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Evaluating the Efficacy of Clustered Visualization in Exploratory Search Tasks

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EVALUATING THE EFFICACY OF CLUSTERED VISUALIZATION IN EXPLORATORY SEARCH TASKS

A Thesis

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To my husband, Sameer for his continuous support and love.

To my parents, for believing in me.

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ABSTRACT

Kothari, Sarika S. M.S., Purdue University, May, 2010. Evaluating the Efficacy of Clustered Visualization in Exploratory Search Tasks. Major Professor: James Mohler.

Information visualization has the potential to improve the quality of Web search results representation providing more context and novel ways to see relationships among items in a result set. The key objective of this research was to evaluate the potential of graphical visualization for representation of Web search results especially for exploratory search tasks.

This is achieved by comparing the commonly used technique of ranked list representation of search results with the novel technique of representing these results using a cluster-based visualization technique. An experiment was designed in which participants performed Web searches for a set of predefined exploratory search scenarios. The number of links visited to complete each search task and the amount of time taken to complete the task was recorded. Participant feedback was collected to compare these two techniques. This information was then analyzed to evaluate efficiency of completing the search task, effectiveness at reaching the search goal, and user satisfaction with the two

techniques. Important observations were made based on participant feedback on cluster-based visualization technique.

This research study demonstrates the potential of cluster-based visualization techniques for Web search results representation as a complementary tool to currently available techniques to improve user experience for exploratory search tasks.

CHAPTER 1. INTRODUCTION

Humans are curious by nature and seek to gain information via different means in order to expand the horizons of their knowledge. In today's digital world, searching the Web has become a fundamental source for gaining information. The majority of the search engines including, Google, Yahoo, and MSN, return a long list of the ranked documents that users are forced to sift through to find the relevant information. Also, the ranked list displays a small number of results per page; results hidden at the end of the ranked list will perhaps never be accessed (Spink, Wolfram, Jansen, & Saracevic, 2001).

In addition, user search keywords might not ensure that the returned results will exactly match their interests or goals of information retrieval. The meaning of a keyword varies depending upon the context in which it is used. Context is crucial in order to direct the users towards the desired information (Nguyen & Zhang, 2006). Also a different sequence of keywords might not always return the same results. Thus, the user needs to either change the sequence or modify the query by including some additional keywords. If the user could not find relevant results in the first few pages, he or she would need to start the process over in order to get the desired results. During this process, the user can easily lose orientation or even get discouraged and abandon the information

search effort (Nguyen & Zhang, 2006). In such circumstances, the common ranked list representation of the documents is unhelpful.

Even supposing that the current search technology has improved the quality of the returned results, there are certain scenarios where only the user can decide which sources to pursue for further exploration (Bonnel, Morin, Telecom, & Cesson-Sevigne, 2005).

1.1. Statement of the Problem

Many search tools have been developed to help users achieve their information goals precisely. To use these tools users need to translate their information goal to a textual query that, when presented to a search engine, returns a ranked list of relevant information. These tools serve the purpose when the goals are fact-based or question-answer scenarios. But what if the users a) are not familiar with the domain knowledge of their information goal, b) do not know what keywords to use in order to achieve the goal, or c) are uncertain about their goals in the first place? This research examined the efficacy of clustered visualization in relation to exploratory search tasks to address these issues.

1.2. Significance of the Problem

Shneiderman (1996) said “Information exploration should be a joyous experience” (pg. 1) and emphasizes the usefulness of the information seeking

mantra: “overview first, zoom and filter, then details-on-demand” (pg. 2). The majority of search engines, including Google, Yahoo, and MSN, return a ranked list of documents in response to a query. The number of returned results may vary from hundreds to thousands of documents. When the information goal is not clear in user’s mind, the ranked list representation is often less than helpful. Moreover, it forces the user to focus on each result separately, thereby loosing the user’s overview of the process. Even though a ranked list interface is a common and popular way to represent search results, visual and interactive interfaces can be more helpful to users in finding relevant information (Hoeber & Yang, 2006b).

One way to represent the large number of results is clustering, which can help users navigate and find relevant information more efficiently (Allan, Leuski, Swan, & Byrd, 2001). Different cluster visualization techniques, including tree-based visualization, graph-based visualization, and 2D and 3D maps, have been proposed by various researchers to help users achieve their information goals precisely.

Most of the visual representation techniques do a very good job in grouping the data, but the usability aspects like an intuitive and uncluttered interface or an interactive guided tour of underlying information still need to be refined. Also the utility of clustering along with graphical interfaces in guiding the users when the search goal is vague or ambiguous has yet not been addressed.

1.3. Statement of Purpose

The purpose of this research was to investigate the efficacy of an alternative technique called clustered visualization in relation to exploratory search tasks. The study compared the ranked list representation by Google (www.google.com) with the clustered visualization by Carrot2 (search.carrot2.org) in order to evaluate their efficiency, effectiveness, and satisfaction.

1.4. Research Questions

This study addressed following research questions:

1. Is the clustered visualization of search results more *efficient* than a ranked list representation to users performing an exploratory search on the Web?
2. Is the clustered visualization of search results more *effective* than a ranked list representation to users performing an exploratory search on the Web?
3. Is the clustered visualization of search results more *satisfying* than a ranked list representation to users performing an exploratory search on the Web?

1.5. Assumptions

The assumptions inherent to the study are:

- The participants in this study were familiar with and had used at least one of the popular search engines currently available.

- The participants were not aware of the research related to this particular topic but had basic knowledge of information technology.
- The background, knowledge, personality, and preferences of the users might have affected the judgment regarding the relevancy of results.
- The time taken to generate a ranked list or clusters in response to a search query was negligible.
- The information goal was static during the entire exploratory search task.

1.6. Delimitations

The delimitations pertaining to this research are as follows:

- The study compared a ranked list representation by Google with a clustered visualization by the Carrot2 search engine in order to evaluate their efficacy in relation to exploratory search tasks.
- The research did not examine the visual properties of search result representations such as color, font size and so on.
- Metrics like novelty of information were not used to assess the performance of exploratory search tasks.
- The feedback from participants was gathered via a post-test questionnaire and responses to an open-ended question.

1.7. Limitations

The limitations intrinsic to this study include:

- The researcher targeted students at the Purdue University, West Lafayette campus in Indiana to participate in the experiments.
- Data was collected from a limited number of users and for a small number of search scenarios.
- The comparison of a ranked list (Google) and a clustered visualization (Carrot2) was done based on the current algorithm implementations of the two search engines (February 2, 2010).

1.8. Definitions

- *Exploratory search:* Exploratory search can be used to describe an information-seeking problem context that is open-ended, persistent, and multi-faceted; and to describe information-seeking processes that are opportunistic, iterative, and multi-tactical (Marchionini, 2006).
- *Search results clustering:* A process of automatically grouping search results into thematic groups (Ngo & Nguyen, 2004).
- *Web clustering engine:* Systems that receive a query from the user, forward this query to one or more traditional search engines, and organize the retrieved results into a set of clusters, also called categories (Di Giacomo, Didimo, Grilli, & Liotta, 2007).

- *Information Visualization:* It is the use of computer-supported, interactive visual representations of abstract data to amplify cognition (Card, Mackinlay, & Shneiderman, 1999).
- *Efficiency* is ability to accomplish a task with a minimum expenditure of time and effort.
- *Effectiveness* refers to producing the intended or expected result.
- *Satisfaction* is a measure of how well something meets expectations.

1.9. PageRank and Lingo Algorithm

The Google search engine uses a PageRank algorithm (Brin & Page, 1998) to generate a ranked list of search results. It assigns a numerical weight to each element of a hyperlinked set of web documents based on the number and weight of incoming and outgoing hyperlinks along with several different parameters, with the purpose of measuring its relative importance within the set.

The Carrot2 search engine uses a Lingo algorithm (Osiriski & Weiss, 2004) to generate the clusters of search results obtained from the Google search engine. It consists of five phases. In the first phase, the input snippets are preprocessed and separated into terms (keywords). In second phase the frequent terms and phrases are identified. In third phase, the labels of the clusters are discovered using induction. In phase four, the content of clusters is discovered. The labels of the clusters are then queried against the input documents and highest scored

documents are assigned to the respective clusters. In the last phase, a score function is applied to clusters to sort them for presentation.

