Footprints: History-Rich Tools for Information Foraging

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ABSTRACT
Inspired by Hill and Hollan’s original work [6], we have been developing a theory of interaction history and building tools to apply this theory to navigation in a complex information space. We have built a series of tools — map, trails, annotations and signposts — based on a physical-world navigation metaphor. These tools have been in use for over a year. Our user study involved a controlled browse task and showed that users were able to get the same amount of work done with significantly less effort.

Keywords
information navigation, information foraging, interaction history, Web browsing

INTRODUCTION
Digital information has no history. It comes to us devoid of the patina that forms on physical objects as they are used. In the non-digital world we make extensive use of these traces to guide our actions, to make choices, and to find things of importance or interest.

We call this area interaction history; that is, the records of the interactions of people and objects. Physical objects may be described as history-rich if they have associated with them historical traces which can be used by people in the current time. For example, if you are driving your car down an unfamiliar highway and approach a curve, you may notice that the guardrail has a number of black streaks on it. Realizing that these streaks have been formed from the “interaction” of the guardrail and the bumpers of other cars, you slow down. You are able to negotiate the curve safely because you can take advantage of the interaction history.

Interaction history is the difference between buying and borrowing a book. Conventional information retrieval theory would say they were the same object, given the same words, same pictures, same organization, etc. However, the borrowed book comes with additional information such as notes in the margins, highlights and underlines, and dog-eared pages. Even the physical object reflects its history: a book opens more easily to certain places once it has been used.

A houseguest may enter your kitchen and by cursory examination of your cookbooks be able to determine your favorite recipes, even if he has never seen you cook before. In Norman’s terms [14], the history-rich object acquires new affordances and we can use these affordances to interact with the object in new ways.

We make use of interaction history every day in dozens of different ways without conscious reflection; we think it is natural. In fact, car bumpers and guardrails are man-made artifacts which we have come to understand and read as a part of becoming adults in our society. The fact that we undergo such extensive learning suggests that interaction history is highly valuable. Our project, called “Footprints” by analogy with the footprints we leave in the world, is an attempt to understand what is valuable about interaction history in the physical world, and to find ways to capture history for use with digital information. We believe that the lack of interaction history information represents a significant loss. Work done by users to solve problems in information systems should leave traces. These traces should be accessible to future users who could take advantage of the work done in the past to make their own problem-solving easier.

For example, recently Maes found herself shopping for a new car on the Web. She visited a number of car manufacturer sites, car dealer sites, read reviews on-line, and looked at various independent reports and tests of a number of different vehicles. At the end of this process, she had not picked a particular car to buy — in fact, her list of possible choices was longer than when she began. But all the work done in this process was lost when she finished. If Wexelblat wanted to take advantage of her work, he might ask her, because he happens to know she has done this task, and she might remember some of what she had done and learned. But for anyone who did not know she had done this work there is no way to recover any of the things she found, nor to avoid any of the mistakes she made.

In the digital realm, problem-solvers must approach situations as though they were the first and only people ever to make use of the information. Maes’ digital footprints are
unavailable, so we all must become information foragers — in the sense of Pirolli and Card [16][17] — over and over again. The Footprints project tries to alleviate some of this kind of problem by allowing users to leave traces in the virtual environment, creating history-rich digital objects.

The term history-rich object and its association with records of the interaction of people and digital information derives from work by Will Hill and Jim Hollan [6][7]. We have taken their initial insight and expanded it into a theoretical framework which allows us to talk about a wide variety of history systems. The next section of this paper gives a basic introduction to the theoretical framework. We then describe the tools we have built to enable history-rich navigation in complex information spaces, particularly the World Wide Web. Finally, we describe our experiment in having people use these tools in a controlled task and discuss our ongoing work in expanding and improving the tools.

**INTERACTION HISTORY FRAMEWORK**

We have developed a framework for talking about interaction history. This framework presents six properties which characterize interaction history systems. The goal of the framework is to bound a space of all possible interaction history systems, and to give designers of such systems guidance as to what things are important in building history-rich interfaces. We use six major properties to describe this space.

