A study of three browser history mechanisms for Web navigation

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A Study of Three Browser History Mechanisms for Web Navigation

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Abstract

Finding a previously visited page during web navigation is a very common and important process. Although most commercial browsers incorporate a history mechanism, when accessing pages that were recently visited users still rely mainly on the "Back" button. In this paper we studied the effectiveness of visually enhanced history browser mechanisms on web navigation.

We used three different history mechanisms as the experiment treatments. Twenty-one college students were the subjects of the experimental trials. With a between subject design, three experimental groups were equally divided according to subject profiles. Users read and completed the given scenario. A quiz was given to measure user performance on the tested mechanism. At the end of the quiz, a subjective questionnaire was given to measure user satisfaction.

The results showed that there is a significant statistical difference among the three mechanisms. The more visually enhanced history mechanism proved to be more effective in web browsing.

1. Introduction

1.1. Experiment motivation

Present browsers lack an efficient method for revisiting web pages. When navigating the World Wide Web (WWW), browser users experience difficulty in finding web pages that they have previously viewed. In fact, in a previous study it was found that 16% of subjects were unable to find web pages that they had recently visited [6]. Additionally, users largely depended on the "Back" button to access visited sites. In the results of the same study, "0.1% of page accesses were through the history list, 42% of page accesses used the Back-Button" for all web pages navigated by subjects.

Personal experience with history mechanisms of popular web browsers, such as Netscape and Internet Explorer has exposed many usability problems. Because of these problems, Netscape history window is usually avoided completely and the user relies on the back button or the "Go" menu selection. Also, a user may not even know that the history window is available, because it is not integrated into the user browser display. Although Internet Explorer has more organized history mechanism, it does not provide an efficient organization of the order in which the user has visited web pages. Accessing pages that were recently visited still relies on the "Back" button, and the back button does not contain all of the history.

As Kandogan and Shneiderman stated in one web browser study, "…current interfaces for browsing on the WWW are still primitive, in that they do not support many of the navigation needs of users…They do not…aid users in accessing already visited pages without much cognitive demands"[9]. One factor that may aid in browser history mechanism performance is providing a mechanism that is more graphically inclined to enhance user's short-term memory of the web pages visited [7].

The goal of this experiment was to determine if significant performance differences exist among several browser history mechanisms including the ones with visual enhancement. This experiment allowed us to gain insights about web browser history styles that would improve user performance in accessing visited pages. In this experiment, we also desired user's comments to gain knowledge of personal preferences and satisfaction levels associated with each browser history style.

1.2. Overview of the history mechanisms studied

Following are brief descriptions of the studied history mechanisms. Only three mechanisms were selected for use in this study. They were chosen based on availability.

1.2.1. Netscape browser. Netscape is one of the most common commercial browsers. It has a history window;

separate from its browser window that appears when the user requests it. This history is textually organized into a list that includes titles (if any) of the web pages visited and the URL addresses of those pages. To access a web page, the user must locate the desired page by name or address, and select it. Netscape‘s mechanism also incorporates “Forward” and “Back” buttons used to move to the next page or the previous page in the history, respectively. In addition, a “Go” menu selection provides the user access to pages through a drop-down list with titles of the most recently visited pages.

1.2.2. GlobalTree browser. The GlobalTree browser was developed at Sun[1]. Its history mechanism is visually organized into a single tree. All web pages visited by the user are represented by thumbnail images of those pages and organized as tree nodes with a global root. Each page is represented only once in the tree, by the first link that was used to access the page. Branches of the tree represent links (paths) that the user has used. Each node can have multiple children, but cannot have more than one parent. Therefore, cycles cannot be formed in the tree; and if the user navigates links in cycles, the last link that causes the cycling is simply ignored and not displayed. The user then can access a visited web page by mouse-clicking the corresponding node in the tree. Additionally, the corresponding node is outlined for the current page that user is viewing. Figure 1 shows the GlobalTree browser window.

