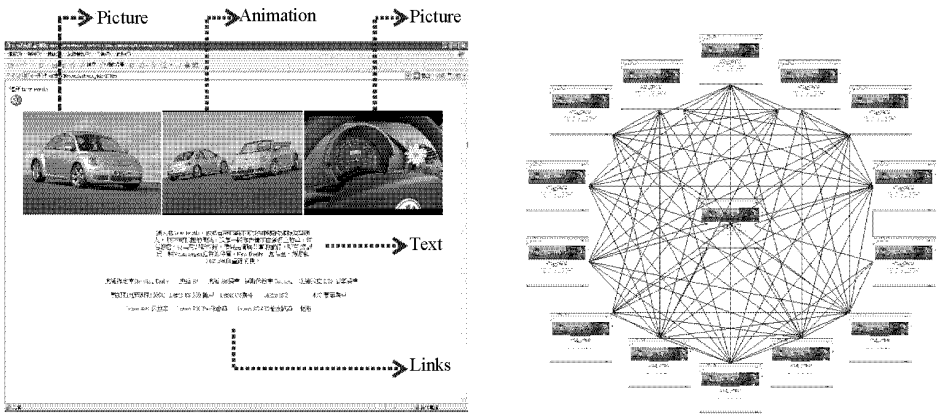


Fig. 3: The network type of hypermedia topology

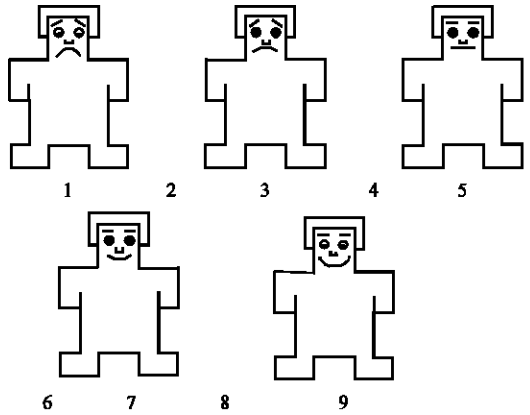


Fig. 4: The self-assessment manikin

received the same seven questions. The answers to the questions could be found in specific nodes in the document. Participants were instructed to navigate through the hypermedia document to locate the answers. Once they had located the answer to a question, they reported their response to the experimenter. They were then given the next question. The presentation order for the seven questions was randomly assigned to each participant. Each question was printed on a card and was handed to the participant by the experimenter. The time taken to find the answers and the number of opened nodes were recorded. After answering the seven questions in order to elicit information about the quality of the participant's interaction, each participant was asked to rate their preferences according to their perceptions concerning their navigation experience in using a Self-Assessment Manikin (SAM) (Fig. 4). The SAM is a nonverbal method for quickly assessing preference associated with an individual's emotional reaction to an event (Mehrabian and Rusell, 1977). The preference scale ranges from 1-9; 1 indicates an unpleasant mood-mostly dislike, 9 indicates a very pleasant mood-mostly like and 5 indicates a neutral mood. This scale corresponds to pictures of the SAM figure that range from smiling and happy to frowning and unhappy.

RESULTS AND DISCUSSION

The descriptive statistics of the topological effects on the navigation performance measures pertinent to the mean time of locating specific nodes and the mean number of nodes opened are shown in Table 1.

Mean time of locating specific nodes: The total time taken to answer the seven questions using the hypermedia document was calculated for each participant. The mean time per condition is shown in the top row of Table 1.

Table 1: Mean time per condition (in sec) and the mean number of nodes opened for the question answering task

	Linear		Hierarchical		Network	
Mean	M	SD	M	SD	M	SD
Mean time	225.00	44.20	279.50	86.98	137.33	51.47
Mean number	18.75	8.48	21.25	4.33	7.17	0.39

Table 2: Mean preference rating for the three different hypermedia topologies

	Linear		Hierarchical		Network	
Mean	M	SD	M	SD	M	SD
Mean preference rating	25.25	2.05	3.92	1.88	6.42	1.38