**Property 1 — Proxemic versus Distemic**

Urban planning and social anthropology use the words *proxemic* and *distemic* to describe the closeness relationship of people and spaces. We consider proximity to be a function of both the physical distance and the cognitive distance between the person and the space. A proxemic space is one which is felt by users to be transparent, in that the signs and structures can be easily understood. People feel close to, or part of, the space. Conversely, distemic spaces are opaque to users. Signals go unseen, usually because the people in the space lack the required background or knowledge to translate or comprehend what they experience. We feel “close” to our bedroom even when far away from it and experience a certain “distance” when we sleep in someone else’s guest bedroom.

Interaction history systems may be more or less proxemic based on how well they relate to their users and how well they take advantage of users’ past experiences and knowledge. For example, the Emacs mode-line history noted above (CVS:1.6) would be completely distemic to anyone who did not know that cvs is a concurrent version-control system which uses numerical markers to distinguish successive versions of a source file.

**Property 2 — Active versus Passive**

Most interaction history is passive; it is recorded and made available without conscious effort, usually as a by-product of everyday use of objects. Conversely, when we stop to think about leaving a record, we are creating an active history element. The active/passive distinction is concerned with the user’s mental state and relationship to history-rich objects.

The most common example of this distinction is in Web browser software, e.g. Netscape Navigator. The “history” or “go to” list is passive history because it is recorded for the user as she browses; the “bookmarks” or “favorites” list is active history because the user must stop to think that she may want to return to this location in the future. The challenge for history-rich computer systems is to find ways to allow interaction history to be passively collected when necessary so that users are not constantly thrown out of the cognitive state necessary to getting their tasks done.

**Property 3 — Rate/Form of Change**

History moves forward, building as more interactions take place. This “accretion” process is how history builds up. However, interaction history does not only accrete, it also fades out. One of the challenges for history-rich interfaces is deciding how to deal with this accretion. Just as a complete video playback of a meeting is usually not as useful as a summary, the total accumulation of history must be summarized so that it can be observed and used quickly. A good real-world example of this are patient charts in hospitals. These charts are annotated and added to by many different personnel under different situations over time, yet a physician must be able to come into the room, pick up the chart, and understand essential facts of the patient’s current state at a glance.

In the digital realm, Hill and Hollan’s “Editwear” tool [6] used a modified scrollbar to show areas within a source file which had been more or less heavily modified. Dozens or hundreds of accesses were summarized by an unobtrusive thickening of the “thumb” component of the scrollbar.

**Property 4 — Degree of Permeation**

Permeation is the degree to which interaction history is a part of the history-rich objects. History may be inseparable from the object, as in a flight of worn stairs, or it may be completely separate, as in records of stolen art. In a history-rich interface, we must decide how closely to link the objects of interaction and the history information. Digital data will only retain that history information which we choose to keep; therefore, any record of this information must be captured and displayed by tools which we create explicitly for that purpose, or by display systems built into existing tools; for example, the mode-line modification to Emacs described above. The tools we have built to display interaction history information are described in the next section of this paper.

**Property 5 — Personal versus Social**

History can be intimate to a person: what have I done? Or it can be social: what has been done here? Many tools focus on personal histories; for example, bookmarks in Web browsers that allow users to revisit sites they have noted. Group histo-
ries, such as knowledge repositories and shared digital libraries are more rare but, we believe, more valuable because most problem-solving tasks are collaborative in nature. One of the primary benefits of interaction history is to give new-comers the benefit of work done in the past. In fact, the slogan for the Footprints project is:

We all benefit from experience; preferably someone else’s

Property 6 — Kind of Information
There are an infinite variety of kinds of interaction history information that can be captured. What kinds of information are important are, to a large degree, dependent on the task that the observer is trying to accomplish. Since we cannot possibly characterize all the kinds of information available, we focus on the uses to which interaction history might be put. We categorize the kind of information available loosely into what, who, why, and how.

