A USER INTERFACE FOR EXPLOITING WEB COMMUNITIES IN SEARCHING THE WEB

Kemal Efe, Alp V. Asutay
Center for Advanced Computer Studies, University of Louisiana Lafayette, LA 70504, U.S.A.

Arun Lakhotia
Center for Advanced Computer Studies, University of Louisiana Lafayette, LA 70504, U.S.A.

Keywords: Web navigation, interaction styles for data mining, graphical user interfaces, screen design, prototyping, theory and methods.

Abstract: We have implemented a novel user interface for Internet search engines that allows users to visualize the graph neighborhoods of search results returned. When the required information is not in the returned result set, it is likely that there is a path from one or more of the returned documents to another document that has the required information. Our proposed interface allows exploring these paths. We performed experiments to measure users' level of success in finding desired information. Given equal time to perform a set of search tasks, on average, the users of our interface were able to find twice as many of the required documents as the users of a traditional interface, using the same underlying search engine. We also found that, on average, users of the proposed interface tried 31% fewer queries per search task.

1 INTRODUCTION

Existing search engines predominantly use the query-response paradigm for information retrieval. For a variety of reasons, documents with the required information may be ranked low, and users may fail to reach required information despite many attempts of revised query submissions. Additional interface tools are needed for users to take control of the search direction instead of relying on the algorithms used by the search engine alone.

This paper describes the user interface of a search engine that we designed, built, and user-tested. In this system, a user can start with an initial list of search results and explore the graph neighborhoods of returned documents by using interface controls provided. Our user experiments with the proposed interface yielded highly encouraging results.

A basic result of earlier research on link-based information retrieval algorithms such as HITS (Kleinberg, 1999) is that topically related documents are clustered in tightly knit communities in the web graph (see Figure 1). If the list of search results contains any subset of members from a community, it is likely that other members of the same community are also relevant. The initial result list provides good starting points to explore the web graph since the listed entries can be used as entry points to their communities. If users are provided with the right set of tools, they can reach desired documents on a subject more easily by following the graph links rather than by reformulating and resubmitting queries iteratively.

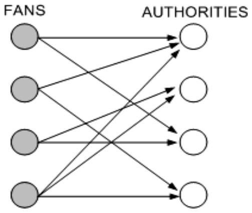


Figure 1: The structure of a typical web community.

The proposed interface enables visualizing the graph neighborhoods in multiple levels of resolution, switch between different levels, and trace the links backward and forward to explore a selected region.

Efe K., V. Asutay A. and Lakhotia A. (2008).
A USER INTERFACE FOR EXPLOITING WEB COMMUNITIES IN SEARCHING THE WEB.
In *Proceedings of the Fourth International Conference on Web Information Systems and Technologies*, pages 114-121
DOI: 10.5220/0001530001140121

2 RELATED WORK

Most users of Internet search engines write short queries which tend to generate high hit counts. In addition, there are a large number of documents on the web that are really relevant to a user query in some sense or other. Besides retrieval algorithms, search engines rely on a variety of additional mechanisms to aid users. Once a list of top hits is determined, a further step of clustering the results (e.g. as in Vivisimo.com) can aid users to focus on the sub-clusters of interest.

The LightHouse project (Leouski and Allan, 2000) displays clusters of search results graphically, with each item in the search results represented by a sphere. The Mapuccino (a.k.a. WebCutter) system (Maarek et al., 1997) displays the link structure at a web site selected by user with page ranks displayed at each node. Other similar examples include the WebCiao (Chen & Koutsofios, 1997) Web Mapper (www.web-mapper.com), and WebView (Cockburn, 1999). Differently, the Hy+ system (Hasan et al., 1995) displays a graph representing the portion of a web site explored by a user.