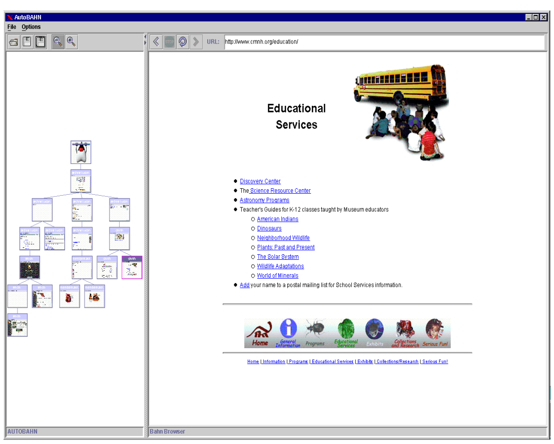


Figure 1. GlobalTree browser window (history tree is shown in the left panel)

1.2.3. DomainTree browser. DomainTree browser was developed at the University of Maryland, College Park (UMCP) [7]. Its history mechanism is similar to GlobalTree mechanism; however, DomainTree history is visually organized into domain trees[2]. It has an extra panel to the left of the browser that contains the domains that the user has visited. Each domain can be selected, by the mouse, to view the specific tree of that domain. The tree functionality is similar to that of GlobalTree mechanism. The DomainTree browser window is shown in Figure 2.

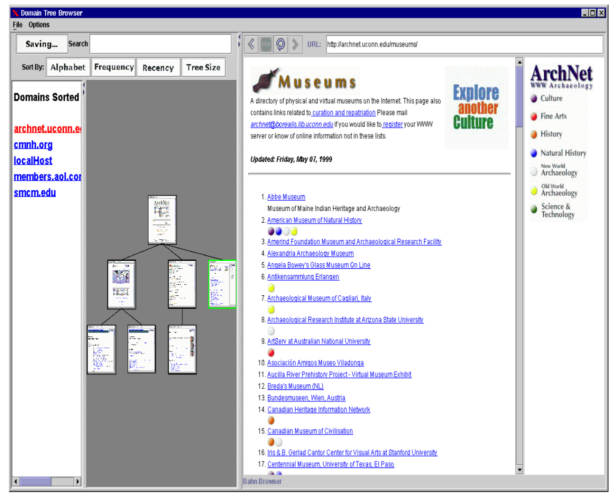


Figure 2. DomainTree browser window (from left to right: domains list, current domain tree and the current web page)

1.3. Review of related experiments

There have been many responses to the usability problems of current history mechanisms. Most approached solutions involve graphical interfaces.

One study done by Bederson and his colleagues included a zooming web browser, called Pad++. Pad++ has a multi-scaling graphical environment, so instead of having a single page visible at a time, multiple pages and the links between them are depicted on a large zoomable information surface [9]. The results of this experiment showed that users answered questions 23% faster with Pad++ over Netscape [3].

Another involved PadPrints, a browser companion that dynamically builds a graphical history-map of visited web pages [4] as in GlobalTree Browser. It was found that PadPrints allowed users to complete tasks 61.2% quicker than those who used the browser without PadPrints and to reduce the number of pages accessed.

Other approaches included WebTOC, which was an attempt to visually depict the contents of a web site with a hierarchical table of contents through Java applets, and MosaicG, which provided a two-dimensional graphical view of the history [10, 1].

[1] This browser is very similar to the PadPrint browser that developed at the University of Maryland.

[2] Each tree represents set of pages located on the same web site. Each tree is showed by the website name on the leftmost panel.

1.4. Relevant psychological or other theories

Graphical over textual representations of web pages represents fundamentally different cognitive tasks. To develop a mental model of the pages in Netscape or Internet Explorer, users are required to mentally associate pages that are presented in one at a time and often in a random order. In addition, the window motion associated with changing pages represents visual noise that likely hampers the user's cognitive visualization process. GlobalTree and DomainTree provide images of the web pages visited and their relationship as well as visual information about the pages content. Finally, users must attempt to mentally recall their internal map of the web site whereas GlobalTree and DomainTree mechanisms are integrated into a panel and are constantly visible.