1.10. Summary

This chapter outlines the research problem with its importance and then proposes to investigate into an alternative solution to the problem. The research questions addressed by this study are introduced. The assumptions, delimitations and limitations inherent to the study are presented, followed by definitions of the terms used in the research. Lastly, it presents brief information about PageRank and Lingo algorithm used by Google and Carrot2 search engines respectively.

CHAPTER 2. REVIEW OF LITERATURE

This chapter presents the literature relevant to this study. It starts with brief history of evolution of World Wide Web followed by the discussion on Web search as integral part of using the Web. Then it continues the discussion of change in the Web searching behavior of users and how the understanding of user behavior has become vital in improving the process of information retrieval. This section is followed by a discussion on the classification of web search activities. It further discuses the limitations of the ranked list representation when the information goal is vague or exploratory. This naturally leads into a discussion on the role of information visualization in guiding users towards desired information. This background information is then used to make the case for the use of clustered visualization of Web search results in exploratory search tasks. This section concludes with the summary of the literature discussed in preceding sections.

2.1. A Brief History of Web and Web Search Engines

The concept of hypertext was envisioned by Vannevar Bush in 1940's and came to life in 1970's followed by the formation of World Wide Web in 1990's, which we simply call the Web today (Manning, Raghavan, & Schütze, 2008). Tim

Berners-Lee is the founder of current Web who also built the first Web server called httpd (HyperText Transfer Protocol daemon). The first website to go online was http://info.cern.ch/ in 1991 (http://www.searchenginehistory.com/). And then with the mass content publishing of information on the web, it became the best way to provide and use information on everything from home remedies to satellite launching.

This wealth of information was useless until it made discoverable by the search engines and directories. Archie was the first search engine introduced (http://www.searchenginehistory.com/), followed by Excite, Lycos, AltaVista, Ask Jeeves, AllTheWeb and many more. Gerard Salton is considered as the father of current Web search technology, who with his team developed the first information retrieval system.

2.2. User Searching Behavior

With the development of Web, understanding users has become crucial in order to satisfy their information need precisely (Manning et al., 2008). In traditional information retrieval systems, the users used to be experts and understood the organization of the collection of documents very well. In contrast, a range of studies have noted the diverse backgrounds, motives and lack of expertise of current users in formulating the queries that reflect their information needs. A study conducted by (Spink, Wolfram, Jansen, & Saracevic, 2001) evaluated the queries from the Excite search engine and illustrated some interesting facts of user search behavior: the average length of a search query

was 2.4 terms. Half of the users entered a single query, while a little less than a third of the users entered three or more unique queries. On average, users viewed 2.35 pages. Over half of users did not access results beyond the first page. Less than 5% of users used advanced search features.

Marchionini (2006) discusses three types of search tasks that are usually performed by the users on the Web: lookup, learn and investigate. Lookup is a fact-retrieval task that returns precise results for a query. Learning searches involve finding, interpreting and comparing results to gain new knowledge. Searches requiring investigation involve finding new information and also tend to discover gaps in knowledge.

2.3. Exploratory Search

An exploratory search is a type of information seeking that requires search systems to help users find information even if the goal is vague, learn from the information, and investigate solutions for complex information problems. “Exploratory search can be used to describe an information-seeking problem context that is open-ended, persistent, and multi-faceted; and to describe information-seeking processes that are opportunistic, iterative, and multi-tactical” (White & Roth, 2009 pg. 6). Exploratory searches may be driven by curiosity or a desire to learn or investigate a solution for a complex information problem. Exploratory search processes mainly involve learning and investigation as depicted in Figure 2.1.

Researchers have proposed exploratory search systems (ESSs) to facilitate the users in information exploration and help them to gain information in complex search scenarios. Browsing systems, information visualization systems, and document clustering are few examples of ESSs.

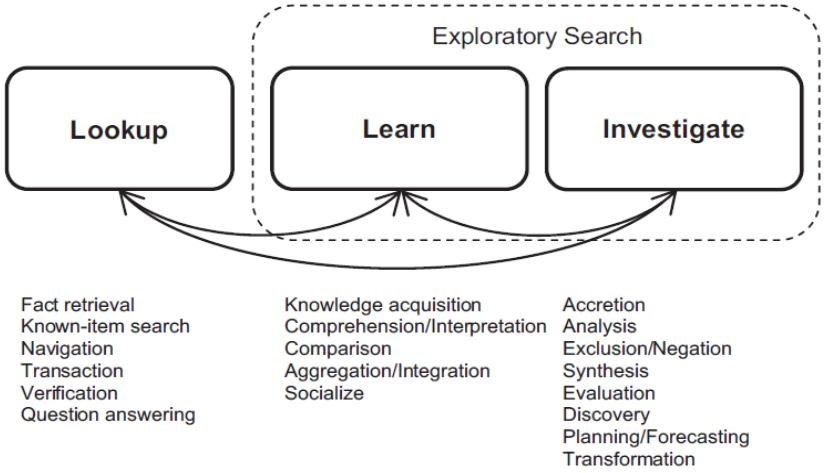


Figure 2.1 Exploratory Search Proceses Involves Different *S*earch Activities (Marchioni, 2006).

WordBars is one such example of an exploratory search system that assists the users in exploratory tasks (Hoeber & Yang, 2006b). It presents a histogram of the occurrences of the terms gathered from titles and snippets of the top 100 documents returned by the Google search engine. Users could add or remove the terms from the histogram to their query in order to refine their query. By selecting a term, a user can resort the search results. The system could support exploration for vague as well very specific queries by the users. User evaluations suggest improvements in performance of the users in crafting

the query but it did not show any significant improvement in user's performance in exploring the result set.

2.4. Limitations of Ranked List

Most of the search engines provide little ability to explore the search results. They return a long list of documents presented according to the likelihood of relevancy to the query called ranked list. The problem with the ranked list is that the relevant documents are not often in the top results of the ranked list. There might be some relevant documents at the top of the list but the rest of them can be obscured in the tail of the list and requires the user to sift through many non-relevant documents (Allan et al., 2001). This problem becomes even more apparent when the user wants to broadly explore a topic and the documents on different topics are intermixed in the list of results (Dumais, Cutrell, & Chen, 2001).

Moreover, list presentation typically only displays a small number of search results per page (typically 10 to 15 results). Although the documents at the end of the list are relevant, they will likely never be accessed (Fahmi, Zhang, Ellermann, & Bouma, 2007). In circumstances where the users are able to formulate the query accurately, it is possible that they can find the relevant documents in the first few pages. But when the queries are broad or ambiguous, the users usually choose to reformulate the query or simply give up searching (Hoeber & Yang, 2006a). Spink et al. (2001) noted that "the public has a low tolerance of going in depth through what is retrieved (pg 6)." A common plain list

presentation is not always effective and makes the process of information searching tedious and unproductive (Leuski & Allan, 2000).

2.5. Web Search Results Representation

There are two main approaches to search result visualization: visualization of additional information about the retrieved documents and visualization of inter-document similarity.

2.5.1. Ranked List with Visual Attributes

This approach uses additional information like document attributes (e.g., size or source) or predefined topics (e.g., news or health) to visualize the search results. Following are some examples of this approach.

In *Category Interfaces,* search results were organized into hierarchical categories and each category with the best matching Web pages was listed as shown in Figure 2.2 (Dumais et al., 2001). The user could expand the category to see additional pages in that category. The use of category names along with the page titles helped users in analyzing the search results effectively. But the interface could not provide an overview of the retrieved instances in one glance. More scrolling was required in analyzing the search results. Also the categories were organized based on the number of matching documents instead of a consistent order.

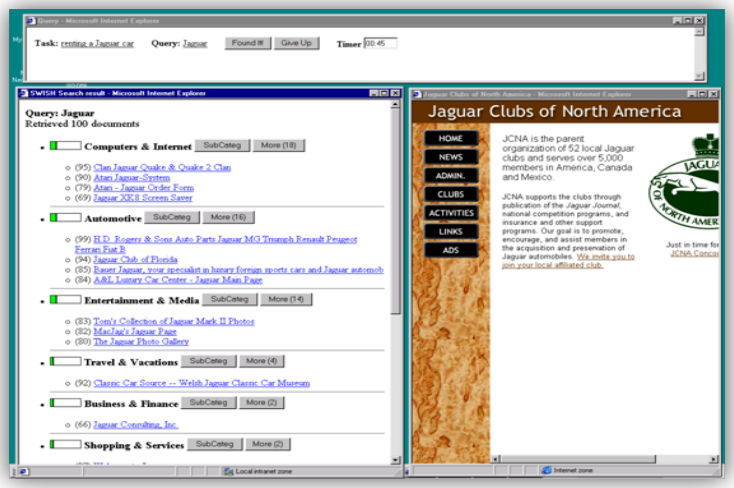


Figure 2.2 A Screenshot of the Category Interfaces.