The PadPrints system (Hightower, et al., 1998) displays the visited pages in a tree structure so that users can easily locate a page visited before. The WebMap project (Doemel, 1994) and the ViewBuilder project (Mukherjea and Foley, 1995) are general-purpose graphic tools for visualizing web graphs. In particular, ViewBuilder allows alternative methods of displaying the history graph, including hierarchical clusters, content-based clusters, and link-based clusters.

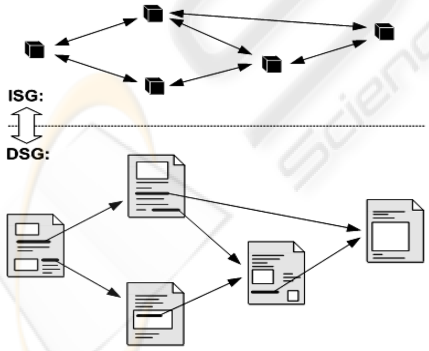


Figure 2: Document Space graph and Index Space graph.

Other interesting systems include the Hogdex system (http://www.hogdex.com), Gnovies (http:// www.gnovies.com), and TouchGraph (http:// www.touchgraph.com). TouchGraph is a powerful Java graphics tool that has been applied to a number of Internet visualisation projects, including GoogleBrowser which displays a graph of similar pages as defined by Google “similar pages” criterion (http://www.touchgraph.com/tggoogleBrowser.html.

None of these interfaces give the user much more control than what is already available through a standard search engine. In particular, they don’t provide any tools for the user to guide the search engine in the right direction.

3 PROPOSED SEARCH MODEL

The concept of web graph is well understood in the literature. The nodes of the web graph represent web pages. The edges on the web graph represent Hyperlinks on web pages. We call this graph the “document space graph,” or DSG.

As our search engine indexes and saves web pages, it creates another graph that we call “index space graph,” or ISG. In this graph, each node represents Meta data saved about a web page. This Meta data comprises the usual information (e.g. page title, description, etc.) displayed about a web page when the page is included in a search results list. The edges in ISG are copied from DSG. Figure 2 illustrates the relationship between ISG and DSG.

An important difference between the two graphs is that edges in DSG are directed in only one way from the citing page to the cited page. These edges allow a surfer to move from one page to another page that it cites, but not in the opposite direction. In ISG, all edges are directed both ways to allow moving between two nodes in either direction with equal ease.

3.1 Surfing the Index Space Graph

In the proposed system, a user initially starts by entering a search query and retrieves a list of search results. Each entry in this list is essentially a node from the ISG. Each entry is associated with a set of outgoing links and a set of incoming links that enable surfing the ISG. Figure 3 represents the immediate the web neighbourhood of a node, where the “start node” represents one of the listed items in the search results list.

In implementation, the ISG is stored in two database tables: a nodes table and a links table. Since a link is specified by its “head” URL and its “tail” URL, the outgoing links and incoming link of a node are retrieved easily. If displayed along with other information about a web page (we discuss display methods in more detail in Section IV), these two sets of links allow a surfer to explore the ISG effectively, going backward or forward as needed.

During a search, a single step of backward or forward move may not be enough. A user may wish to repeat this process an arbitrary number of times, and explore a large region in ISG. Figure 4 represents the wider neighbourhood of a node that can be explored by starting with the "start node" of Figure 3. This wider neighbourhood is defined by iteratively considering the immediate neighbours of the start node as new "start nodes."

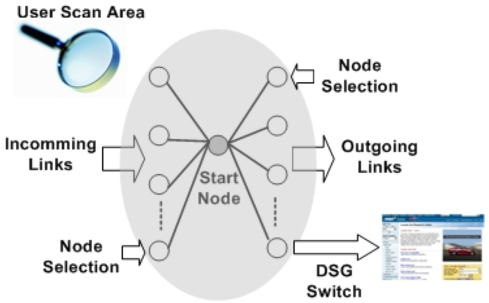


Figure 3: Web neighbourhood of a document in ISG.