DomainTree also provides additional level of hierarchy by dividing the action of accessing a page into two smaller action steps: first, knowing in which domain the page is located, and second, choosing the page within that tree. This permits the history to be more manageable if the tree becomes relatively large. GlobalTree and Netscape history mechanism, on other hand, would overload the user with information if the history is relatively large.

2. Experiment

2.1. Hypothesis and variables

2.1.1. Hypothesis. The null hypothesis of the experiment was: "*There is no significant difference in user performance and satisfaction among the different browser history mechanisms*". According to the results of the experiment, we would either accept or reject this null hypothesis. The dependent variables would be recorded, and then statistically analyzed to determine the significance.

2.1.2. Independent variable. There was one independent variable in this experiment, the web browser history mechanism. We had three distinct treatments Netscape browser, GlobalTree browser, and DomainTree browser.

Netscape was chosen to represent the standard (i.e., non-graphical) history mechanism in use today. GlobalTree and DomainTree were chosen for their visually enhanced history mechanisms. The difference between GlobalTree and DomainTree allowed the testing of the same type of mechanism each with different display features. For example, the DomainTree browser allows users to have several history trees maintained based on their domain names, whereas GlobalTree incorporates only a single history tree.

2.1.3. Dependent variables. The experiment measured user performance and satisfaction relevant to the web browser history mechanism. Therefore, tools had to be developed to capture these inherently qualitative attributes.

The first dependent variable was the time elapsed during completion of each task (the nature of the task will be explained later in the paper). The second variable was the number of pages visited for each task. The last variable measured was subjective satisfaction.

These three variables captured user performance and satisfaction associated with the history mechanisms. Analysis of these dependent variables is discussed in the result portion of this paper.

2.2. Pilot study

The pilot study was conducted with three UMCP[3] students. Each student used a separate and distinct web browser history mechanism.

The pilot study was used to determine user feedback and also, to answer some key questions in the experimental design. For example, we wanted to know how long the user would take to complete the experiment. Also, we wanted to make sure if the directions and written instructions would be clear to follow and understand. The last question we wanted to know was if the experiment would progress smoothly.

After the pilot study, subjects were asked to evaluate the experiment. Their overall impression was that the instructions needed to be made clearer. In response, we simplified the directions and made them more direct. Also, we complemented the written instructions with oral explanations. To ensure undesired delays, we offered to answer any questions users might have prior to the start of the task scenarios.

2.3. Preliminaries

2.3.1. Environment and system. All trials were conducted on five systems in the same on-campus computer lab. The five systems were standard Sun System Ultra workstations. They had the identical screen size, mouse, chair, and keyboard. The trials were performed approximately at the same time of the day. To accommodate the problem of network delays, a proxy server was developed to cache all the pages during the scenario part of the experiment.

2.3.2. Informed consent. Informed consent form was given to each subject. Subjects were required to sign and accept the terms of the experiments before continuing. The form requested subject's permission to use the results for research purposes, and it informed them that the data would be anonymous. It was made clear that participation

[3] University of Maryland – College Park

was voluntary, and that the subject may leave at any time during the experiment.

2.3.3. Background survey. A background survey was given to subjects to identify their individual profiles and to help determine experimental groupings. The survey asked the subject's age, experience with web browsers, time using browsers, and computer background.

2.3.4. Training. Each subject was given a written and oral explanation of the specific history mechanism that he or she was going to test. The written explanation of the history mechanism was designed to quickly orient the user to certain aspects of the history tool. During the training, each subject could go to any site, explore the site, and use the history mechanism until they feel familiar and comfortable with its usage. Training took approximately 10 – 15 minutes.