Knowing what was done can be useful if users are searching for value, particularly among clutter, or if they are in need of reassurance. This is particularly helpful for novices who lack the kind of practice which helps them know what is reasonable to do with a given computer system. Knowing what was done can also give guidance; that is, the process of directing someone in a task or journey.

Knowing who has done something is important for reasons of companionability (doing things with friends), sociability (doing things with people who are similar to me), and for establishing authority and possibly authenticity.

Knowing why something was done can be important for reasons of similarity of purpose. I may care a great deal about something that was done by people with a goal similar to mine. A related reason is goal discovery, the process of starting off on one task and realizing that it relates to, or can be co-accomplished with, another task. Finally, knowing why something happened is crucial for explanation and learning.

Knowing how some bit of interaction history was done can be important for issues of naturalness. For example, Microsoft Office’s assistant has a “show me” mode in which it will show the user how to select the correct options from menus, how to fill in dialog boxes, and so forth.

APPLICATION TO THE WEB
In an effort to validate the theoretical framework above, we have built a series of tools applying our theory to the problem of navigation in a complex information space. Earlier versions of these tools have been described in [19] [22]. The Footprints tools focus on helping people navigate the Web; in particular we assume that people know what they want but may need help finding their way to the information and may need help understanding what they have found. Therefore, we do not use history to make recommendations. Instead we provide tools which use history information to contextualize Web pages that the user is seeing. This is a form of information foraging: exploration combined with exploitation.

Our architecture is based on a proxy server (front end) and a database (back end). Both the front and back ends are written in Java and work on any platform with any standard Web browser. The front end controls the user interface tools, and records standard Web logs. These logs are sent to the back end once per user session and are incorporated into the database overnight. The front end and the back end communicate via a TCP/IP socket. Thus, the interaction history information seen by users changes as they move from Web page to Web page, but the database itself changes only slowly. The one exception to this is user comments, as noted below.

Our tools are based on a metaphor of navigation: maps, trails and signposts are all items familiar from the physical world which we have implemented in the digital realm. There are, of course, many other tools which could have been implemented, but these both fit our metaphor and allowed us to explore interesting points in the space of possible interaction history systems described above.

![Figure 1 — Screen Shot of Footprints in Use](image)

Our tools are active navigation aids. Each visualizes interaction history information in a different way, but all are tools with which the user can navigate, rather than static visualizations. The tools act in coordination. Selecting a document in one tool highlights it everywhere; focus is also coordinated. Tools also have some control buttons for manipulating document titles and helping users who get lost; these are explained below.

When the user starts up Footprints, she is given a control panel window. Buttons on this panel allow the user to show
or hide each of the tools (maps, trails, and annotations) separately. Users can also shut down Footprints from the control panel. The Map and Trail tools appear in separate windows alongside the Web browser. Figure 1 shows a screen shot of a user visiting the Media Lab Research Web page with all three tools turned on.

Over the course of the project, we have designed, tested and implemented several different versions of these tools. Our goals have always been to test our theories and to make systems which people will actually use. As a result, our designs have changed significantly over time, though our basic metaphor has stayed the same.

All our tools use Web navigation transitions as their basic information. Footprints does not have a notion of user identity; all user data is anonymized and merged with the data of other users. This has the advantage of protecting users’ privacy — no one can tell what Web sites you have visited — but it has the disadvantage of not allowing users to see each others’ trails. This is a deliberate trade-off; other, equally valid trade-offs could be made but the focus of our research is on the interaction history itself and not on mechanisms for personal privacy.

The first tool is the map, pictured in Figure 2. This map shows the traffic through a Web site. Nodes are documents and links are transitions between them. Note that this is not all the documents and transitions, only the ones which people have actually visited or used. This is, typically, only a fraction of the actual site content. Additionally, we track all transitions made by the user, whether they come from selecting a link on the page, typing in a URL, selecting a bookmark, etc. The result of this is that links on the map often do not correspond directly to links embedded in the Web page.