Kules and Shneiderman (2008) evaluated the effectiveness of *categorized overviews* in exploratory search tasks. The results indicated that the users explored deeper to find out relevant information. They agreed that the categorized overviews helped them to organize, explore, and assess their results. Figure 2.3 provides the interface used in the user evaluations. Although no significant differences were found, the results indicate that with further research the use of categorized overviews has potential for commercial implementation.

Käki (2005) proposed a user interface called *Findex* to categorize Web search results. The interface automatically computes categories based on the frequencies of the words in the result set provided by the Google search engine. The categories are provided on the left side of the user interface and selecting the category results in filtering and showing the results corresponding to that

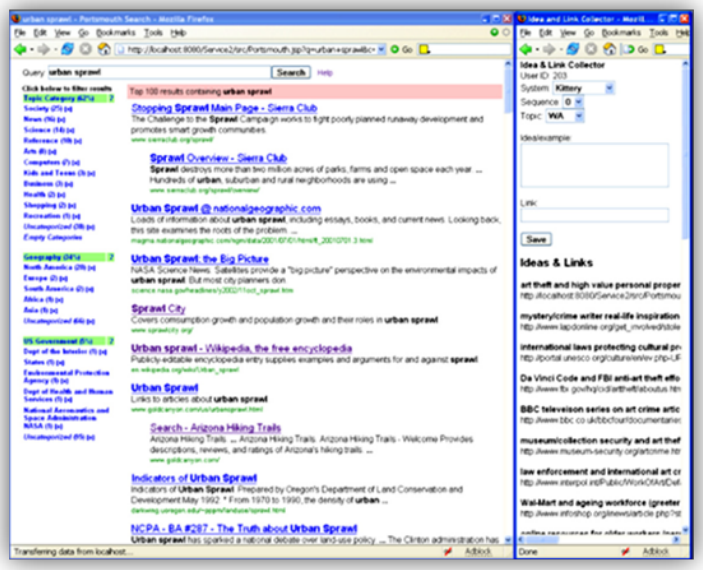


Figure 2.3 A Snapshot of the Categorized Overviews Interface.

category on right side of the interface (see figure 2.4). The researchers evaluated the interface by analyzing the user logs and questionnaires. The results of the study suggest that categories can be useful in finding relevant results and sometimes are more beneficial than a ranked list when the query is vague and general. Results also indicated the potential for usefulness of categories in exploratory search tasks. Figure 2.4 provides a screenshot of the Findex interface for a query on the term 'jaguar'.

Zamir and Etzioni (1999) presented a clustering interface called *Grouper* for the HuskySearch engine and compared it with the ranked-list interface of the same. They used the post-retrieval document clustering algorithm called Suffix Tree Clustering (STC) to group the search results dynamically into coherent

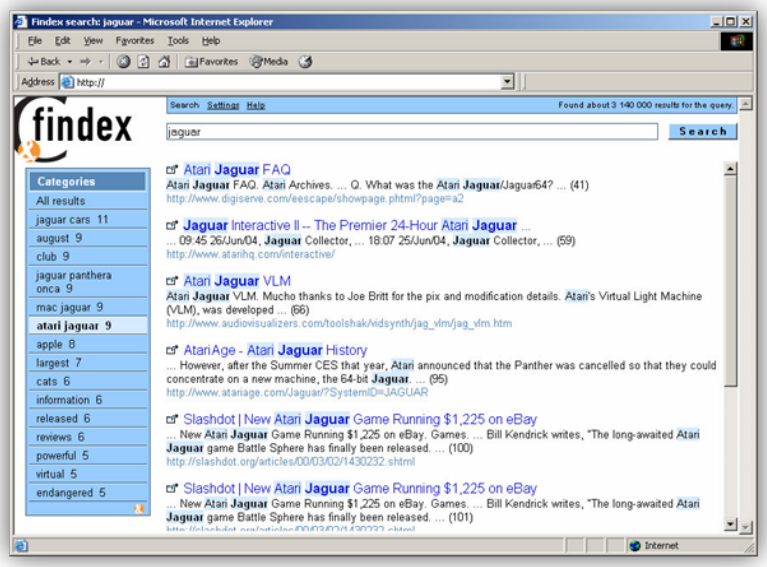
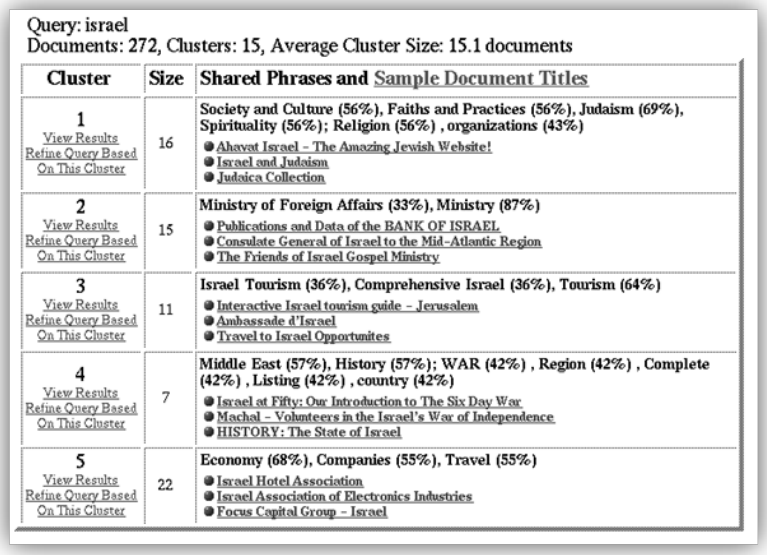


Figure 2.4 A Screenshot of Findex Search User Interface.

groups. By analyzing the user behavior logs of Grouper and HuskySearch, the researchers measured the relevancy and efficiency of the search results for the two interfaces. The results indicated that time and effort spent in finding the first few interesting documents was greater for Grouper than the HuskySearch interface. Once the user has spent some time and effort in understanding the clusters, further exploration becomes faster. The researchers also mention that clustering is not helpful for all search tasks. Figure 2.5 shows a snapshot of the Grouper interface for a query on the term ‘Israel’.



Query: israel
Documents: 272, Clusters: 15, Average Cluster Size: 15.1 documents

Cluster	Size	Shared Phrases and Sample Document Titles
1 View Results Refine Query Based On This Cluster	16	Society and Culture (56%), Faiths and Practices (56%), Judaism (69%), Spirituality (56%); Religion (56%) , organizations (43%) ● Ahavat Israel - The Amazing Jewish Website! ● Israel and Judaism ● Judaica Collection
2 View Results Refine Query Based On This Cluster	15	Ministry of Foreign Affairs (33%), Ministry (87%) ● Publications and Data of the BANK OF ISRAEL ● Consulate General of Israel to the Mid-Atlantic Region ● The Friends of Israel Gospel Ministry
3 View Results Refine Query Based On This Cluster	11	Israel Tourism (36%), Comprehensive Israel (36%), Tourism (64%) ● Interactive Israel tourism guide - Jerusalem ● Ambassade d'Israel ● Travel to Israel Opportunites
4 View Results Refine Query Based On This Cluster	7	Middle East (57%), History (57%); WAR (42%) , Region (42%) , Complete (42%) , Listing (42%) , country (42%) ● Israel at Fifty: Our Introduction to The Six Day War ● Machal - Volunteers in the Israel's War of Independence ● HISTORY: The State of Israel
5 View Results Refine Query Based On This Cluster	22	Economy (68%), Companies (55%), Travel (55%) ● Israel Hotel Association ● Israel Association of Electronics Industries ● Focus Capital Group - Israel

Figure 2.5 A Snapshot of the Grouper Interface for a Query on Term 'israel'.