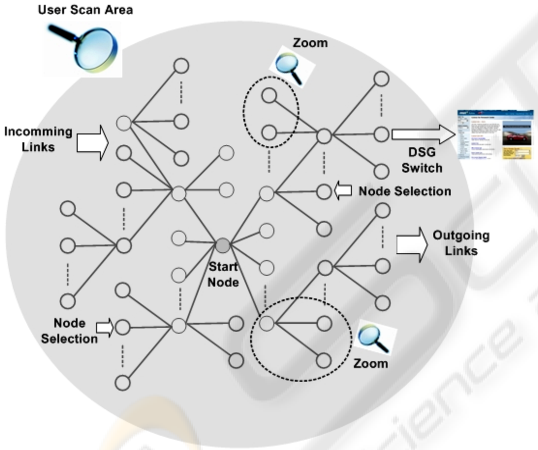


Figure 4: Extended neighbourhood of a document.

3.2 Surfing the Two-Level Graph

During a search, a user can also switch between ISG and DSG graphs at will. After locating an entry in the initial search results list that looks like it might contain the desired information, a user can select the corresponding document. This moves the user from a node in ISG to a document in DSG. Once on DSG, the user looses the ability to move backward from a cited page to a citing page. If the required information is nearby, the user may be able to reach it after a few clicks. If this turns out to be a wrong move, the user needs a mechanism to switch back to ISG. Clicking the "back" button of the web browser is one way, but often insufficient. Instead of the last point of departure at the ISG, user may wish to move to a different neighbourhood, for example a set of documents similar to the current page.

To implement this feature, a tool bar associated with the web browser can be used to submit a query to the search engine that will retrieve a list of related pages; e.g. by using an algorithm such as the one proposed by Dean & Henzinger, (1999).

3.3 Orientation Support

During exploration in ISG, users need to be able to orient themselves so as to return to a prior decision point and try alternative paths. To provide orientation, the interface must gracefully scale the neighborhood displayed where the complexity and comprehension meet at a satisfactory level for the user. Rendering a large graph may make the display incomprehensible. On the other hand, rendering only the immediate neighborhood of a document will not let users to identify their position. The neighborhood moves as the user moves on the ISG so the user will only be aware of the current locality. The system must also construct a trace, and provide clues of different paths to reach that position. The user must be able to select the previously explored neighborhoods or distant regions that are at least two steps away backward or forward.

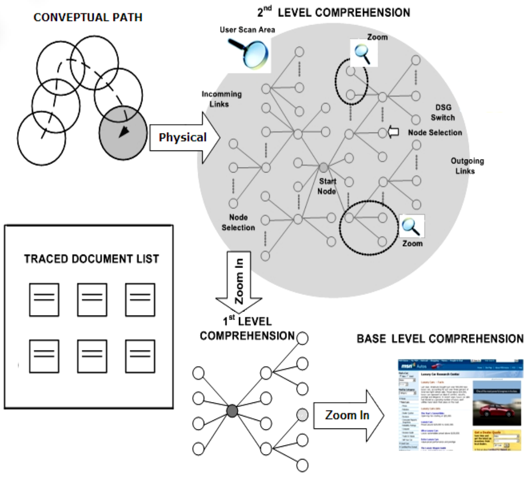


Figure 5: Multi Level Search Interface.

The trade-off between scalability and comprehension can be resolved if the interface provides multiple scales of resolution where levels are rendered starting from an abstract representation with an option to retrieve detailed representation of selected regions. There needs to be a cross communication between levels to pass the ISG state information.

Figure 5 describes the hierarchy starting from the base (page) level up to the third level. The third level is the conceptual path in the mind of a user. The second level is the ISG, where the interface renders all the neighborhood nodes created incrementally so far. The interface also shows the current vicinity of the user as a clue for orientation. In the first level interface, user sees the immediate neighborhood around the selected node. Each circle in the second level is associated with a region rendered in the first level.