2.4. Subjects

2.4.1. Profile. All subjects were UMCP students with:

- more than 2 years of web browsing experience
- more than 4 years of computer experience
- more than 2 hours per week spent on web browsing

2.4.2. Subject design. A between subject design was used for this experiment. The experiment had 21 subjects divided into 3 treatment groups. Each group experienced one of the history mechanisms. Age, experience, and education level were considered when constructing the groups.

2.5. Experimental setup

2.5.1. Introduction. After the training phase on the browser, the subject was given further information about the experiment. Specifically, the introduction described the idea or purpose of the scenario and the subject goals and objectives during the scenario. For this experiment, the subject was instructed to research certain archaeological information by going to the Archeology Virtual Library. The goals and objectives were to get the gist of the information on each web page and then, to move on.

2.5.2. Scenario. The scenario was a list of 29 instructional steps. Subjects were expected to read each step, follow it, obtain the gist of the information, and move on to the next instruction.

There were several considerations when creating the scenario list. The first was that the information on each web page had to be distinctive and useful. Therefore, users more likely would recognize the information on a certain page when questioned later about it. Also, the scenario was to be logically sequenced. A natural method of exploration was critical in attempting to emulate a real life situation. Random links were not accessed, and so the sequence of links was sensible. Finally, the most important consideration was to create a non-linear history. A tree with several branches would create a realistic exploration that users would normally do, and therefore would give a distinct advantage towards using a visually enhanced history mechanism. The scenario took 20 – 25 minutes to complete.

2.6. Quiz

2.6.1. Setup. After completing the task scenario, the subject took the quiz[4]. The quiz constructed to test how long it would take users to locate the information they had seen during the instructional scenario. The quiz was administered via the computer and captured task time and the number of pages accessed for each question. There were 22 questions, each shown on a separate frame. Figure 3 below shows the first question of the quiz. The dialog box allowed the subject to respond to each question on the computer screen. After each question was answered, a pause box was displayed. The subject moved on when he or she was ready to answer the next question. The subject was expected to use the history mechanism to answer the question. Figure 3 contains an example of question and pause boxes.

2.6.2. Format. The quiz was in a multiple-choice format (Figure 3). This format was used to eliminate possible confounding variables (for example, typing speed) that might affect the data. Other potential problems that were avoided through application of a multiple-choice format include handling of misspelled words and imprecise answers.

The multiple choice-format also reduced the experimental time, which was another advantage. Overall, the time range for the quiz was approximately 20 – 25 minutes.

2.7. Subjective questionnaire

After completing the scenario and taking the quiz, subjects were asked to repeat the instructional scenario and part of the quiz with the other two browsers to familiarize themselves with what the experience would have been like with the other two types of history mechanisms. The quiz was not administered and performance data was not collected during the familiarization activity. Since there were an odd number of the subjects in each group, the order of presentation of

[4] The quiz is a set of questions related to the scenario the user experienced.

