

Frontier: A Directed Graph System for Web Navigation

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ABSTRACT

Today, the Internet is a truly ubiquitous technology. Every day the vast population of Internet-enabled devices and web based platforms grows at an alarming rate; allowing users to consume web content with a considerably diversified experience. Despite this extensive choice in experience, the majority of Internet users access online content through desktop or mobile web browsers. Yet while web browsers have become faster and more powerful over time, growth in the innovation of the underlying browsing methodology has remained relatively stagnant. The Frontier project aims to enhance the user interface for modern web browsers and introduce new methods for consuming web content. In particular, we seek to develop a user-friendly graph interface that improves web browsing in three areas: 1) explicit representation of page relationships, 2) history navigation, and 3) organization of web content. Through the development of our browser extension and user testing, we seek to show that such an interface provides significant improvements over what current browser interfaces offer.

CCS Concepts

•**Human-centered computing** → **Graphical user interfaces**; *Graph drawings*; HCI theory, concepts and models;

Keywords

graph visualization; web navigation; session management; contextual History;

1. INTRODUCTION

Although web browsers have made enormous advancements in terms of speed and compatibility over the last two decades, the core web browser interface has remained mostly

static; it provides a linear navigation experience that makes it difficult to understand spatial relationships between web pages. Users follow links or perform searches, and they can only move backward or forward along one path or view their history as a flat list. These older interfaces worked well considering the limitations of software and hardware in the early to mid 1990s. Since then technologies for user interfaces, visualization, and bulk data processing have undergone tremendous improvements. The underlying structure of the web is best visualized as a directed graph (as depicted in many popular illustrations of the internet). However modern browsers provide minimal support for graph-style traversals of pages in history and link navigation. For instance, navigating back from a web page, then subsequently traversing forward to a new link, replaces any previously accumulated forward history. The replacement can cost the user a considerable amount of time, resulting in tedious backtracking in search for desired web content. Such limitations may especially interfere with any user who consumes a large amount of content online.

Humans possess impressive spatial and visual intelligence. Unfortunately, the document-oriented structure that is popular in current browsers fails to use human visual intelligence to its full potential. Users compensate for the deficiencies of current systems by saving bookmarks and grouping browser tabs in order to establish relationships between the pages they are interested in. Page links play a significant role in objectively evaluating the quality of web content [2]. For many users, it may be common to skim the contents of pages, open links of interest in new tabs, and use their browsers' history features to go back and study pages in more detail. However, such techniques do not scale well when the user needs to track a large number of pages.

At its core, the Frontier project aims to reshape the nature of web session tracking, navigation, and page management. We explore alternative means of navigating and organizing content from the web. In addition to leveraging the inherent graph structure of the web in a user's current session, Frontier can save session history for subsequent access across browsing sessions. User behavior such as following a link or opening a new tab produce different interactive visualizations of browsing session activity. All of these capabilities were developed to help users better understand the contextual nature of their browsing habits. Frontier culminated with the development of a Chrome browser extension for

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CHI Italy 2015, September 28-30, 2015, Rome, Italy

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DOI: <http://dx.doi.org/10.1145/2808435.2808465>

which more information about the implementation is provided following the Related Works section. We conclude with a discussion of our user studies and results.

2. RELATED WORKS

The development of graph-based interfaces to hypertext systems is not entirely new. The field of spatial hypertext has explored and verified the utility of graph visualization as a means of traversing hyperlinked systems [6]. The gIBIS system is one of the earliest known spatial hypertext systems [8]. The authors of gIBIS demonstrated how the directed graph system could enhance the design process. More recently Heer and Boyd used interactive graph visualization for displaying social networks [7]. Browsing behaviour information is provided via interactive graphs in the browser extension Visual History [4]. The utility of graphs for conveying spatial-temporal data is established in [3, 1]. Mahyar and Tory demonstrated how interactive visualization can enhance collaborative research teams and provide an excellent example for evaluating such systems [9]. Won et al. establish the importance of browser history for users and identifies that existing interfaces for history are underutilized [11]. In addition to the vast amount of work showing the value of graph-based hyperlink interfaces, there are several related projects which warrant more discussion.