In the proposed system, the interaction state of a user is characterized by his/her current orientation, which is defined by the currently selected node and trace history. When switching between different levels of abstraction, state information needs to be cross-communicated. Whenever the user surfs backward, forward or jumps to a particular node on the ISG, orientation has to be modified in all the levels of the hierarchy.

When a user selects a particular region on the second level interface, the first level interface renders that region. The cross communication in that case is a “zoom in” operation that commands the lower level interface to render that particular region. In a similar manner, user can switch from the first level interface to the base level. The base level is rendered when the ISG node is selected using either first level interface or second level interface. The hierarchic structure of the multi-level model does not require a zoom-out operation because the outer-level neighborhood is continuously rendered at a dedicated region of the screen.

4 IMPLEMENTATION

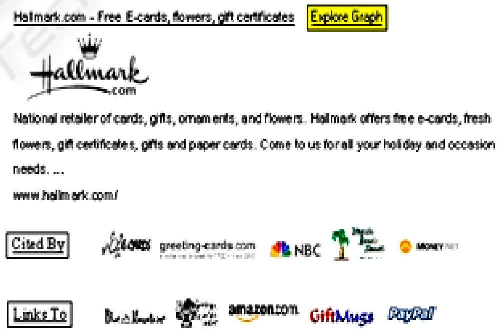
4.1 Display Structure

As explained, our proposed navigation model is based on tracing the edges of a graph structure. The main question here is what method of display to use so that users can effectively trace the graph structure. There is a trade off between using text and graphics in terms of the ability to convey information. Graphical interfaces are useful for visualising topical relationships between documents, but there is a loss of information that can be carried by words more effectively. Often, information carried by text is difficult to codify in a graphic display.

From the ergonomics point of view, users need not know that they are tracing the edges of an underlying graph structure. Graphs or other mathematical representations may not appeal to users with insufficient analytical skills to interpret or comprehend displayed objects. On the other hand, text-based display methods are inherently poor for effective navigation since inter-node relationships are harder to represent without the aid of graphics. As a compromise, in the implemented system we provide a text-based interface and a graphical interface. The user initially starts with the text-based interface, and if needed, switches to the graphics-based interface to explore the web neighbourhood of a node in detail.

4.1.1 Text-based Neighbourhood Support

In the text-based interface our design uses the traditional components for each entry in the result list. In addition, we added new controls to allow moving from an ISG node to one of its graph neighbours. We also added an image or logo derived from the web page being represented by the entry. The purpose of these images is to provide a mental hook for the users so that they can easily remember a familiar web site when they see it again among the search results.



Hallmark.com - Free E-cards, flowers, gift certificates

National retailer of cards, gifts, ornam ents, and flowers. Hallmark offers free e-cards, fresh flowers, gift certificates, gifts and paper cards. Come to us for all your holiday and occasion needs. ...

www.hallm ark.com/

Figure 6: Screen-shot of a sample entry in search results.

Here the task is to convey the basic idea of Figure 3 about each entry without using a graph explicitly. We do this by associating each entry in the search results with two sets of hyper links as shown in Figure 6: one set of Hyperlinks for the pages cited by the entry, another set for the pages that cite the entry. The nodes in these sets are also represented by images derived from their corresponding pages. Due to limited screen space we limit the number of graph neighbours in each set to six, selected after sorting them by their relevance to the user query. When clicked, these Hyperlinks retrieve their corresponding web pages. This moves the user from ISG to DSG.

There needs to be a mechanism for users to stay in the ISG and continue exploring the neighbourhood without moving to DSG as in Figure 3. This requires a basic step of moving from an ISG node to a neighbouring ISG node with both nodes and their neighbourhoods displayed. With a text-based interface this is difficult to achieve. Besides scalability (the ability to repeat the same display method for subsequent moves), comprehensibility of inter-node relationships is difficult to maintain. Therefore, we decided on an indirect method for moving between ISG nodes as follows: Associated with each entry, we provide two Hyperlinks labelled "links-to" and "cited-by," which retrieve corresponding sets of nodes, as implied by their names. For example, clicking on "cited by" in Figure 6 retrieves the list of web sites cited by the Hallmark web site. Each item in the retrieved list is associated with its own "links-to" and "cited-by" Hyperlinks. This mechanism allows moving from one ISG node to another ISG node, repeating this process an unlimited number of times.