The above interfaces, *Categorized interfaces, Categorized overviews, Findex* and *Grouper* help in guiding the users toward the desired information more effectively than a ranked list. But the interfaces do not make use of the user's visual capabilities in the search process.

2.5.2. Need for Information Visualization

The traditional approach of presenting Web search results in a list format can be effective in situations where the information goal is well-defined. But when the information goal is not clear or the user wants to investigate more broadly on a particular topic, information visualization can play a significant role in guiding the user towards the desired information. Information visualization offers the

unique means that enable users to handle abstract information by taking advantage of their visual perception capabilities (Nguyen & Zhang, 2006).

A recent study showed that 80 percent of users reformulate the search query if they do not find what they need in the first three pages (http: //www. iprospect.com). Information visualization techniques can help users deal with the information abundance problem by making use of their visual capabilities. Good visualization techniques can help the users to perceive more information at one time (Kroeker, 2004).

2.5.3. Visualization of Inter Document Similarity

The second approach to visualization of Web search results, visualization of inter-document similarity, can help the user to get an overview of the collection of results or help the user to find similar documents, once an interesting document is found. Maps, graphs, trees, scatter plots, Venn diagrams are some of the techniques to visualize inter-document similarity. The following are few examples of this second approach.

WebSearchViz uses the solar system along with its planets and asteroids revolving around the sun as shown in Figure 2.6 (Nguyen & Zhang, 2006). It also uses several parameters like location, movement of the objects, color, and spatial distance of the objects in the visual space to represent the semantic relationships between a query and relevant Web pages. Users can dynamically change, redefine, add, or delete the subjects of interest by interacting with the two dimensional visual space. But dealing with so many parameters affecting

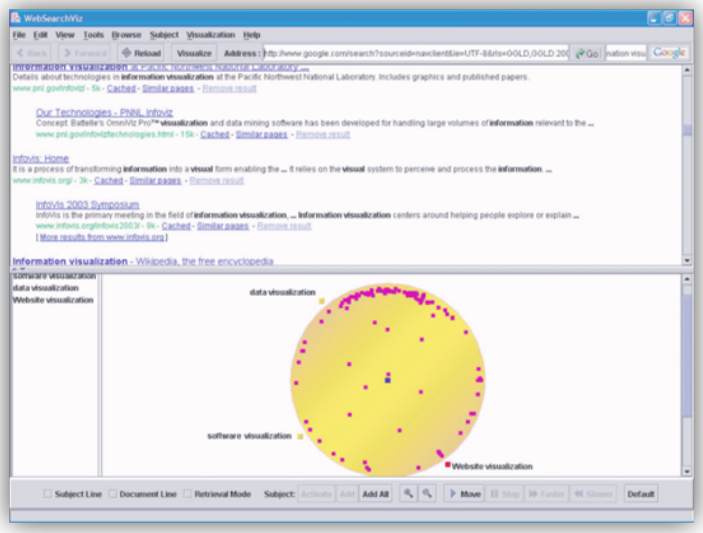


Figure 2.6 A Screenshot of WebSearchWiz Interface.

the Web search results can overwhelm the user and may distract him from searching.

Lighthouse (Leuski & Allan, 2000) is an on-line interface for a Web-based information retrieval system. The system integrates two known presentations of the retrieved results: the ranked list and clustering visualization. It accepts the users input and adjusts the document visualization accordingly. Documents in Lighthouse are clustered if they are semantically related to each other. The visualization presents the documents as spheres floating in space and positions them in proportion to their inter-document similarity as shown in Figure 2.7. If two documents are very similar to each other, the corresponding spheres are closely located, whereas the spheres that are positioned far apart indicate very different page content. The system interface consists of ranked list of 50 results without

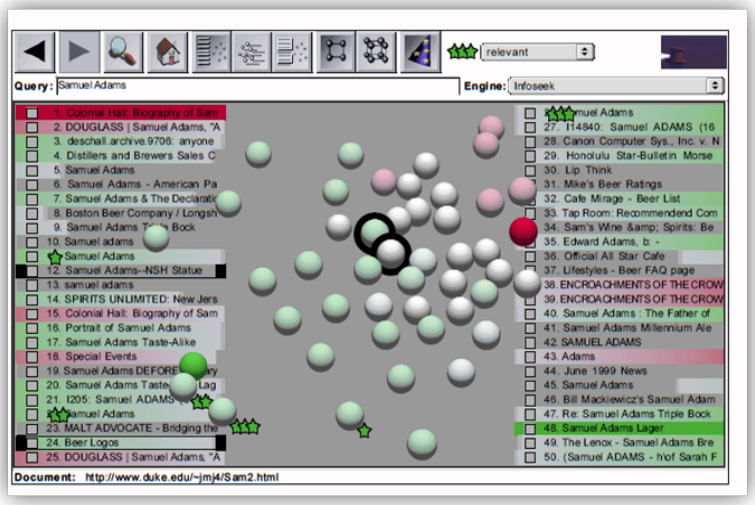


Figure 2.7 A Snapshot of the Lighthouse System.

any snippets and the spheres representing each result are arranged according to their semantic relationship. This makes a really cluttered interface and the user may lose focus.

Akhavi, Rahmati, and Amini (2007) propose the 3D metaphor for visualizing the hierarchal clustered results based on fractal trees representation. The prototype visualizes the search results returned by the Carrot2 search engine into 3D space as shown in Figure 2.8. It uses two alternative metaphors: single-tree and forest for visualization. The former transforms all the retrieved results in a single tree while in the later each parent cluster is represented by a separate tree. Each branch represents a cluster and a fruit represents an URL of the corresponding webpage. Thickness of a branch represents the density of results. Difficulty in navigating through the results, complexity of the structures

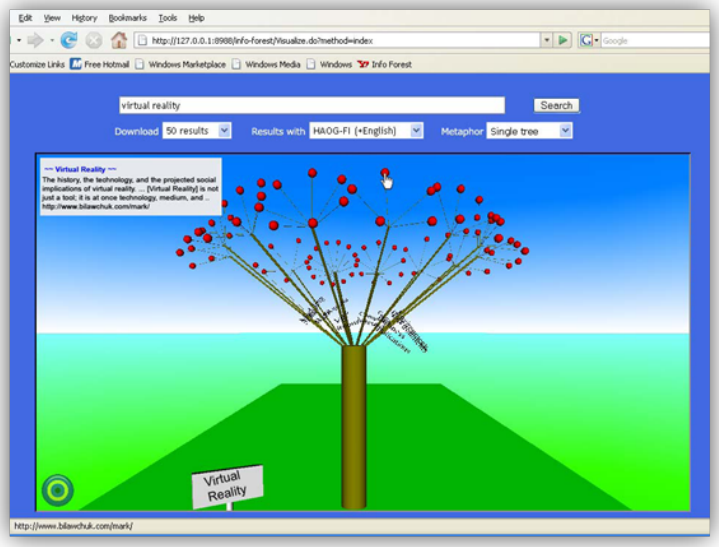


Figure 2.8 A 3D Visualization of Results for 'Virtual Reality' Query Term for Top 50 Results in the Single Tree Metaphor.

and scalability are various shortcomings of 3D metaphor.

Di Giacomo, Didimo, Grilli, and Liotta (2007) present a graph based interface for organizing search results of the Web clustering engines. The researchers developed a prototype named *WhatsOnWeb,* which presents a clustered graph of the retrieved information. Figure 2.8 presents snapshot of the user interface for a query of the word 'Armstrong'. Each cluster and sub cluster represents a set of documents that are semantically related to each other. They use this prototype to compare effectiveness of a graph-based visualization with a tree-based visualization for the Web clustering engines. By analyzing the recorded log of user behavior for a predefined set of queries, the researchers measured number of clusters expanded while searching and number of correct

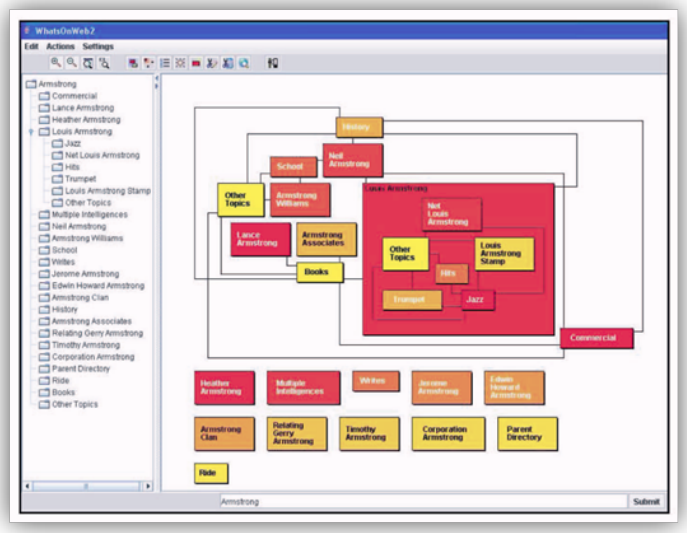


Figure 2.9 A Map for the Query ‘Armstrong’, with the Expansion of the Category ‘Louis Armstrong’.

pages found. The results shows that the number of correct pages found for each user and query were compatible in the two interfaces. Also the effort required in finding correct pages was lower for the graph-based interface than the tree-based interface.