2.1 Oracle’s Hierarchical Model

Firstly, we will discuss a patent by researchers at Oracle called ‘Hierarchical Model for Web Browser Navigation’ [10]. The patent, established in 2009, proposes that the functionality of traditional back/forward buttons should be extended with additional buttons that facilitate navigation to neighboring nodes in a graph-based session as seen in Figure 1.

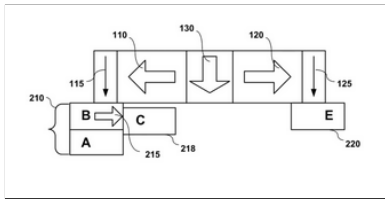


Figure 1: Example of additional buttons included with back and forward for advanced path navigation.

The engineers at Oracle demonstrate that from the current page one can navigate to nodes B and A as they were pages used to navigate to the current web page within the session. Node C is a web page that one can navigate forward from node B (note that node C is not the current web page). Node E, in a similar fashion, is a web page one can navigate forward to from the current web page.

2.2 Session History Tree by Daniel Dawson:

The Session History Tree is one of the most popular solutions to attempt inclusion of the concept of tree-based web navigation. In its implementation, the Firefox plugin stores users’ sessions as a tree structure and offers a system of sub-menus (similar to those found in the Windows XP OS file explorer) for users to click and navigate to web pages within their browsing session [5]. Figure 2 shows an example of the plugin in use.

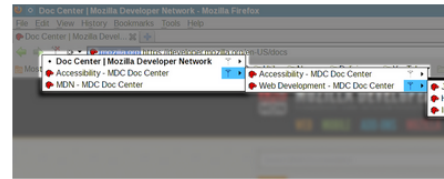


Figure 2: The FireFox Session History Tree plugin in use.

With the design of Frontier, we differ from Session History Tree’s implementation in that our UI allows navigation to only neighboring nodes within a session graph in order to encourage a simple, yet effective design. Navigating to nodes further in the graph would require users to visit our history page, but future works can certainly improve the traversal to non-neighboring nodes (web pages linked by traversals to one or more other web pages).

2.3 From Where to Where by Xuan Wu:

Another alternative for users is the ‘FromWhereToWhere’ plugin for Firefox. This extension not only displays related links to a selected link on the current web page, but a menu located in the Firefox toolbar allows a simple navigation of the user’s history. In the extension’s history menu, the list of web pages are supplemented by sub-menus of web pages navigated to and from each of the pages in the list [12].

Frontier differs from this approach by deviating from a cumbersome sub-menu system. Our solution attempts to not only fit the mental model that a user’s session is a directed graph, but introduce a simple and intuitive design language.

3. IMPLEMENTATION

3.1 Overview

Frontier seeks to introduce a navigational interface that enables users to browse the web in three dimensions. The three dimensional concept of web browsing can be broken down in the following manner:

- **First dimension:** The traditional back/forward navigation that has existed from the very beginnings of web browsing facilitated through back and forward buttons.
- **Second dimension:** A solution that enables users to navigate to multiple web pages previously visited within their session from a single web page. For example, a user may perform a search and click on a link. After moving back and selecting another link, the path along the initial link is lost unless multiple back/forward navigation paths are saved.
- **Third dimension:** In addition, we explored methodologies to improve the concept of tabbed navigation. We have introduced a feature that would enable users to separate their history into multiple “sessions”. While the concept of session separation has been used in browser back ends for a time now, our session management system would enable the user to partition their web history based on intent of use.