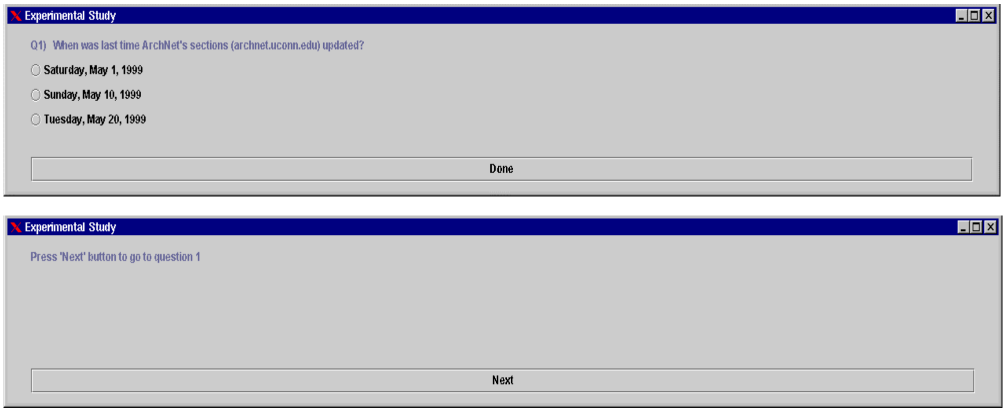


Figure 3. An example of the quiz screen and pause screen

the other browsers during this familiarization was counterbalanced to the extent possible (i.e., the presentation order of the other remaining history mechanisms was reversed for nearly half of each group). After working with the other two mechanisms, a subjective questionnaire designed to compare and rate the mechanisms was completed. The rating scale was 1-9. The subjective questionnaire took approximately 20 minutes to complete.

3. Results

3.1. Data gathering

We used an automated mechanism for timing. We measured the ***time*** needed by a subject to answer a question from the moment the subject pressed the "**Next**" button on the pause screen to the moment he or she pressed the "**Done**" button on the question screen. Also, we counted the ***number of pages*** the subject visited to answer each question starting from the moment he or she pressed "**Next**" to the moment he or she pressed "**Done**". We used a proxy server, in addition to its caching feature, to count the pages visited or accessed by the subject. The process of timing and counting were transparent so that subjects were less likely to be affected by performance anxiety.

3.2. Data analysis

Questions with incorrect answers were removed from the analysis. In addition, questions were the subject accessed a very large number of pages[5] were also removed from the analysis. We believe this behavior did not represent a subject attempting to recall the location of the required information but rather was searching for the data.

[5] Three times or more the average accessed pages for the question, was considered as a very large number of pages.

We categorized the questions, according to the effort needed to answer them, into two categories:

<u>Simple Questions (8 questions):</u> Simple question was defined as a question in which required the subject to locate a specific piece of information on a single page. Example:

The Archaeological Society of Maryland Inc. web page was designed by:
a) AppNet
b) Net Impression
c) Windy's Design Studio

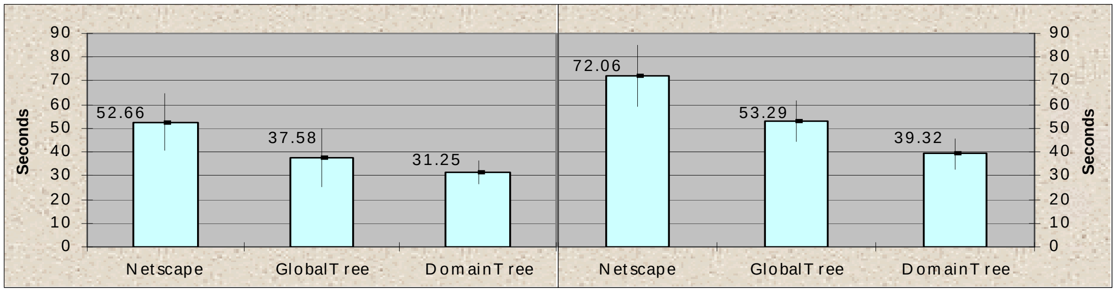
<u>Complex Questions (14 questions):</u> Complex question was defined as a question in which the subject was required to search for and locate information that could answer the question and may have required comparisons between pages. Example:

Which page was recently revised and updated: the Museum page, or the Picture Gallery of Ceramics page?
a) Museums page
b) Picture Gallery page
c) Can't say, some information is missing

3.3. User performance

3.3.1. Time. For each treatment the performance times for the corresponding trials of all 21 subjects were compiled and the mean, standard deviations, maximum, and minimum for each question category were computed. Table 1 shows these results and a graphical representation of these statistics shown in figure 5.