Another prototype organizes the results according to their meaning using a Kohonen self-organizing map and visualizes them in three dimensions based on a city metaphor as shown in Figure 2.9 (Bonnel et al., 2005). Each building of the city represents one web page and the buildings are grouped by districts. The building texture represents the document content. The height of the building represents the relevancy of the pages. Each district represents a neuron of the self- organizing map and is placed on ground as 2D grid. Different colors are

Figure 2.10 A Snapshot of SmartWeb Prototype with the City Visualization Metaphor.

used to represent different districts. The documents in the same district are closely related to each other and two neighboring districts represent two closely related topics. This 3D metaphor provides the users an overview of a large number of results. It enables users to personalize the visual interface and interactions. But the researchers reported that even though the visualization is intuitive, navigating through the city metaphor to find relevant documents is not an easy task for the user.

The above mentioned search results visualization techniques present post-retrieval document visualization as an alternative to the ranked list presentation. The techniques suggest that clustering the search results and making the textual interfaces more graphical can help the users in finding relevant information more easily.

2.6. Summary

The limitations of plain list representation of the search results in guiding the users towards desired information have been identified by numerous researchers and solutions have been proposed to address these issues. Researchers suggested use of category views to avoid the disorientation of the users while searching for the needed information. Others suggested use of cluster maps, graphs, tree structure and other metaphors along with two dimensional and three dimensional representations of the search results in order to help the users to utilize their visual capabilities while searching for desired information. Based on the discussion above most of the visual representation techniques do a very good job in grouping the data but the usability aspects like an intuitive and uncluttered interface, and an interactive guided tour of the underlying information are still need to be refined. Also, the utility of clustering along with graphical interfaces in guiding the users when the search goal is vague or ambiguous has yet not been addressed. The next chapter describes the methodology of the current research and its attempt to address this gap.

CHAPTER 3. METHODOLOGY

This chapter presents design of the study and procedure used to conduct this experiment. It also addresses the research questions along with the variables and procedure for measurement of variables. It further describes the sampling process, data collection and analysis procedures used in the research.

3.1. Study Design

The study used quantitative methodology in order to evaluate and compare the efficacy of clustered visualization with ranked list representation in relation to exploratory search tasks. In this study, an open-source clustered visualization based search engine called Carrot2 (February 2, 2010) was used and its search representation was compared with ranked list representation by Google (February 2, 2010). Figure 3.1 represents a snapshot of the ranked list interface by Google and the clustered visualization by Carrot2 for the query ‘irradiated food’.

To evaluate the two search result representation techniques (clustered and rank), commonly used parameters of efficiency, effectiveness and satisfaction were selected.

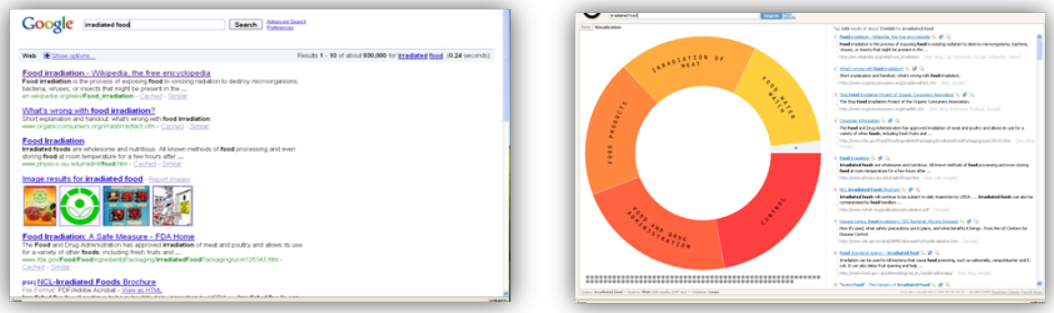


Figure 3.1 A Snapshot of Google Interface and Carrot2 Interface for a Query on the Term ‘irradiated food’.

A pre-test questionnaire was designed to gather participant demographic information and search engine preferences. An online handout with a brief description of e Carrot2 interface was designed to familiarize participants with clustered interface.

Four exploratory search tasks were designed following the guidelines established by National Institute of Standards and technologies (http://trec.nist.gov/) to ensure comparable difficulty level for each task.

The researcher decided to use the Mozilla Firefox web browser to record the browsing history of each participant during the experiment. Mozilla Firefox stores the browsing history in a well structured database with URLs and associated time stamps. A tool named SQLite Manager was selected to query the browsing history of participants.

A post-test questionnaire was designed to gather feedback on the effectiveness and satisfaction of the two search representations. The researcher

decided to use a five-point Likert scale to record participants feedback. The Qualtrics survey software provided by Purdue University was chosen to collect the responses to the questionnaire. To gain insights into participants search engine preferences, an open-ended question was designed.

3.2. Procedure

A link to the online survey was posted on CPT 175 Visual Programming course website to make it accessible to participants. The participants followed this link to conduct the survey. In the survey, a pre-test questionnaire followed by four search scenarios and post-test questionnaire was presented to all the participants. During the experiment, the browsing history of each participant was recorded. After the experiment, the browsing history data for each participant was collected on a flash drive. Figure 3.2 presents a simple flowchart of the procedure used in this research.

At the beginning of the experiment, a pre-test questionnaire was provided to each participant to collect demographic information, search engine usage frequency, and preferences. Followed by pre-test, brief information about the two interfaces (Google and Carrot2) to be used in the experiment was provided along with the instructions to follow in the experiment. Then the participants were asked to perform two exploratory searches using each interface. One of the approaches could have been asking each participant to perform each search task using both interfaces. But it might have influenced the search behavior of the participants as they already had a clue about the relevancy of certain search results from the

previous session. To avoid this bias, participants were provided with different search tasks of comparable difficulty level for each interface. A textual description of the information need for each search task was provided to the participants along with the interface (Google or Carrot2) to use to perform the task. Appendix B provides a list of the search tasks used in this study.

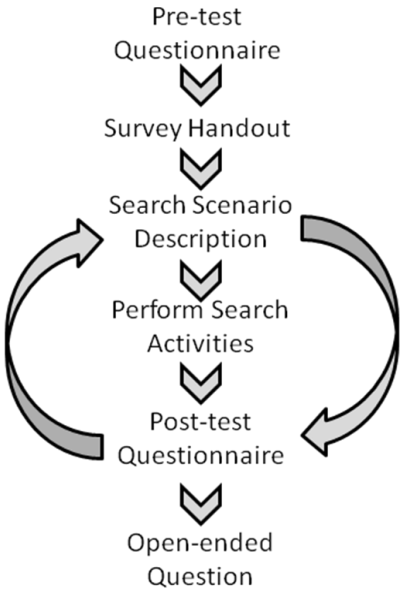


Figure 3.2 A Flow of the Procedure of the Study.

Following each task, a post test questionnaire was provided to gather feedback from the participants. It also included an open-ended question to gain insights in the searching behavior and interface preferences of the participants.

3.3. Metrics

Research question 1 aimed to investigate the efficiency of clustered visualization and ranked list representation in the exploratory searches. Efficiency was measured using metrics like number of URLs visited and time taken to complete the search task. Research question 2 addressed the effectiveness of two representations that can be measured in terms of relevancy of the documents. But relevancy can be subjective and may vary as per the user preferences in the exploratory search task. Therefore commonly used precision and recall measures were not used. Instead effectiveness was gauged with the help of a post-test questionnaire. Research question 3 looked into participants satisfaction feedback that was gathered via post-test questionnaire.