4.1.2 Graphical Neighbourhood Support

Associated with each item in the search results list, we provide a Hyperlink labeled "Explore Graph." This Hyperlink opens a new search interface as shown in Figure 7. Space restrictions don't permit including a screen shot large enough to meaningfully represent all its features, so we show a schematic drawing in Figure 7 of available components in it. In this window, display area is divided into three regions that contain the four components below:

1. Bird's-Eye View: The bird's-eye view displays the largest region of the ISG graph traced by the user, but it displays the least amount of detail. When the window is first opened, it displays the immediate neighborhood of the selected ISG node as in Figure 3. To save screen space we omit displaying links. Each node is represented by a box containing its URL. The central node of Figure 3 is highlighted with a red frame around it. The nodes citing the central node are displayed as a row of boxes on its left, ordered by their relevance scores with respect to the user query so that more relevant nodes are closer to the central node. The nodes cited by the central node are displayed on its right, ordered similarly.

Once the window is opened, the bird's eye view graph can grow arbitrarily large. The mechanism of growth is by creating further neighbourhood plots as in Figure.3 with their central nodes chosen from among nodes already displayed and connecting with the rest of the graph. This process creates two copies of a node displayed; one as a member in some other node's neighbourhood, and one as the central node in its own neighbourhood. The new neighbourhood plot is added to the existing graph as a new row of boxes. The new row is justified so that its central node is vertically below its position in the original graph where it appears as a member. To further highlight this relationship, the two copies of a node are connected by a vertical line (area-1 in Figure 7).

2. Detail View: By selecting a node in bird's-eye view, a user can display detailed information about the immediate web neighbourhood of an ISG node (see area-2 in Figure 7.b). Here a description is provided about each document. The central node of the neighbourhood is displayed at the top. The set of nodes citing it are displayed in a column below-left from the central node, and those cited by it are displayed in a column below-right from the central node. Since the screen space is limited, only four nodes are displayed from each set, but scroll buttons are provided so that user can change the subset of nodes displayed from each set.

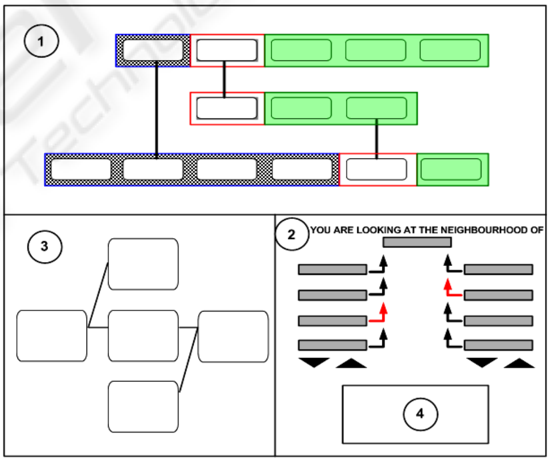


Figure 7: Graphics-based display overview.

A user can move backward or forward to a neighbour of the central node by clicking on the arrowhead next to the neighbour. When this happens, the detail view refreshes so that the selected node moves to the top, with its immediate neighbours displayed on its left and right, as before. The bird's-eye view also refreshes to add the new neighbourhood, if not already included in the bird's-eye view graph.

3. Trace History: This is the trace history diagram (see area-3 in Figure 7.b) of the visited documents, i.e. appeared as the central node in detail view area.

The trace is rendered as a zigzag chain based on the forward and backward movements on the ISG. Each node contains a description of the document it represents.

