Structure and Memorability of Web Sites

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ABSTRACT
The growing World-Wide Web requires scientific research to strengthen and extend design guidelines. Exploratory research was undertaken to investigate the relationship between (1) site size and structure and (2) user navigation and perception. Experimental results showed that strongly hierarchical sites are more usable; site size has little effect on user navigation and mental models; nodes high in the hierarchy tend to be more memorable; and strongly hierarchical sites are perceived as smaller than weakly hierarchical sites, other factors being equal. Results also showed that structural landmarks tend to be poor predictors of behavioral landmarks.

KEYWORDS
World-Wide Web, navigation, information structure, Web site design, landmarks

INTRODUCTION
The World-Wide Web is transforming business and personal information access, manipulation, and communication, by capitalizing on synergies between network, graphics, and multimedia technologies. The Web, the world's largest hypertext, is often described as "the multimedia section of the Internet." In expanding from research laboratories to general use, the Web continues to experience explosive growth. Nielsen recently estimated its size at 40,000,000 documents and 200,000 servers [10]. Despite many technical advances and practical design guidelines, relatively little scientific work has grounded these guidelines in sound research. Such research is required for designers and developers to understand the principles governing Web authorship and use, particularly from the perspective of Human-Computer Interaction (HCI).

Web users frequently experience disorientation, in which they lose a sense of browsing history, current situation, and future goals. Hypertext researchers have referred to this phenomenon as being "lost in hyperspace." Accordingly, a key area for Web research is the interaction between structure and the user's wayfinding activities. These activities include cognitive mapping, decision making, and decision execution [12].

This paper will present exploratory research conducted in the Department of Industrial Engineering at the University of Toronto. This research investigated the effects of Web site size and structure on user navigation and mental models. A group of sites was chosen according to several criteria. In a multi-part experiment, a set of users then explored these sites in controlled ways. The sites and user sessions were next analyzed structurally and behaviorally. Analysis focused particularly on landmarks, which are distinctive nodes that feature prominently in wayfinding. The remainder of this paper will review previous research, discuss our experiment and results, and present some design guidelines drawn from the research.

PREVIOUS RESEARCH
As virtual environments become more complex, a key research question is the extent to which principles from the physical world apply to electronic worlds. Significant research in urban design has considered the relationship between structure and navigation. Urban planner Kevin Lynch conducted experiments in several cities. He sought to identify residents' aggregate mental maps, in order to derive design principles [8] His research techniques included interviews, map sketching, on-location navigation, and expert analysis. Lynch sought to create "imageable" (legible) cities; he defined imageability as "that shape, color, or arrangement which facilitates the making of vividly identified, powerfully structured, highly useful mental images of the environment" [8]. Lynch's experiments revealed five design elements that are essential for legibility: landmarks, paths, districts, nodes (hubs), and edges (boundaries). Imageability is a valid goal for Web design, particularly since legible designs are likely to be memorable, thereby generating strong mental models, which should facilitate wayfinding. Research is required to adapt Lynch's model to electronic worlds, however, particularly with regard to the relationship between structure and perception. In investigating this adaptation, Lynch's research techniques can be used as models.

Passini later extended Lynch's work to consider the wayfinding cycle described above [12]. Note that Passini considered paths and landmarks to be the most important of Lynch's five design elements. Complementing Lynch's focus on physical aspects of the environment, Passini focused on semantic ones. On the basis of behavioral experiments in complex urban environments, Passini proposed three new urban design elements: organizational scheme, spatial enclosures (containers), and spatial correspondence (between design elements). Recent research by Darken and Silbert has confirmed that wayfinding principles apply to large-scale virtual worlds [5].

Ingram and Benford have adapted Lynch's design elements to information spaces, including the Web [7]. Their prototype, LEADS (Legibility for Abstract Data Spaces) enhances overview diagrams in database and visualization systems. Lynchian elements are created by techniques such as cluster analysis, nearest neighbors, cluster centroids, triangulation, and minimum spanning trees. The authors report good results, which could be improved by system usage statistics, such as access frequency. User testing is needed to confirm the utility of Lynch's elements in these electronic environments, as well as optimal construction algorithms. Chalmers, Ingram, & Pfranger have recently extended this research to virtual landscapes for information retrieval [4].

Canter, Rivers, & Storrs characterize user navigation in complex database structures [1]. The authors describe five information-seeking strategies to characterize user navigation topologically: browsing, searching, scanning, exploring, and wandering. Their characterizations of navigational behavior are useful, and they could be extended by correlation with (hypermedia) database structure. To support user navigation, the authors recommend identifying and clarifying landmarks.