3.4. Sample Size Calculation

The required sample size was calculated using the following formula (Morris, 1985):

$n = N\,x\,/\,[(N\text{-}1) * E2 + x]$

Where n is Sample size, N is population size (20000), and x is mean which is calculated as below:

$x = Z(c/100) * 2r * (100\text{-}r)$

Where c is confidence level (90%), $Z(c/100)$ is critical value (1.645), and r is response distribution (50).

This calculation is based on the normal distribution of data, and assumes there are more than about 30 samples. Based on this formula, the calculated sample size was 68.

3.5. Participants

The researcher targeted students at the Purdue University, West Lafayette campus, Indiana to participate in the study. Ninety-seven students volunteered to participate in this experiment. All the students were from the College of Technology. Most of the participants (85 of 92) were male. Eighty-four of the participants were undergraduate students and eight were graduate students. Almost all the participants (85 of 92) used search engines everyday others used them few times a week. Eighty-nine percent of the participants preferred to use Google, 9% preferred Yahoo, and 2% preferred the Bing search engine. Most of the participants (78 of 92) claimed that they usually find the information they are looking for in first few pages.

3.6. Data Collection

As mentioned above, data collection was done using a post-test questionnaire and browsing history logs of participants for a set of search scenarios. The pre-test questionnaire collected information like the participant's frequency of Web search usage and search engine preferences. The post-test questionnaire was used to gather feedback on search tasks from the participants.

It also included an open-ended question to gain qualitative feedback from the participants.

3.7. Summary

The study aimed to compare the ranked list representation of the search results by Google with the clustered visualization of the same by Carrot2 search engine in terms of efficiency, effectiveness and satisfaction in relation to the exploratory search tasks. A combination of post-test questionnaires and browsing history logs were used to collect the data. The next chapter presents the data analysis procedures used in this study.

CHAPTER 4. DATA ANALYSIS

This chapter presents the analysis of data. It presents the findings for different metrics used to evaluate the efficiency, effectiveness and satisfaction of clustered visualization. It further provides the summary of participants qualitative feedback.

4.1. Efficiency

Research question 1 addresses the efficiency of clustered visualization in exploratory tasks. Here efficiency is defined as ability to accomplish a task with a minimum expenditure of time and effort. Efficiency was measured using metrics: the number of URLs visited during the search activity and the time taken to complete each search activity (search time).

This data was extracted from the participants browsing history recorded during experiment, using the Mozilla SQLite Manager Software. For analysis, the data from 26 participants was discarded because either the participants did not complete all the search tasks or the data files were corrupt. The data obtained was found to be non-normal. As same participants were used to conduct the search tasks using both interfaces, the Wilcoxon Signed Rank test was used for analysis of this data. It was analyzed using MiniTab software.

4.1.1. Number of URLs Visited

This analysis explored if there was a statistically significant difference in total number of URLs visited by each participant for the Google interface and the Carrot2 interface.

The statistical analysis shows significant differences (Wilcoxon statistics (w) = 1042.5, p= 0.000) in number of URLs visited by participants for the clustered interface and the ranked list interface. The participants visited fewer URLs to find the required information for the Carrot2 interface than the Google interface. Hence the clustered interface appears to be more efficient in accomplishing the search goals presented in this study. Figure 4.1 shows a line graph of the total number of URLs visited by each participant using the Google interface and the Carrot2 interface.

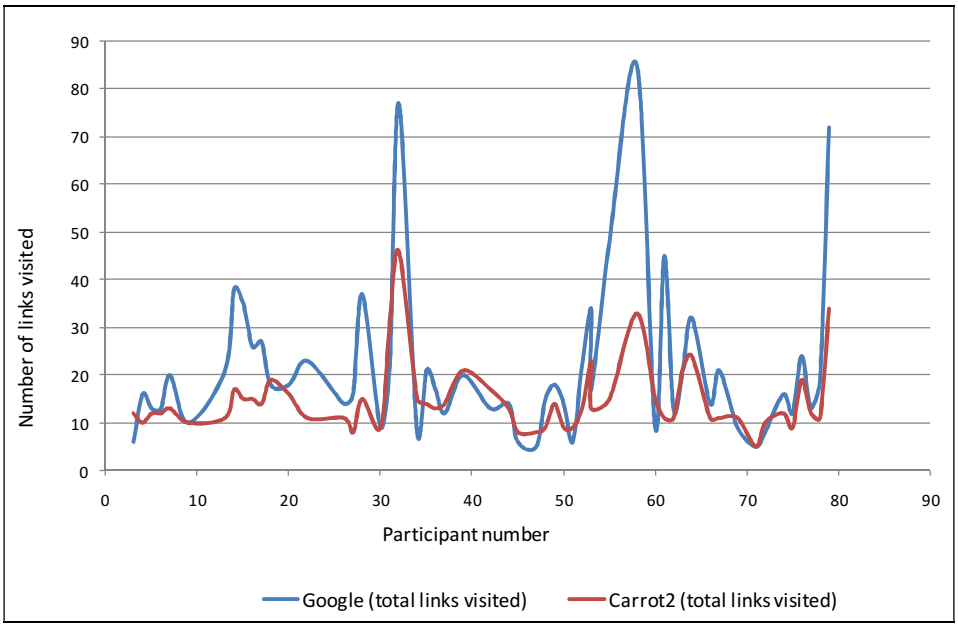


Figure 4.1 A Line Graph Showing Total Number of Links Visited by Each Participant using Google and Carrot2 Interface.

4.1.2. Search Time

This analysis explored if there was a statistically significant difference in total time spent by each participant for the Google interface and the Carrot2 interface.

The statistical analysis shows no significant differences (Wilcoxon statistics (w) = 865.0, p= 0.147) in total time spent by each participant using the Google interface and the Carrot2 interface for performing search tasks. Hence the ranked list representation and clustered visualization appear to demonstrate comparable performance.

Figure 4.2 shows a line graph of the total time (in seconds) spent by each participant using the Google interface and the Carrot2 interface.

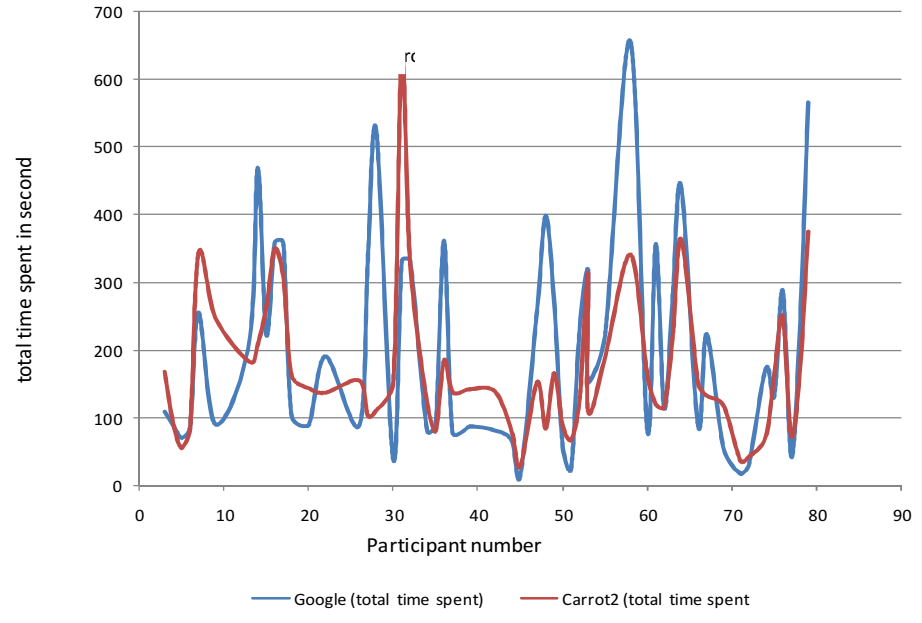


Figure 4.2 A Line Graph of Total Time (in Seconds) Spent by Each Participant using Google Interface and Carrot2 Interface.

Based on the discussion above the clustered viualization appears to be more efficient in terms of the number of URLs visited while its performance in terms of total time spent was equivalent with the ranked list interface. The participants visited less number of links to find required information in Carrot2 interface and total time spent was the same in both interfaces, clustered interface appeared to be more efficient for exploratory search tasks. The results of the analyses for efficiency are shown in Table 4.1.