4. DSG Window: This is a small, framed window (see area-4 in Figure 7.b) displaying the content of any selected document. This is useful when a user wants to take a peek at the web document without leaving the displayed graph structure. Since this window is small, scroll bars are provided to see the page.

5 USER EXPERIMENTS

We tested user's level of success in finding information with the proposed interface and compared it with users provided with a traditional interface (as in Google interface) both using the same underlying search engine.

5.1 Test Subjects

Each user group consisted of 25 computer science graduate students, randomly assigned to their groups. In a questionnaire that we asked them to fill, they all said that they used search engines on a daily basis, and are familiar with the task. However, none of them had ever seen the specific search engines they were asked to use. Before the tests, we gave each user group 15 minutes to "play with" the search engine they were to use and familiarise themselves with different controls provided by the interface. Our suggestion was received with puzzled looks by the group using the traditional interface, as though to say "what is there to familiarize with," but the group using the proposed interface were quite busy trying different features not found in other search engines. We provided no additional training for either interface users since we felt that users in the real world don't receive any special training either.

5.2 Test Environment

We built a search engine as a test bed for experimental use in our research projects (see http://www.chabook.com/graphical/search.aspx). It originally started as a web directory in April 2004. In August 2004 a Meta search service was added (available at http://www.chabook.com). In January of 2005, a prototype search engine with its own crawler was added to support various research projects, because the Meta search engine does not provide the link information needed for our model.

The search engine's database contains 200,000 documents connected by about 2 million Hyperlinks. These nodes and links constitute the ISG graph described in this paper. The system uses MySQL database and its built-in full-text search algorithms based on the Vector Space Model. The documents were obtained by starting with 55,000 documents downloaded from the "reference" section of the Open Directory Project (http://www.dmoz.com), and then by crawling the neighbourhoods of this initial set of documents. As we traced the outgoing links of the initial document set, we added newly discovered nodes to the database until the number of documents reached 200,000.

For the purpose of experiments we built two different interfaces, both using the same underlying search engine. One is a traditional style interface like the user interface of Google. The other is the interface described in this paper. The test subjects were only told to carry out the search tasks given to them by using the interface provided, but they were not told about the alternative interface they were not using. Both groups were given the same set of search problems, and the same amount of time to complete the search tasks.

5.3 Test Procedures

Test subjects were given a number of search tasks and a limited time to perform the required searches. Since two groups of test subjects are used, one with the proposed interface and the other with a traditional Google-like interface, the group that can perform more number of successful searches within the given time must have been more effective. Since the underlying search engine was the same for both groups, and the test subjects were equal in intellectual capacity, any performance difference is due to the interface used.

Test 1-Document Search:

Duration of this test was 60 minutes for both user groups. In this test, the test subjects were asked to find a set of 10 documents based on a brief description of the information content on the page. Test questions all started with the statement "Find a document that…" followed by a description of the document as specifically as possible. They were asked to record the page URL when they think they have found the correct page.

This is a realistic scenario of search engine usage in real life since users start with an idea about the desired information content of a page that satisfies their information needs. We selected the target documents in the test by querying the search engine with the set of queries below before the test, inspecting the search results, and choosing one of the entries on the first page of search results.

1. Thematic world maps
2. Science and Religion
3. Science Fiction Term definitions
4. Prehistoric Monuments
5. Baseball discussion forum
6. Agriculture Software Package
7. Library and information science news digest
8. African Diaspora Web Pages
9. Internet sites archive, digital library of archived internet sites
10. Antique Maps and Prints + Cartography + Collecting Society

Test subjects were not given this list, or the specific URLs of documents they were to find. Instead, they were told to find documents with the required information based on provided descriptions. They were told to use any query they saw appropriate while doing their searches.