3.2 Back-end Component

One of the two primary components of Frontier is the back end. The main background script is responsible for management of the web session graph. The script constructs the graph one edge at a time by listening for page transition events fired by the Chrome run-time system. The graph data structure consists of three sub-structures: a JavaScript Object that maps page URLs to page node objects and two adjacency list structures (forward-links and back-links) that identify mappings between the graph's nodes. The forward-links adjacency list is a JavaScript Object where the key is a page URL and the value is a JavaScript Set consisting of outgoing hyperlink URLs. Using the Set object helps prevent duplicate edges. Subsequently, the back-links adjacency list is the transpose of the forward-links structure. The back-links for a given URL could be computed on demand, but we find time efficient to simply cache these links; more specifically, when we add an edge to the forward-links graph we also add the inverse of the edge to the back-links graph. Favicon URLs are also saved using a tab listener callback so that they can be accessed by the front end.

Chrome's message passing framework is used to communicate between the front end and the back end. This simplifies modifications to any of the software components because we have the flexibility to change data structures without breaking other components. Additionally, this architecture improves security because access to sensitive structures is governed by a software interface.

3.3 Front-end Component

The UI consists of two principal views. The compact view is displayed in the upper-right corner of the Chrome Browser when triggered by a click event on the extension's "badge icon" (refer to letter "G" in Figure 3). This view will only show navigational relationships between neighboring nodes on the graph. Alternately, a more comprehensive view overrides Chrome's history page and displays a complete list of visited pages and their navigational relationships represented by a directed graph.

3.3.1 Injected Menu

Shown in Figure 3 is a navigational menu that allows for back and forward traversals across previously visited web pages. This menu can be triggered on a click of the Frontier Extension button (G). Please refer to Figure 3 for the following references to UI elements in the navigational menu.

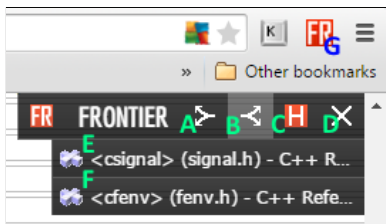


Figure 3: The primary components of the Frontier dropdown menu.

A. Back Link Button - On hover, all the links that lead to the current page will be displayed below.

B. Forward Link Button (Active in the picture above) - On hover, all links that originate from the current web page

will be displayed below. In this case, the user has directly traversed to two links from the current page.

C. History Button - This opens Frontier's history page (explained in the next section) in a new tab.

D. Close Button - Closes the menu.

E. and F are either forward links or back links depending on which button is selected. In this case they are forward links; meaning that both links originate from this page. When clicked, the page will open in the current window.

G. Frontier Extension Button - This opens the injected menu that is shown above in the upper-right corner of the window.

3.3.2 History Menu

Figure 4 depicts a screenshot of Frontier's history page in use. Please refer to Figure 4 for the following references to UI elements within the history page.

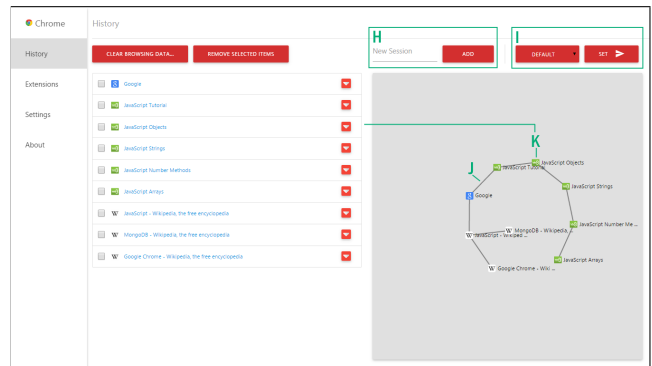


Figure 4: A sample visualization of a session provided by the graphical layout of history coupled with the stack based layout of unrepeated browsed links.

H. Here you can create a new browsing "sessions". This creates the ability to separate the history into meaningful categories for easier history traversal.