To determine if the history mechanism had a significant effect on performance time, a 3x1 (single factor) analysis of variance was computed. The ANOVA determined that the different types of history mechanisms *had a **statistically significant difference*** on performance time at alpha=0.01 level for both the ***simple question***



Simple Question *Complex Question*

Figure 5. Time measurements of simple question category and complex questions category

category ($F_{2,18}$=7.96, p<0.005), and the ***complex question*** category ($F_{2,18}$=19.67, p<0.00001).

Table 1. Time measurements (in seconds)

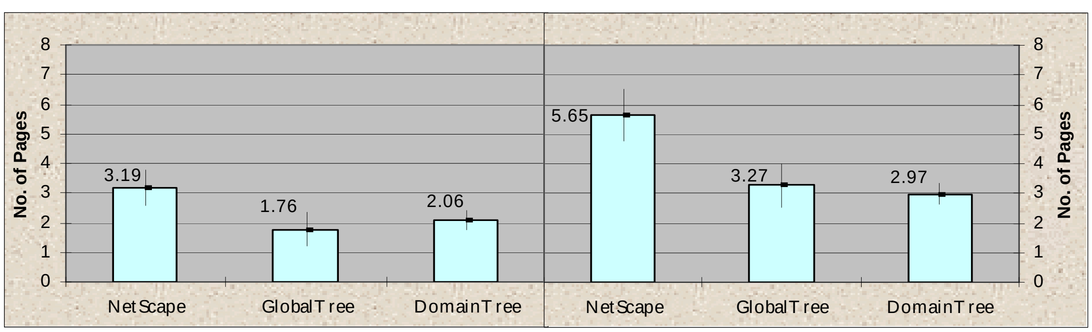
	Simple Questions			Complex Questions		
	Net Scape	**Global Tree**	**Domain Tree**	**Net Scape**	**Global Tree**	**Domain Tree**
Mean	52.66	37.58	31.25	72.06	53.29	39.32
Std. Dev.	12.18	12.07	4.98	12.83	8.64	6.55
Max	66.06	48.10	38.73	88.78	68.30	52.79
Min	35.58	20.23	24.67	49.14	39.10	34.54

A further analysis to determine the effects of the history mechanisms, a t-test for the independent samples (for each possible pair) was computed as shown in Table 2.

Table 2. The t-test of the time performance

	Simple Questions		Complex Questions	
	t_{12}	$P_{two\text{-}tailed}$	t_{12}	$P_{two\text{-}tailed}$
NetScape - GlobalTree	2.33	0.038	3.21	0.008
NetScape - DomainTree	4.30	0.001	5.95	0.000
GlobalTree - DomainTree	1.28	0.224	3.32	0.006

3.3.2. Number of Pages. As we did with performance time, for each treatment the number of pages for the corresponding trials of all 21 subjects were compiled and the mean, standard deviations, maximum, and minimum for each question category were computed. Table 2 shows these results with a graphical representation of these statistics shown in figure 6.



Simple Question *Complex Question*

Figure 6. Number of pages accessed of simple question category and complex questions category

Table 3. Number of pages accessed

	Simple Questions			Complex Questions		
	Net Scape	Global Tree	Domain Tree	Net Scape	Global Tree	Domain Tree
Mean	3.19	1.76	2.06	5.65	3.27	2.97
Std. Dev.	0.61	0.58	0.33	0.89	0.74	0.36
Max	3.93	2.86	2.36	7.12	4.12	3.29
Min	2.23	1.18	1.38	4.37	2.13	2.25

The reason for having the average of the GlobalTree less than the average of the DomainTree in the simple questions category is: for most of the questions, in using DomainTree you have to move first to the specific domain which contains the target page and then access the target page. But in GlobalTree, you can get to the target page directly since all the pages are reachable by single click of a mouse. This means that for most of the questions, users used DomainTree had to access one more page than the optimal number than can be reached by using GlobalTree history mechanism.

To determine if the history mechanism had a significant effect on performance time, a 3x1 (single factor) analysis of variance was computed. The ANOVA established that the different history mechanisms also had ***statistically significant difference*** in reference to the number of pages accessed at the alpha=0.01 level for both the ***simple questions*** category ($F_{2,18}$=13.54, p<0.0005), and the ***complex questions*** category ($F_{2,18}$=30.31, p<0.00001).