Test 2-URL Search

Duration of this test was 30 minutes for both user groups. Users were asked to perform searches as they saw appropriate on the subject “used books” and see how many of the URLs listed in Table 1 below they come across during their search. The subjects were instructed to indicate the ones they found by circling the entry on the list.

Table 1: List of URL’s used in the second test.

addall.com	bookspot.com	edif-spectacle.org
booktalk.com	biblio.com	bkdirectory.com
resourcehelp.com	iblist.com	fetchbook.info
bksalefinder.com	irabooks.com	zulbabooks.com
smith.tripod.com	dig-librarian.com	bookwire.com
bookrecycler.org	cl-resource.com	abaa.org
pbfa.org	bookfinder.com	booksweep.com

5.4 Test Results and Discussions

The purpose of Test-2 is to validate the first test. We anticipated some degree of difficulty in interpreting the user answers from the first test, because the same information may be available on several different sources. During a test, users may find any one of these pages and think that they have found the correct one. This complicates the interpretation of responses given. We would have to make judgements about what to consider a correct answer. In real life, users search for information rather than documents. A user seeking information doesn't care which of the several possible sources contain the information. Thus we felt that we should consider a URL as a correct answer if the page substantially meets the specifications provided its description. Still, it would be difficult to justify using our judgements in evaluating user answers.

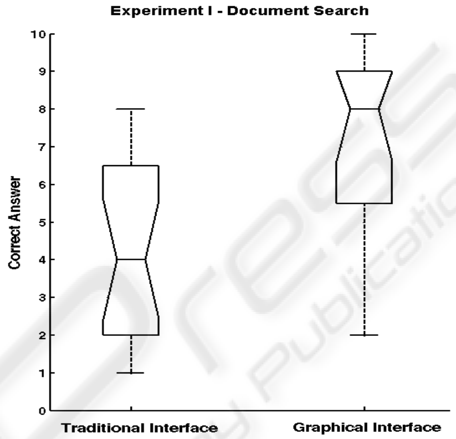


Figure 8: Number of documents found box plot (Test-1).

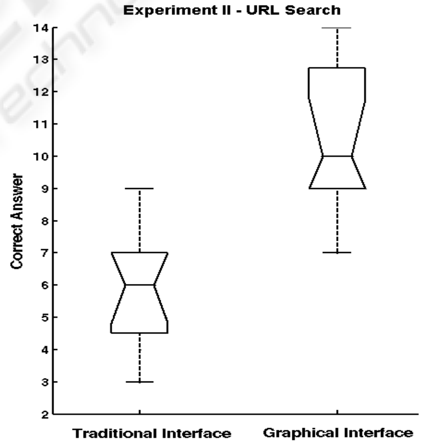


Figure 9: Number of documents found box plot (Test-2).

Given these concerns, we wanted to validate our interpretations of user answers by a method that did not depend on our judgement. For this purpose, we designed Test-2 since in this test there is no uncertainty about correctness of a URL found. If the same user group performs better than the other group in both tests to an equal degree, then our interpretation of test results must have been without bias. We note that our methodology of using two tests, one to validate the other, is novel. Although interpreting user answers is always open to subjectivity, none of the previous researchers validated their evaluation of user answers.

In both tests, users of the proposed interface found significantly more number of the required documents when they were given equal time. Figures 8 and 9 show these results by using box-plot graphs. As can be seen in Figure 8, the median value of correct answers given by test subjects who used the proposed interface is 8 while the mean value is 4 for the users that used the standard interface.

In the second test, the mean values were 10 (out of 21 URLs) for the users of proposed interface and 6 for the users of traditional interface. The strong agreement of outcomes in the two tests demonstrates the validity of test procedures, and the outcome strongly supports the original hypothesis of this research.