In Footprints these user-created transitions are considered to be as important as the transitions (i.e. links) provided by Web-page designers. In some sense they are more important, since they reveal user’s models of how information should be connected. As we described in [19] and [22], the patterns shown in the maps and trails are an externalization of users’ mental models. This theory is reinforced by our experiment, described below.

The map visualization we use is derived from [12]; it provides a fisheye view with more detail in the center. Users can drag the display in any direction to bring nodes from the edge towards the center. Individual nodes can be single-clicked to show their titles, or double-clicked to bring that document up in the Web browser. Titles might overlap, so the user may right-drag to rotate the map.

Popularity of documents is shown by shades of red — the hottest documents are in red, then shades of pink down to white (shown here as shades of grey). The current document — the one displayed in the browser — is shown in black. Because users can get lost while viewing the map, there is a “Recenter map” button which redraws the map, centered around the node in which the user expressed the most recent interest, either by single-clicking it or double-clicking it.

In the terms of our framework, the map view is social, passive, distemic, and unpermeated.

The second tool is the path view, shown in Figure 3. If we think of the map as the high-level view, the path view is “lower” level in that it shows the user what trails have been followed by other people. Trails are coherent sequences of nodes followed by an individual. We use a number of heuristics, including referrer consistency, dwell time, and session boundaries to determine what makes up a trail.

Referrer consistency means simply that if A is followed by B is followed by C, then A must be the referrer of B, which in turn must be the referrer of C. Dwell time refers to the time spent on the page, measured as the time between successive page loads. If the mean dwell time over all users who follow a given transition is too large (currently greater than 2 minutes) we assume that two sequential pages are unrelated and thus should be on different trails. Session boundaries are set when the user starts and stops the Footprints tools. Log files
are transferred to the back end each time the proxy server is started. Each log file is considered to be one session. Of course, the user may leave Footprints running for hours or even days, but this is detected by our dwell-time heuristic.

The number of trails formed this way is very large, of course, so we only show the trails which are relevant to (include) the current document. Note that trails with common starting points are merged, so users can see branching (forks in the road) more easily.

Trails also respond to single clicks — by showing titles — and double-clicks, by taking the user to the new document. There is also a button which allows users to see (or hide) all titles at once. Since the path view is arranged in a stair-step fashion, titles can be shown in the same window.

Users can click on the circles to bring up a simple text window. If comments already exist for that trail, they are shown and the user has the option to add a comment. Clicking on an “Add Comment” button takes the user to a text input widget. Comments are social, active, proxemic and permeated.

Unlike the passive history information, comments are entered into the database immediately. Once the user clicks “OK” on the add comment window, the path view updates so that the circle is filled if it was not before. Clicking on the filled circle brings up the comments, including the new one, sorted so that the most recent comment is at the top. Older comments appear below. We do not delete comments; users can read the entire history and can converse or exchange ideas.

With our small user population this has worked; as Footprints is used by larger groups, we will investigate whether any editorial policies are necessary.

**USE OF THE TOOLS**

Earlier versions of our tools have been in use for over a year. The first version was used only by alpha testers in-house, and at two Media Lab sponsor companies. The first public beta version of Footprints occurred in October 1997 via our Web site (footprints.media.mit.edu) and improved versions were released to sponsors for internal use. The third major release, which is documented here, occurred in August 1998. Each release has been used by a wider audience.

Although, as noted above, we have been guided both by a navigation artifact metaphor, and by a desire to explore the space of possible interaction history systems, we have also been fortunate to have continual feedback from our users. Many of the features found in the current implementation are a result of requests from users; for example, the identification of “hot” documents in the map and the recenter button were both originally suggested by our users.