Also, a t-test for the independent samples (for each possible pair) was computed. Table 4 shows the results for each question category.

From table 2 and 4, GlobalTree-DomainTree row showed a significant difference in the time measurement between GlobalTree and DomainTree and no difference in the number of pages accessed. One possible explanation is that because GlobalTree displays more visual information (nodes) than DomainTree, users prefer to spend more time identifying their correct target node instead of exploring nodes of which they are less certain.

3.4. User satisfaction

The subjective satisfaction ratings were also compiled and analyzed. The means and standard deviations were calculated for all the 5 scores of the subjective questionnaire. The results are in table 5 with a graphical representation in figure 7.

Table 4. The t-test for the number of pages accessed

	Simple Questions		Complex Questions	
	t_{12}	$P_{two\text{-}tailed}$	t_{12}	$P_{two\text{-}tailed}$
NetScape - GlobalTree	4.49	0.001	5.40	0.000
NetScape - DomainTree	4.30	0.001	7.32	0.000
GlobalTree - DomainTree	-1.21	0.251	0.96	0.358

Table 5. User satisfaction

	Net Scape	Global Tree	Domain Tree
Mean	5.11	7.42	8.04
Std. Dev.	1.87	1.07	0.94
Max	8.00	9.00	9.00
Min	1.00	5.00	5.00

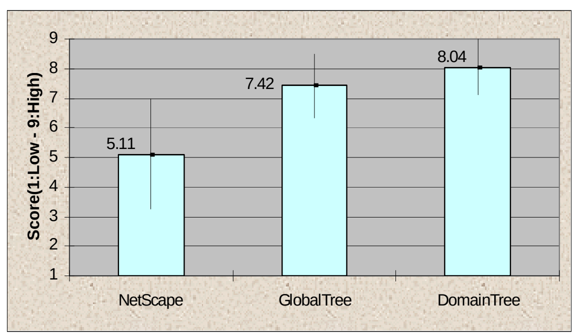


Figure 7. User satisfaction

As with performance time, a 3x1 (single factor) analysis of variance was used for each treatment to detect if the history mechanisms significantly affected users' satisfaction. The ANOVA showed that there ***is statistically significant difference*** at the alpha = 0.01 level ($F_{2,60}$=29.95, p<0.00001)

The following table shows the result for the t-test on the independent samples:

Table 6. The t-test for the user satisfaction

	t_{40}	$P_{two\text{-}tailed}$
NetScape - GlobalTree	5.16	0.000
NetScape - DomainTree	6.73	0.000
GlobalTree - DomainTree	2.11	0.041

3.5. Rate of Error

We calculated the number of questions in each treatment that were either answered incorrectly or that resulted in an extremely large number of pages accessed. Table 7 shows these counts:

Table 7. Number of incorrect answers

	Net Scape	Global Tree	Domain Tree
Wrong Answer	4	2	4
Large Number of Pages	2	5	2

4. Discussion

4.1. History mechanism and performance issues

The statistics rejected our null hypothesis. The results indicates the existence of statistically significant differences in the user's performance in terms of time and number of visited pages among the three treatments. From the above statistics, we can see that the DomainTree history mechanism is the best when assessing performance by time and number of visited pages. The t-test proved that there is a significant difference associated with performance time between DomainTree and GlobalTree history mechanisms for the complex questions category. One interpretation for having a significant difference on the user time performance and not having that difference on the number of pages between GlobalTree and DomainTree is: GlobalTree display more visual information (nodes) than DomainTree which make users prefer to spend more time to recognize their correct target node instead of going to suspicious wrong node.