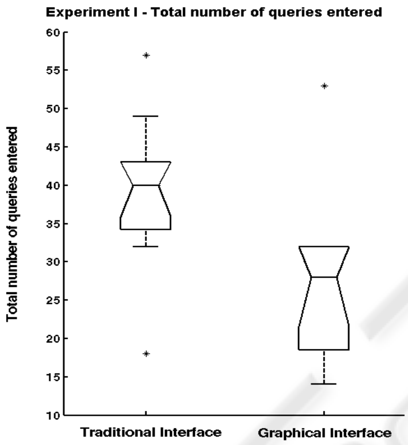


Figure 10: Total number of queries entered box plot.

During the experiments, we logged the activities of test subjects to record the number of queries they tried. Figure 10 compares the number queries test subjects tried during the first test. The outcome for the second test was similar. Here the numbers on the vertical column shows total number of queries tried by a user for 10 search tasks. Even though they found substantially more of the required pages, users of the proposed interface tried substantially fewer queries than users of the traditional interface. These results imply that users were able to navigate to the correct document even starting from a sub-optimal initial search results list.

6 CONCLUSIONS

For any document of non-trivial content, there is always a query that returns it among the top results, but the query required to retrieve a document may not be one that a user would think to use, at least initially, if ever. The fact that users of our proposed interface completed more successful searches while writing fewer queries implies that future systems designed along these ideas can be more satisfactory for users.

REFERENCES

Chen, Y-F., Koutsofios, E. (1997). WebCiao: A Website Visualization and Tracking System. *Proceedings of the World Conf. on the WWW and Internet (WebNet97).* Toronto Ontario, AACE, Norfolk, VA.

Cockburn, A., Greenberg, S., Mckenzie, B., Jasonsmith, M., and Kaesten, S. (1999). WebView: A Graphical Aid for Revisiting Web Pages. *Proceedings of the Australian Conference on Human Computer Interaction, (OzCHI'99).* Wagga Wagga, Australia, November 28-30. IEEE Press, Piscataway, NJ, 15-22.

Dean, J. and Henzinger, M. R. (May 1999). Finding Related Pages in the World Wide Web. *Computer Networks,* 31, 1467-1479.

Doemel, P. (1994). WebMap - A Graphical Hypertext Navigation Tool. *Proceedings of the 2nd International World-Wide Web Conference (WWW '94).* Chicago, IL, USA. ELSEVIER Science, Toronto, Canada, 1994, 785-789.

Hasan, M., Mendelzon, A., and Vista, D. (1995). Visual Web Surfing with Hy+. *Proceedings of the 1995 Conference of the Centre for Advanced Studies on Collaborative Research (CASCON'95).* Toronto, Ontario, Canada, November 7-9. IBM Press, Lewisville, TX, 1995, 218-227.

Hightower, R. R., Ring, L., Helfman, J. I., Bederson, B. B., Hollan, J. D. (1998). Graphical Multiscale Web Histories: A Study of Padprints. *Proceedings of the 9th ACM Conference on Hypertext and Hypermedia (HYPERTEXT '98).* Pittsburgh, PA, USA, June 20-24. ACM Press, New York, NY 58-65.

Kleinberg, J. (1999). Authoritative sources in a Hyperlinked environment. *Journal of the ACM,* 46, 604-632.

Leouski, A., Allan, J. (2000). Improving Interactive Retrieval by Combining Ranked List and Clustering. Pro*ceedings of Computer Assisted Information Retrieval Conference (RIAO '00).* Paris, France, April 12-14. Springer Verlag, New York, NY, 2000, 665-681.

Maarek, Y., Jacovi, M., Shtalhaim, M., Ur, S., Zernik, D., and Shaul, I. B. (1997). WebCutter: A system for dynamic and tailorable site mapping. *Proceedings of the 6th International World Wide Web Conference (WWW '97).* Santa Clara, CA, USA, April 7-11. ELSEVIER Science, Toronto, Canada, 713-722.

Mukherjea, S., and Foley, J. D. (April 1995). Visualizing the World-Wide Web with the Navigational ViewBuilder. *Computer Networks and ISDN Systems,* 27, 1075-1087.