Table 4.1

Wilcoxon Signed Rank test analyses for efficiency

Metrics	Wilcoxon statistics	p-value
Total number of URLs visited	W = 1042.5	p = 0.000
Total search time	W = 865.0	p = 0.147

4.2. Effectiveness

Research question 2 addressed the effectiveness of clustered visualization in exploratory search tasks. Here effectiveness refers to the ability to produce the intended or expected result. Effectiveness was measured using two metrics: successful completion of the task and the relevancy of the top results. This data was gathered from responses to the post-test questionnaire

obtained using the Qualtrics survey software. The data was ordinal and non-normal; hence the Wilcoxon Signed Ranked test was used for analysis.

4.2.1. Task Completion

Analysis was done on the participant ratings for completion of the task on a five-point Likert scale. Results suggest that the Google interface was better (w= 877.0, p=0.044) than the Catrrot2 interface in effectively completing a search task. The results of the analyses for effectiveness are shown in Table 4.2.

4.2.2. Relevancy

Relevancy of the results presented in both interfaces was gauged by participant ratings on a five-point Likert scale. The results of the Wilcoxon Signed Rank test suggest that there was no statistically significant difference (w = 1006.0, p=0.077) in relevancy of top results of the two interfaces. Participants in this experiment did not find top results more relevant in one interface than the other.

Based on the discussion above the ranked list representation appears to be more effective in terms of task completion and its performance in terms of relevency of search results is comparable to the clustered interface. Hence, the ranked list representation appears to be more effective for exploratory search tasks. The results of the analyses for effectiveness are shown in Table 4.2.

Table 4.2

Wilcoxon Signed Rank test analyses for effectiveness

Metrics	Wilcoxon statistics	p-value
Task completion	w = 877.0	p = 0.044
Relevancy	w = 1006.0	p = 0.077

4.3. Satisfaction

Research question 3 investigated user satisfaction with clustered visualization in exploratory search tasks. Satisfaction is considered as a measure of how well something meets expectations. Ease of use and ease of navigation are the two commonly used metrics that were employed to evaluate user satisfaction of the two interfaces. This data was collected from responses to post-test questionnaire obtained using Qualtrics survey software.

4.3.1. Ease of Use

Analysis was performed on the participant ratings for ease of use of the interface on a five-point Likert scale. Wilcoxon Signed Rank test was used to evaluate if there was a statistically significant difference in ease of use of the two interfaces. Results indicated that the Google interface was significantly better (w=1235.0, p=0.009) than the Carrot2 interface in terms of ease to use. Table 4.3 shows the test results of this analyses.

4.3.2. Ease of Navigation

Analysis of participant ratings on a five-point Likert scale was done to evaluate the differences in ease of navigation for the two interfaces. Results demonstrated that the Google interface was significantly better (w=1070.0, p=0.027) than the Carrot2 interface in terms of ease of navigation.

Based on this analysis, the ranked list representation was better in terms of both ease of use and ease of navigation. Hence, the ranked list representation is more satisfactory than the clustered visualization for exploratory search tasks. Table 4.3 shows the results of analyses for satisfaction.

Table 4.3

Wilcoxon Signed Rank test analyses for satisfaction

Metrics	Wilcoxon statistics	p-value
Ease of use	w = 1235.0	p = 0.009
Ease of navigation	w = 1070.0	p = 0.027

4.4. Qualitative feedback

One of the important objectives of the survey was to gather additional insights into user preferences regarding exploratory search results representation and search engines. This was achieved by presenting a series of simple questions to the participants to receive qualitative feedback on their experience.

Out of 92 participants, 86 participants provided qualitative feedback. Their feedback is quoted in Appendix A. Figure 4.3 summarizes the participant qualitative feedback. The statistical highlights and representative responses from participant feedback are described below.

In response to the question *'Did you like the way Carrot2 search engine presented the search results? Will you use Carrot2 or similar search engine in future? Why or why not?'* 77 % (66 of 86) of participants indicated that they liked the clustered search result representation in the Carrot2 search engine. Among these participants, 42 % (28 of 66) liked the organization of the results in meaningful clusters. Twelve percent (8 of 66) found the graphical visualization of results very helpful and easy to use. Twenty-one percent (14 of 66) stated that the clustered visualization of results made searching easier and provided a lot of relevant information. It also saved time and the participants

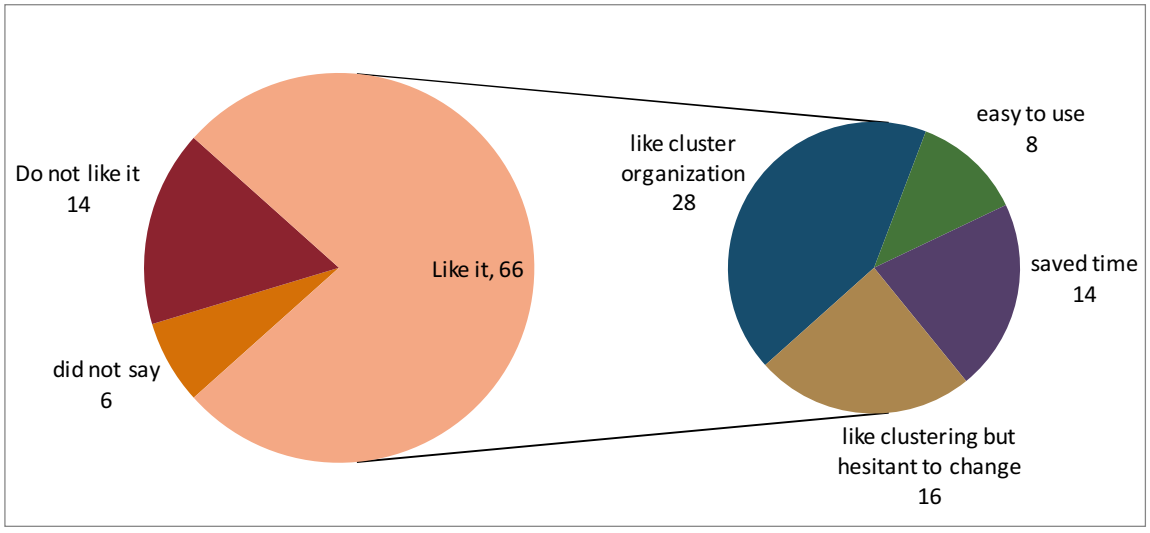


Figure 4.3 Summary of Participant's Qualitative Feedback on Clustered Visualization.

really enjoyed using it. Here are some representative responses from the participants:

> I loved Carrot2 because it seems more efficient and gave better information. It's easier and it gives you better options on the side. This was way better than Google and all its mishaps.
>
> At first I didn't know how to use it but once I figured it out, it made searching for things much easier. I will probably use this in the future because it saves time.
>
> Yes it was very neat. It is a different way to search for things and have it presented to you. I really like the Visualization wheel that is really cool.

Responses from 24 % (16 of 66) of participants indicated that they liked the clustered visualization by Carrot2 but are used to using a ranked list provided by search engines like Google and Yahoo. They expressed resistance to change. Here are some representative quotes from these participants:

> I like Carrot2, but I don't know if I will change from Google because I am so accustomed to using Google.
>
> Yes, Carrot2 might be the next generation of search engine and I find it pretty useful. However I will still use Google for the general searching since I'm used to it. I'll try Carrot2 if I need more analyzing on the topic I'm searching.

A group of 16 % (14 of 86) of the participants did not like the clustered representation of search results and indicated a preference for the ranked list

based search engines like Google, Yahoo, and Bing. Below are some representative responses:

> I did not like Carrot2's interface. It seemed to be a little bit more useful if what I was searching for returned varied results, but it was a little bit too distracting for me.

> No. I did not like the way it worked or the way in which it was layed out for the user. I prefer the Google layout where the user can type in the info desired and it scrolls through possibilities as you type.

The remaining 7% (6 of 86) of the participants stated that the clustered visualization is an interesting tool but were concerned about aesthetic properties of the Carrot2 interface like color, text size, layout or speed. Here are some representative responses:

> Results were crammed very tiny on the right side of the page. They should utilize the entire screen space.