**EXPERIMENTAL RESULTS**

In addition to collecting feedback from our beta users, we have performed controlled experiments to evaluate both the subjective and objective usefulness of the tools. We had users perform a timed (20 minute) browsing task, one group unaided and one group with the Footprints tools. Subjects were told that they had approximately $20,000 to spend on a car and were to find cars which might be interesting to them. They were encouraged to use their normal Web browsing patterns and tools. The second group had available the interaction history generated by the first group, and received a 5-minute instruction on how to use the Footprints tools based on a data set we created around the Media Lab Web site.
In testing a system which is designed to help people with an imprecise task such as browsing, it is hard to find useful measures. We settled on two objective and two subjective measures. Objective measures were the number of alternatives generated (that is, how many car makes/models they found), and the number of pages visited to generate those alternatives. Subjective measures were the users’ sense of satisfaction and judgement of how easy the task was.

Twenty subjects participated in each of the two conditions. Subjects were volunteers given a token reward for participation. All subjects were expected to be familiar with Netscape Navigator before the experiment. Full details of the experimental conditions and evaluation can be found in [20].

Our pre-test hypotheses were that Footprints tools would increase the number of alternatives generated and reduce the number of pages visited. We also hoped that users would find it easier to find and understand relevant information, and would have a greater sense of satisfaction. The available interaction history information could lead people to a greater sense of having explored the problem.

The experiment partially supported our first hypothesis and gave a surprising result on our second. The number of alternatives generated by the two subject groups was not significantly different; however, the mean number of pages required to reach the same alternative level was significantly less for the Footprints group: 24.8 pages for the unaided group versus 18.75 pages for the Footprints group (p <.05).

In measuring the subjective responses, no significant differences were observed, with one exception. There was a significant interaction effect across conditions for those subjects who had, prior to the experiment, looked for car information on the Web, as shown in the ANOVA below. In this table, we test the interaction of user’s previous activity (looked means that they have looked for car information on the Web before this experiment) with their response to a question about their satisfaction with the experience. Satisfaction was measured on a scale of 1-5, with 1 representing “Totally Satisfied” and 5 representing “Totally Dissatisfied.” The table shows that while there is no significant effect for either effect considered separately, the two-way interaction of experimental condition (unaided vs. Footprints) and previous experience (looked vs. has not looked) was significant (p<.01).

This was somewhat surprising. We had been assuming that interaction history models would help naive users; instead we seem to have found a situation in which past users’ models are recognized and used by experienced browsers. In fact, naive users — in our case users who do not have experience with the domain — find themselves less satisfied when seeing these models.

### TABLE 1. Interaction of Previous Experience with Satisfaction

<table>
<thead>
<tr>
<th>Variation Source</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effects</td>
<td>1.607</td>
<td>2</td>
<td>.803</td>
<td>1.5</td>
<td>.237</td>
</tr>
<tr>
<td>Expmt #</td>
<td>.207</td>
<td>1</td>
<td>.207</td>
<td>.385</td>
<td>.539</td>
</tr>
<tr>
<td>Looked</td>
<td>1.079</td>
<td>1</td>
<td>1.079</td>
<td>2.014</td>
<td>.164</td>
</tr>
<tr>
<td>Interacts</td>
<td>4.872</td>
<td>1</td>
<td>4.872</td>
<td>9.093</td>
<td>.005</td>
</tr>
</tbody>
</table>

This most likely relates to our notion of proxemic/distemic, and reminds us that all naive Web users are not alike. Those who had a mental model of what car information on the Web was like found the Footprints representations much more proxemic and were able to make much better use of them.

This conclusion was reinforced by other subject-reported experiences. In particular, subjects who rated their level of Web expertise lower reported having a harder time finding information that was relevant to their problem and less satisfaction with the solutions they found.

At this writing we are doing more detailed analyses of how subjects used the Footprints tools. Informal observation and post-test conversation suggested three patterns of use were in evidence. Some subjects simply took off in directions we had not seen before and so received little or no help from Footprints. This suggests that our test data set could be improved. Other subjects started off using Footprints information — for example, to avoid having to perform their own Web searches — then went off in new directions since their tastes in vehicles differed from those of our first group of subjects. This was expected; we cannot possibly cover all the possible car makes and models in which subjects might be interested.

The third group of subjects did not start out using the Footprints information. They had different search strategies. However, they ended up using Footprints information once their searches brought them near to popular car-related sites. At this point, the map proved particularly useful; as one subject put it: “As soon as I got there, the map had a bunch of alternatives and I used those.”