In the Web domain, Mukherjea and Foley have developed an algorithm to identify structural landmarks [9]. To determine whether a given node (page) is a landmark, the algorithm considers the number of other nodes reachable via directional links in one or two steps: outdegree = O (one step forward); indegree = I (one step backward); second-order connectedness = SOC (two steps forward); and BSOC = back second-order connectedness (two steps backward). The procedure has two steps, as follows:

1. Calculate importance = $((O + I) \times wt1) + ((SOC + BSOC) \times wt2)$, where $wt1 + wt2 = 1$. The best results were obtained with $wt1 = 0.4$ and $wt2 = 0.6$.

2. The given node is a landmark if and only if importance > 10% of the total number of nodes.

The value of such structural landmarks depends, of course, on the extent to which they are also behavioral or useful landmarks. This correspondence should be validated by user testing.

In one of the relatively few studies of Web browsing behavior, Catledge and Pitkow captured UI (user interface) events in a Web browser for three weeks with many users [3]. The authors characterized users as serendipitous (unfocussed) browsers , general-purpose (moderately focussed) browsers, or (very focussed) searchers. Overall, users tended to remain in a small area within a site; their navigational paths resembled a hub with spokes, on account of frequent backtracking. Users rarely traversed more than two layers in a hypertext structure before returning to a home point. It is tempting to identify navigational "hubs" as landmarks, whose design attributes are worth investigating. Analogous to subject observation during real-world wayfinding, the technique of capturing UI events is promising for Web research.

Recent research by Pirolli and Card has applied principles of biological foraging theory to information environments [13]. Information-seeking users follow identifiable strategies designed to maximize retrieved information ("information diet") while minimizing costs ("energy expenditure"). Users often seek information-rich clusters, which recall the hub-and-spoke sub-sites identified by Catledge and Pitkow [3]. Further investigation can clarify the role, identification, and placement of such clusters. A research prototype named the Web Forager embodies some of these concepts in a Web-based VR workspace [2].

EXPERIMENT

In research on Web structure and navigation, these issues have seldom been investigated together. Moreover, landmarks stand out as an important design element to which research should be applied from several fields. Finally, it is important to explore the adaptation of principles and methodologies from the physical world to electronic ones. With these considerations in mind, we conducted an experiment to explore the notion of behavioral landmarks, that is, often-visited and memorable nodes.

We selected four Web sites that represented two structural types – strongly versus weakly hierarchical – and two sizes – small versus large. The four sites were selected for quality from the top 5% of sites rated by Pointcom, as well as for general interest. Structural type was determined by inspection and automated analysis (see below), and size was determined by counting HTML pages. Ideal examples of each category could not be found for analysis, but the current selection proved to be experimentally useful. The names, types, and sizes of the sites are described in the following table:

Hierarchy \ Size	Large	Small
Strong	Travel Montana (1277)	Nye Labs (254)
Weak	WebMuseum (353)	Hawaii (109)

TABLE 1: Site Sizes

Applying the structural-landmark algorithm of Mukherjea and Foley (see below), we find that the weakly hierarchical sites have a much higher percentage of landmarks than do the strongly hierarchical sites. This difference stems, not surprisingly, from the higher connectivity of the weakly hierarchical sites.

Hierarchy\Size	**Large**	**Small**
Strong	Travel Montana (1.64%)	Nye Labs (8.26%)
Weak	WebMuseum (78.47%)	Hawaii (79.81%)

TABLE 2: Site Structural Landmarks

After choosing the sites, we designed experimental tasks to give the users broad and deep exposure to each site. Subjects were given procedural instructions and thematic information about the sites. Five minutes of exploratory browsing, followed by ten question-based search tasks, required twenty to twenty-five minutes to complete. The search questions were not designed to test efficiency, but rather to move the user around each site. The subjects were given a questionnaire after using each site and after using all four sites. The questions were presented in random order, and the order in which the subjects used each site was balanced. Each of twelve subjects completed four trials, one per site, for a total of forty-eight trials.

Subjects were selected for English fluency and Netscape experience. Located by word of mouth, they were paid $20 for a two-hour experiment. All subjects were university students or recent graduates. Four of the subjects were female, and the subjects' backgrounds were evenly split between technical and non-technical disciplines. All of the trials were performed in Netscape 2.0, on a single Macintosh PowerPC with a high-speed connection to the Internet backbone of the University of Toronto.

The site-specific questionnaire asked subjects to describe the site; to name the distinctive pages; to recall nodes; to draw a site map, and to name the important nodes. The overall questionnaire asked subjects to comment on their favorite experimental site, and to give guidelines about site design on the basis of their experiences. The subjects were also asked to rank the sites by size. During browsing sessions, each subject's Web navigation was logged electronically by an AppleScript utility, which received the EchoURL events sent at run-time to Netscape clients.

To gather data about the structure of the four Web sites, we employed a Web crawler named MOMspider. [6] This crawler generated a set of four large HTML files. Among other information, each file listed site pages by name, URL (Uniform Resource Locator), and child nodes (outgoing links). This information sufficed to construct a reasonably complete graph of each research site.