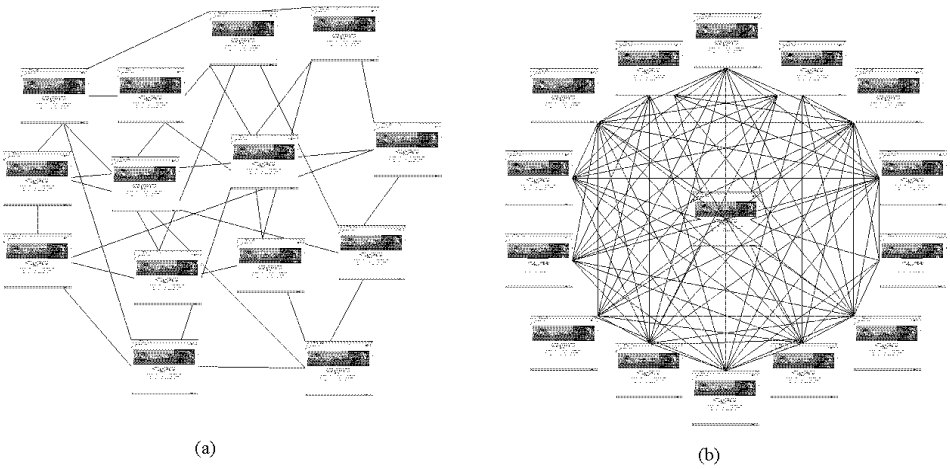
The results generated from the one-way ANOVA revealed a significant effect of subject group ($F_{2,33} = 15.22$, $p<0.01$). Tukey HSD tests also indicated that participants in the network condition answered the questions significantly faster than did the participants both in the hierarchical and linear conditions. There was no significant difference between the hierarchical condition and the linear one.

Number of nodes opened: The number of nodes opened by each participant to locate the answers for the seven questions was calculated. The mean number of nodes opened for each of the three conditions is shown on the bottom row of Table 1. The results from the one-way ANOVA indicated a significant effect of subject group ($F_{2,33} = 22.40$, $p<0.01$). Tukey HSD tests indicated that participants in the network condition opened significantly fewer nodes than did those in either in the hierarchical and linear conditions. There was no significant difference between the hierarchical and linear conditions.

Preference rating: The descriptive statistics of the topological effects on the SAM questionnaire are shown in Table 2. The SAM data were analyzed using a Kruskall-Wallis test. The test indicated significant differences among the three groups ($X_2 = 9.28$, $p = 0.01$).

Further analysis, using Mann-Whitney tests indicated that more participants using the network document rated themselves as having a significantly positive experience than did those in the hierarchical condition ($Z = -3.03$, $p = 0.002$). There was no significant difference between the hierarchical and linear conditions or between the network and linear conditions.

The purpose of this study is to explore the effects of different hypermedia topologies on users' navigation performance. According to the outcomes of this study, the results supported the proposition by Conklin (1987) that network topology of hypermedia distinguishes itself from traditional linear information processing in aspects of rapid nonlinear information access and higher level of control in document exploration.



(a) (b)

Fig. 5: The comparison of two different network topologies, (a) incomplete network topology and (b) complete network topology

However, most previous studies argued that this same benefit of nonlinear information seeking led to difficulty in user orientation (McDonald and Stevenson, 1998; Lin, 2003a, b, 2004). In the present study, three different topologies were examined and the results showed that the form of the network topology used in this study was not reported as associated with participant disorientation. Moreover, participants' navigation performance in the network topology was significantly better than in both the linear and hierarchical topologies. Some explanations as follow, may account for the differences among this study and the past research studies (McDonald and Stevenson, 1998; Lin, 2003a, b, 2004). The study conducted by McDonald and Stevenson (1998) examined the effects of hierarchy and nonlinear topologies on navigation performance and compared them to a linear version of the same document.

The results showed that participants performed better with the linear text than with the nonlinear text, while performance on the hierarchical document fell between these two extremes. Regarding the nonlinear topology of their study, the nodes in the document were linked to form a network based on a number of cross-referential links, whereby any node could be connected to any number of other nodes. A link was established via keywords or text buttons in the text of each node to other related nodes, so that the positions and arrangements of the links on each hypertext were placed according to the content of the text itself.