### RELATED WORK

Our theoretical work derives from two major influences. The first is ethnographic studies of how people work in teams in real situations, primarily research from Hutchins [10], Orr [15], and Suchman [18]. The second is urban studies, particularly the work of Lynch [13] and Brand [1]. From these we have developed our theory of how interaction history infor-
Hypertext systems have used map and trail mechanisms for many years. However, these are typically top-down created artifacts put in the system by the designer for guidance or pedagogical purposes. Zellweger’s “Scripted Documents” [23] are an excellent example of this. This notion is also being carried into the Web domain by projects such as CMU’s WebWatcher [11], a tour-guide agent for the Web, and Walden’s Paths [5], a K-12 educational application of scripted paths.

Some related work falls into the category of assisting social navigation. Dieberger [4] describes an enhanced MOO system, which keeps track of how many people use passages between rooms in the MOO and augments textual descriptions with information on how heavily used the passages appear. Dahlback, Hooks and others in the PERSONA project [3] have been exploring a number of different aspects of social and personal navigation, including the uses of artifacts in these processes and individual differences in the navigation process.

Other related work has been done in the area of community-created information sources. Hill and Terveen, particularly in their PHOAKS project [8][9], have been active in creating new techniques for mining existing information — on the Web and in Usenet newsgroups — for traces which can be collected and made available to future users. PHOAKS collects URLs that have been positively mentioned from postings and Frequently Asked Questions documents. These URLs are then provided as recommendations on a central server to people interested in the topic of the newsgroup from which they were extracted. Alexa (www.alexa.com) provides a real-time local Web-page recommendation system. They use history information as part of their input in determining what pages to recommend; however, it is unclear just how history is used or how it is integrated with the keyword matching which forms the basis for their recommendations.

Footprints can also be considered an attempt to create what, in the hypertext community, are called metadocuments. These are higher-level structures which link information related by topic or interest. Two projects that we are aware of have had some success in doing this. IBM’s Aqui (http://www.aqui.ibm.com/) and Web rings (http://www.webring.org/). Aqui maintains a database on its server of links which people think ought to be present but which are not. Users can “vote” on which links they think should be associated with a given page and the most popular are listed. Web rings is a way for authors to loosely associate their pages with similar pages written by possibly unknown other authors. Members of a ring include links on their page which refer back to the ring server; this server then supplies the “next” page in the ring. This may be different on different traversals of the ring.

CONCLUSIONS AND FUTURE WORK
We have built a set of tools to support undirected Web browsing. The tools are based around the concepts of interaction history and the notion that the work done by past users can be important to helping current users solve problems such as navigation in a complex information space. Our tools have been in use and available on the Web for over a year. The user community is small but growing. Our tools have been popular with Web information users and designers.

We are implementing one more tool for Footprints: a purposes tool. Our goal is to have a method for users to communicate why they are doing a particular browse. Although some of that information can be inferred from the content — e.g. a trail containing a Web search for cars followed by series of pages from car manufacturers — our users have expressed an interest in being able to know the goal(s) pursued by past users.

The experiment reported here showed that our tools are successful in two respects:

- they enable users to get the same work done with significantly less effort, and
- experienced users were able to recognize the information models left behind by other users and reported a significantly higher sense of satisfaction when working with these models.

We plan to conduct a further series of tests, using a larger interaction history base and allowing users to work with the active history tools (comments and purposes). More work remains to be done in testing the use of active history tools, as well as scaling up our user community. Applications of these ideas to areas such as electronic commerce and information management are also being investigated.
Finally, we set out to take something pervasive in the physical world, characterize it, and extract use from it for the digital realm. We have begun to show success in this endeavor; we have given history to digital information.

Thanks
Work on Footprints has been funded by the MIT Media Laboratory's News in the Future consortium. Code for the Footprints tools was written by Felix Klock, Alex Lian, and James Matysczak. Jennifer Smith helped with the statistical analyses.

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