I. This dropdown list allows switching between stored sessions. The graph rendering and page list of the current session are also updated to reflect a change in session.

J. This is a link between two pages. The link establishes a navigational relationship between web pages.

K. This is a single page; a node. Each visit to a particular page in a session is condensed into one node. All user traversals to and from this page are represented by the edges leading from it. Clicking on the node will open the page in a new tab.

There are at least two clear strategies for constructing the web session graph. The first is to generate a hypertree structure, but this would not permit cycles or allow for multiple incoming edges. Every page transition would generate a new edge (even moving back and forward along the same links). We chose to create the graph strictly from hyperlinks that are traversed by the user. This means that even if a user performs the same page transition multiple times, no duplicate edges are produced. The advantage to this approach is a more compact graph that can convey browsing information better than traditional list-based interfaces.

4. USER STUDIES

In order to validate our design principles, test our application in real world scenarios, and improve core functionality, we collected observations on 28 users. Users were asked to identify a targeted idea for information that they currently seek, like finding the right apartment for their next lease, and search it online. Once the user found satisfactory results or answers to his/her targeted idea, they were asked to evaluate Frontier via a post-experimental questionnaire.

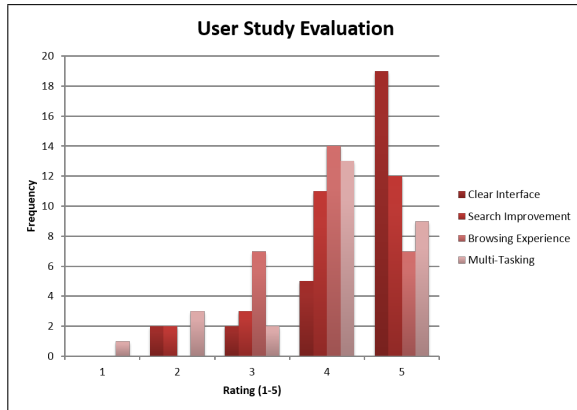


Figure 5: Post-questionnaire evaluation of Frontier across 28 users of various backgrounds.

The chart in Figure 5 is a compilation of responses from the users. The post-questionnaire consisted of eight questions across four categories including interface usability, improvement to search, overall browsing experience, and benefit to multitasking. In each question the user was asked to rate their experience on a scale of 1 (poor) to 5 (great). User responses were largely positive regardless of background, with fewer than half the tested users evaluating the design of the interface with a rating of 4 or less. With regards to improvement to search, browsing experience, and ability to multitask, most users gave a rating of fair. One explanation for this feedback is that because Frontier does not interfere with traditional back/forward navigation, and when considering that the majority of users who tested Frontier were more inclined to use the tried and true Chrome controls, user attitudes of the new navigational menu were largely passive. One theory is that the navigational menu may be more beneficial when used in place of standard navigation. We received a rather wide-spread impression that despite the intuitive nature of our UI, a person who is already well taught on the management of multitasking on the web, is not particularly inclined to our solution to meet their productivity needs. We also received feedback about providing more customization of graph layout, which we will explore in future versions.

5. CONCLUSION

Web browsers have used essentially the same interfaces for many years. Frontier is a browser extension that seeks to give users more control over their web navigation techniques by using the underlying graph structure of the web. In our evaluations, we sampled prospective users with a wide range of technical backgrounds. Our preliminary findings show that users without experience in computer science are not

overwhelmed by Frontier’s web session visualization. Overall, users appreciate the power of the graph visualization as modality for relating spatial-temporal relationships among content in the web session. The graph abstraction is intuitive and mirrors users’ mental models of web browsing and page relationships, and we hope that the impact of extensions like Frontier will be to advance the navigation model of all browsers.

6. ACKNOWLEDGEMENTS

The authors would like to thank the members of the Sketch Recognition Lab for their support, particularly Cassandra Oduola, and the Computer Science and Engineering department at Texas A&M University.

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