Therefore, the different text contents produced different positions and arrangements of the links. Consequently, users had to search for their needed links within the text contents. Thus, users had to simultaneously focus on reading the text information to find the answers for the questions and searching for the target links within the text in order to orient themselves within the hyper-textual space. Regarding the network topology used in this study, the links were arranged at the bottom of each web page in the same position and in the same order. Users did not have to search for the desired links, while simultaneous reading the information.

In studies by Lin (2003a, b, 2004), user performance in the hierarchical topology was also significantly superior to that in the network topology. The structure of network topologies used in their studies were incompletely constructed (Fig. 5).

For instance, the network topology which was used in the study by Lin (2003a), mimicked the real world gigantic WWW database structure. The links of each web page could not connect to all other nodes. Within this incomplete network structure, users could not foresee the relationships among different nodes.

In the present study, users knew that any node could be connected to any number of other nodes. Therefore, users did not need to use extra mental resources to memorize the relationships between links and nodes.

These two arguments regarding the different forms of network topologies used in the present study and past research studies mentioned before, would clarify the different results for the effects of the network topology on users' navigation performance. Regarding the subjective preference rating, the analysis of the SAM questionnaire data indicated a similar trend in user performance. More participants who had used the network document reported having experienced significantly positive mood and preference than did participants who had used the linear and hierarchical documents.

The difference in performance among the linear, hierarchical and non-linear conditions may be accounted for by the disparate amount of choice offered to the user in terms of the number of links and directions whereby they had freedom to browse.

The network structure places no constraints on user movements. That is, users have unlimited freedom to explore a richly connected network of ideas. Again, this result was different from the results of previous studies. The reasons for the differences are similar to the reasons mentioned above. The complete network structure placed the freedom to travel on the web pages and without the resulting disorientation.

CONCLUSION

Past research studies indicated that the network topology of hypermedia allows rapid access to large amounts of information and extend users' control, giving them the freedom to explore the documents according to their information needs. However, researchers commented that hypermedia users often got lost or became disorientation within this nonlinear topology. However, the result of this study indicates that there might be a specific circumstance for traveling efficiently and freely within the hypermedia network topology without disorientation or a higher cognitive burden placed on the user in terms of the availability of memory resources. According to the results generated from this study and comparing the different forms of network topologies used in this and previous research studies, the implications for designing an efficiently network topology should be as follows: each node within a network topology of hypermedia should have links completely connecting it to any other node and all the links of each web page should be arranged in the same order and position. Following these two suggestions, users may gain the freedom to explore the network topological documents according to their information needs, without experiencing any disorientation.

REFERENCES

Conklin, J., 1987. Hypertext: An introduction and survey. IEEE Comput., 20: 17-41.

Foss, C.L., 1989. Tools for reading and browsing hypertext. Inform. Process. Manage., 25: 407-418.

Kim, J., 1999. An empirical study of navigation aids in customer interfaces. Behav. Inform. Technol., 18: 213-224.

Lin, D.M., 2003a. Hypertext for the aged: Effects of text topologies. Comput. Hum. Behav., 19: 201-209.

Lin, D.Y.M., 2003b. Age differences in the performance of hypertext perusal as a function of text topology. Behav. Inform. Technol., 22: 219-226.

Lin, D.Y.M., 2004. Evaluating older adults' retention in hypertext perusal: Impacts of presentation media as a function of text topology. Comput. Hum. Behav., 20: 491-503.

Locatis, C., G. Letourneau and R. Banvard, 1989. Hypermedia and instruction. Educ. Tech. Res. Dev., 37: 65-77.

McDonald, S. and R.J. Stevenson, 1998. Effects of text structures and prior knowledge of the learner on navigation in hypertext. Hum. Factors, 40: 8-27.

Mehrabian, A. and J. Rusell, 1977. Evidence for a three-factor theory of emotions. J. Res. Pers., 11: 273-294.

Nelson, T., 1974. Computer Lib: You Can and must Understand Computers Now. 1st Edn., Hugos Book Service, Chicago IL., ISBN: 0893470031, pp: 1-69.

Shin, C.E., D.L. Schallert and W.C. Savenye, 1994. Effects of learner control, advisement and prior knowledge on young students learning in a hypertext environment. Educ. Tech. Res. Dev., 42: 33-46.