The experimental results were collected, summarized, and analyzed. Three types of information were collected: structural, session logging, and subject responses. The information was collected on two scales, site and node. Key items included the following: structural – landmark identification and node level; session logging – number of visits and virtual landmark identification; and subject responses – nodes recalled, drawn, and judged important. Subject responses also included a subjective site size ranking. “Level” refers to distance from the root in a breadth-first traversal; “virtual” sites were created for analysis from user navigational paths; “nodes mentioned” added together nodes recalled and nodes drawn; and structural landmarks were identified, as mentioned, by the algorithm of Mukherjea and Foley [9].

RESULTS

Two main analyses were carried out on the experimental data. On a site scale, the first analysis sought to identify and to explain differences between sites. On a node scale, the second analysis considered the characteristics of behavioral landmark nodes. For this analysis, regression analysis identified the best predictors of nodes mentioned or judged important. Analysis of variance (ANOVA) then determined the node characteristics that predicted visit frequency. No learning effects were detected. These statistical analyses were completed with SPSS for the Macintosh; an alpha level of 0.05 was used in all tests of significance reported in this paper.

The experiment yielded a number of preliminary results. On a site scale, structure had a significant effect on user navigation, with the strongly hierarchical sites having a greater number of nodes accessed ($F[1,23] = 127.76$, $p < .001$) and visited ($F[1,23] = 133.53$, $p < .001$) than did the weakly hierarchical sites. Moreover, site structure had a significant effect on user perception, with strongly hierarchical sites being perceived as smaller than weakly hierarchical ones ($p < .001$), as shown in Table 3.

Attribute \ Name	Travel Montana	WebMuseum	Nye Labs	Hawaii
Structure	Strong Hierarchy	Weak Hierarchy	Strong Hierarchy	Weak Hierarchy
Number of Nodes	1277	353	254	109
Mean Subject Rank	2.75	1.25	3.33	2.67
Perceived Rank	3	1	4	2
True Rank	1	2	3	4

Table 3: True versus Perceived Site Size

Finally, users' site drawings consistently revealed a strongly hierarchical structure, regardless of actual site structure. Of forty-eight maps, only five showed any cross-linking between structural branches.

On a node scale, nodes recalled, drawn, and mentioned were highly correlated (> .96). The total number of visits to a node is the best predictor of its memorability, as measured by importance judgement and mention. Surprisingly perhaps, node level (i.e., distance from the root node) predicts visit frequency better than status as a structural landmark.

DISCUSSION

In analyzing the experimental data, we derive four general results: the effect of site structure, the lack of effect of site size, the causes of node memorability, and errors in subjective site size ranking.

Site structure significantly affected user navigation. The strongly hierarchical sites generated much more activity than did weakly hierarchical ones, as measured by accesses, percentage visited, and virtual landmarks. This increased activity probably compensates for the limited horizontal paths of a strong hierarchy, which require extra steps for inter-branch navigation. The more numerous structural landmarks of weakly hierarchical sites did not increase the memorability of their nodes.

Unlike site structure, site size affected none of the experimental measures significantly.

As learning theory might suggest, the most memorable and judged-important nodes were those visited most often. Moreover, node level better predicts judged importance and memorability than do connectivity and status as a structural landmark. (Because our experimental subjects started browsing at root nodes, this result accords with the work of Catledge and Pitkow, who found that users tend to travel few links from their starting position [3].) Accordingly, node level is a better predictor of status as a virtual landmark than is status as a structural landmark. In weakly hierarchical sites, the algorithm used to identify structural landmarks generally finds them at low levels, where connectivity is greater. In strongly hierarchical sites, where connectivity is lesser, the procedure tends to find few structural landmarks. It appears that the algorithm of Mukherjea and Foley [9] may not be effective for finding behavioral landmarks in common Web site structures.

Surprisingly, Web site structure seems to affect significantly a subjective size ranking. Note that the weakly hierarchical sites appear larger to users: the largest experimental site (strongly hierarchical) was judged smaller than the smallest experimental site (weakly hierarchical), on account of differences in structure. For a weakly hierarchical site, we could speculate that the greater number of navigational options generates a sense of extent and range; the converse would be true for strongly hierarchical sites. Web site designers could use this result to influence user perceptions. A large site can employ a strong hierarchy, for example, so as to seem small and manageable. A small site can use a weak hierarchy, by contrast, so as to seem large and exciting.

In general, these experimental results suggest that strongly hierarchical sites have greater usability. They exhibit more accesses and a greater percentage of visits, greater memorability, perceived smaller size, and a correspondence to user's mental models. It is unclear whether strongly hierarchical sites reflect more organized and thorough designers, or whether these sites match innate human perceptual and cognitive styles. The strongly hierarchical sketch maps encourage the latter explanation, as does Parunak's suggestion that simpler hypermedia topologies are easier to navigate [11]. These questions, however, can be answered only by further research.