From the error counts (table 7), the total numbers of errors of the different mechanisms are the same. On the other hand, the number of answers counted as errors due accessing large number of pages for the answer is significantly differ between the GlobalTree mechanism and the other mechanisms (table 7). Although subjects were asked to skip any question they could not answer, but the GlobalTree subjects tried to answer most of the questions even if they had to access a large number of pages. This attitude might reflect the nature of the GlobalTree history mechanism that shows all accessed pages in which it temps or forces the subjects to find the answer even if they had to visit a large number of pages.

4.2. History mechanism and subjective satisfaction

Results from the subjective satisfaction questionnaire showed existence of statistically significant difference between the three treatments. Users preferred the visual effect of the history mechanism. None of the subjects demonstrated any difficulty in using the three history mechanisms, and they rated the mechanisms with similar ease-to-use scores. Thirteen of the 21 subjects indicated a preference for the DomainTree history mechanism, while 5 wanted to have the GlobalTree history mechanism implemented in their browsers. Following are some of the comments

- "The tool of having all the pages visible is VERY useful."
- "DomainTree and GlobalTree are far better in terms of history but they cut space which lead to scrolling."
- "DomainTree is more logical in representing the history."
- "I like the performance of the DomainTree. It would be nice if I could bookmark the pages from the history tree or save the history itself."
- "The visual history tree was very helpful. Branching definitely assisted with retention of where I could quickly access desired information."
- "The "Back" button in DomainTree is not needed."
- "I personally liked DomainTree's history tool more than GlobalTree because it separated the trees by domain. It would be best to make this as an option of the browser."
- "The pages in the tree of the GlobalTree are so small that you might get confused to figure which is which."
- "The technique of DomainTree allows the use of separate trees resulting in bigger icon images that showing more information in these images thus helping in accessing the targeted page."
- "GlobalTree is more complicated. Images become tiny and hard to differentiate between them."

4.3. Comment

The overall experiment went smoothly. The environment was stable and quiet. Subjects were very cooperative. Although we tried our best to counter-balance the environment, we were not able to hold all the experiments at the same time. This was due to resource limitations of the lab and availability constraints of the subjects. All subjects used the DomainTree and GlobalTree for their first time during the experiment. We believe we could obtain more impressive results, if subjects had a longer time (for example, two weeks) to familiarize themselves with the browsers.

Negative feedback from subjects about the experience were in reference to the small size of the GlobalTree images and the overall length of the experiment.

Some also noticed a slow down in GlobalTree and DomainTree due to the their nature in drawing the history tree images. One main reason for the slow down may due to their implementation language. Java is used to implement DomainTree and GlobalTree, while Netscape is implemented by C. At present, C is more efficient than Java. In the future if GlobalTree and DomainTree are in implemented in C, or if Java become faster and more efficient, a significant increase in performance of these history mechanism will be noticeable.

5. Conclusions

5.1. Impact for practitioners

The experiment's results showed that the use of history mechanisms in web browsers may have a direct effect on user performance or satisfaction when revisiting web pages. Statistics indicated that the use of visual aids in a history mechanism is more powerful than using text or the current history methods. In addition, our experiment demonstrated that DomainTree is better than GlobalTree. Research needs to be conducted on individual components of web history mechanisms to see what impact they may have on web revisitation patterns. In our experiment, we noted that the subjects mainly depended on layout out of their navigation paths while completing the scenario. They, also relied on web page titles, URLs provided as tooltips, or status bar information as reference points for identification of previously visited web pages.

5.2. Suggestions for future researchers

We believe that we could obtain more impressive results by increasing the speed of DomainTree and GlobalTree and by letting subjects gain greater familiarity with the browsers before the start of the experiment. Some subjects recommended that DomainTree's usability could be improved by making the list of domains more informative. Some subjects suggested questions for future browser research:

- "For someone who likes to stay on [the Internet] for four hours, it is very easy to have an enormous and unmanageable tree!"
- "When opening multiple windows, how will this be handled by DomainTree and GlobalTree?"

6. Acknowledgments

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