The current experiment has limitations arising from the small number of sites used, one for each combination of size and structure. Accordingly, the results may reflect idiosyncratic site qualities. In general, though, these results accord well with HCI theory and prior research findings. In any event, this methodology and experiment were designed for exploratory research into a relatively new area. It is hoped that future researchers will be able to verify and build on these findings.

CONCLUSIONS

Although exploratory, these experimental results have three implications for Web site designers. First, site structure can be varied between strongly hierarchical and weakly hierarchical to influence user perceptions of site size. Second, a strongly hierarchical structure appears more usable than a weakly hierarchical one. A weakly hierarchical structure's horizontal links do increase navigational efficiency, but at the cost of some disorientation. Finally, important information should be placed in nodes near a site's root, where the node will be most memorable and often visited (other factors being equal). These experimental results can profitably complement a Web designer's intuition and training.

This paper has described exploratory scientific research in a relatively new area, which involves Web structure and user wayfinding. Because of the Web's growth and increasing importance, such research is essential. In this paper, we have discussed the importance of site structure and node level on user wayfinding. In particular, we have noted the advantages of strong hierarchies and high node levels. While intuitive, these conclusions are strengthened by exploratory research.

This paper has also demonstrated that structural landmarks have surprisingly little value as behavioral landmarks. Other researchers have showed their co-existence in the physical world [8]; the creation of structural landmarks in information visualizations [7]; and the identification of structural landmarks on the Web [9]. But the current research is among the first to consider the relationship between structural and behavioral landmarks in electronic worlds. In doing so, this research provides useful guidelines for Web site designers considering issues of structure, and location of important information. Further research is still needed in the area of Web user navigation and perception, as well as issues of site size and structure.

Finally, we have investigated a new methodology for Web research. This methodology combines graph-theoretical, site structure analysis; recording and analyzing of user navigation in browsing sessions; and extracting cognitive maps from subjects via questionnaires, sketch maps, and interviews. We hope that this methodology will be useful for future research on the Web and other electronic worlds.

REFERENCES

1. David Canter, Rod Rivers, and Graham Storrs, "Characterizing User Navigation through Complex Data Structures." In *Behavior and Information Technology*, Vol. 4, No. 2, pp. 93-102. 1985.
2. Stuart K. Card, George G. Robertson, and William York, "The WebBook and the Web Forager: An Information Workspace for the World-Wide Web." In *Human Factors in Computing Systems: Proceedings of CHI '96*. New York: ACM, 1996.
3. Lara D. Catledge and James E. Pitkow, "Characterizing Browsing Strategies in the World Wide Web." In *The Journal of Computer Networks and ISDN Systems*, Vol. 27, pp. 1065-1073. Elsevier Science, 1995.
4. Matthew Chalmers, Robert Ingram, and Christoph Pfranger, "Adding Imageability Features to Information Displays." In *Proceedings of UIST '96.* New York: ACM, 1996.
5. Rudolph P. Darken and John L. Silbert, "Wayfinding Strategies and Behaviors in Large Virtual Worlds." In *Human Factors in Computing Systems: Proceedings of CHI '96*. New York: ACM, 1996.
6. Roy Fielding, "Maintaining distributed hypertext infostructures: Welcome to MOMspider's Web." In *The Journal of Computer Networks and ISDN Systems*, Vol. 27, p. 193. Elsevier Science, 1994.
7. Rob Ingram and Steve Benford, "Legibility Enhancement for Information Visualization." In *Proceedings of IEEE Visualization '95*. 1995.
8. Kevin Lynch, *The Image of the City*. Cambridge, Massachusetts: The MIT Press, 1960.
9. Sougata Mukherjea and James D. Foley, "Showing the Context of Nodes in the World-Wide Web." In *Human Factors in Computing Systems: Proceedings of CHI '95 (Companion Volume)*. New York: ACM, 1995.
10. Jakob Nielsen, *Multimedia and Hypertext: The Internet and Beyond*. Boston: AP Professional, 1995.
11. Van Dyke Parunak, "Hypermedia Topologies and User Navigation." In *Proceedings of Hypertext '89*. New York: ACM, 1989.
12. Romedi Passini, *Wayfinding in Architecture*. New York: Van Nostrand Reinhold, 1984.
13. Peter Pirolli and Stuart Card, "Information Foraging in Information Access Environments." In *Human Factors in Computing Systems: Proceedings of CHI '96*. New York: ACM, 1995.
14. Pointcom, "Pointcom Web Reviews FAQ." "http://point.lycos.com/faq," 1996.