> Yes I do but I don't like how it doesn't have suggestions like on Google. I might use it in the future. The GUI doesn't look that appealing though. It's too bland. Needs some color.

4.5. Summary

This chapter presented the quantitative analyses of objective and subjective data gathered in this research. It also provided the summary of qualitative feedback from the participants. The next chapter presents summary of the conclusions and recommendations for future directions of the research.

CHAPTER 5. CONCLUSIONS, DISCUSSIONS, AND FUTURE DIRECTIONS

This chapter summarizes the findings in this research. It further provides a general discussion and directions for further extension of this research.

5.1. Conclusions

The researcher evaluated the clustered visualization (of Carrot2) as compared to the ranked list representation (of Google) in terms of efficiency, effectiveness and satisfaction in relation to exploratory search tasks.

The total number of URLs visited in the clustered interface was significantly less than the same in the ranked interface, while the total search time in the clustered interface was comparable to that of the ranked interface; therefore, overall clustered visualization was more efficient than the ranked list representation.

Relevancy of the top search results of the clustered interface was comparable to the same of the ranked interface. The ranked interface performed better in completing the search tasks than the clustered interface. Overall, the ranked list representation was more effective than the clustered visualization.

The ranked list interface provided better ease of use and ease of navigation. Hence participants rated it higher in user satisfaction.

Qualitative feedback shows that 77 % of the participants positively responded to the idea of using a clustered visualization for exploratory search tasks. Sixteen percent of the participants did not like the clustered visualization over the ranked list, while 7% of the participants liked the idea but were concerned about issues like aesthetics of interface and speed. Overall, the participants liked the idea of clustered visualization of search results.

5.2. Discussion

The ranked list has become a de-facto standard for presenting search results. It performs well when the search tasks are fact-based or are question-answer scenarios. But still clustered visualization of search results has potential to act as a complementary tool to a ranked list when the nature of the search task is exploratory. The major hurdles in this path are user resistance to change and the accuracy of the clustering algorithms. This research suggests that the clustered visualization delivers on the promise of guiding the user to desired search goal more efficiently. As the data from 26 participants was discarded in statistical analyses of efficiency; the confidence level for these results was affected. Clustered visualizations for exploratory searches are still a new technology and need a lot of improvement in the underlying algorithms to enhance accuracy of cluster formation. Also, the qualitative feedback suggests that clustered interfaces need improvement in aesthetics and usability.

5.3. Future Directions

The sample population used in this study was mostly under-graduate and graduate students at the Purdue University. The study can be further improved by using a more diverse population to make sure that all the demographics are adequately represented. Also, a large number and variety of exploratory search tasks can be included in the experiment to avoid any bias due to user background or prior knowledge of the subject matter.

Another extension could be evaluating various methods of cluster representation like tree, graph, two and three dimensional views etc. to study user preferences for different representations.

One of the areas with exciting potential could be examining user interaction and decisions made during the search process to get insights into cognitive learning process. Further insights could be gained by analyzing user logs for an extended period instead of using only the survey data.

5.4. Summary

This chapter summed up the findings in this research. It also presented a general discussion and recommendations for future extensions of the current research.

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LIST OF REFERENCES

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APPENDICES

Appendix A

IRB Approval

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	JAMES MOHLER KNOY 347
From:	RICHARD MATTES, Chair Social Science IRB
Date:	12/02/2009
Committee Action:	**Exemption Granted**
IRB Action Date:	12/02/2009
IRB Protocol #:	0911008637
Study Title:	Evaluating the efficacy of clustered visualization in exploratory search tasks

The Institutional Review Board (IRB) has reviewed the above-referenced protocol and has determined that it qualifies for exemption pursuant to Federal regulations 45 CFR 46.101(b) exempt category(2) .

If you wish to revise or amend the protocol, please submit a revision request to the IRB for consideration. Please contact our office if you have any questions.

We wish you good luck with your work. Please retain copy of this letter for your records.

Appendix B

Consent Form

I am a graduate student in the department of Computer Graphics Technology at Purdue University, West Lafayette campus. As a part of my thesis research, I am working in the area of Information Visualization. I need your assistance to conduct this research experiment. It will take around 20- 30 minutes to complete. The experiment will start with a pre-test questionnaire followed by a brief training session. Then you will conduct few web searches and fill out the second questionnaire. Please notice that

This study is approved by IRB, Purdue University.
Participation in this study is completely voluntary.
The study will NOT collect any identifying information like Name, Phone number etc.
During the study, the links you visited and the time taken to complete a task will be recorded.

If you have any questions, concerns, or trouble accessing the survey, do not hesitate to contact us at jlmohler@purdue.edu or kothari@purdue.edu.

Thank you for your valuable time!

If you want to participate in this study, click on **Continue** to proceed.

Please use Mozilla Firefox only to conduct this survey, otherwise your response will not be recorded.

Pre-test Questionnaire

Please take few moments to answer the following questions.

1. Gender: ☐ Male ☐ Female
2. What is the highest level of education you have completed or working on?
   - o Post Graduate Degree
   - o Graduate Degree
   - o High School Degree
   - o Other
3. What is your major? _____
4. How frequently you use search engines to find information you want?
   - More than 5 times a day
   - 1-5 times a day
   - Few times a week
   - Not at all
5. Which search engine do you prefer to use?
   - Google
   - MSN
   - Yahoo
   - Other (Please specify)_____
6. Do you usually find the information you are searching for in first few pages?
   - Yes
   - Sometimes
   - No
   - Not sure
7. How do you consider your searching capability?
   - Good
   - Average
   - Not so good
   - Not sure

Post-test Questionnaire

Click HERE to open the Survey Handout.

It will give you some basic information regarding the experiment and walk you through the steps to follow.

After going through the presentation, click on continue to proceed..

Please read the following problem description carefully.

Task A Description: (Use Google only)

Find as much relevant information as you can find on earthquakes.

Documents that discuss scientific causes of earthquakes, geographic areas where earthquake activity occurs most frequently, recent earthquakes, precautions to take, after shocks, ongoing research on earthquakes and any other information that you think is important are all relevant.

Please click **HERE** to go to **www.google.com** and search for the information. While searching, **Bookmark** the links that you find relevant to the problem. Once you finish searching click on **Continue**.

Please rate how strongly you agree or disagree with the following statements in regard to Task A:

I was able to find all the information I needed to complete this task

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

I found the links at the top of search results relevant to the information I was looking for

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

It was easy to find the appropriate information on the search task

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

It was easy to navigate through the search results

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

Please read the following search problem description carefully.

Task B Description: (Use Carrot2 only)

Find as much relevant information as you can find on Tornadoes. Documents that discuss the meteorological and atmospheric conditions necessary to create a tornado, how it is formed, recent tornadoes, where they occur frequently, types of tornadoes, safety measures to take, ongoing research on tornadoes and anything else that you think is important are all relevant.

Please click **HERE** to go to **search.carrot2.org** and search for the relevant information. While searching, **Bookmark** the relevant links. Once you finish searching click on **Continue**.

Please rate how strongly you agree or disagree with the following statements in regard to Task A:

I was able to find all the information I needed to complete this task

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

I found the links at the top of search results relevant to the information I was looking for

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

It was easy to find the appropriate information on the search task

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

It was easy to navigate through the search results

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

Please read the following search problem description carefully.

Task C Description: (Use Google only)

You are planning a one week vacation to Greece this summer**.**

Find out as much information as you can relating to the places to visit, culture and cuisine, transportation etc.

Please click **HERE** to go to **www.google.com** and search for the information you need. While searching **Bookmark** the relevant links. Once you finish searching click on **Continue**.

Please rate how strongly you agree or disagree with the following statements in regard to Task A:

I was able to find all the information I needed to complete this task

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

I found the links at the top of search results relevant to the information I was looking for

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

It was easy to find the appropriate information on the search task

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

It was easy to navigate through the search results

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

Please read the following search problem description carefully.

Task D Description: (Use Carrot2 only)

You are planning a one week vacation to Austria this summer. Find out as much information as you can relating to the places to visit, culture and cuisine, transportation etc.

Please click **HERE** to go to **search.carrot2.org** and search for the information you need. While searching, **Bookmark** the relevant links. Once you finish searching click on **Continue**.

Please rate how strongly you agree or disagree with the following statements in regard to Task A:

I was able to find all the information I needed to complete this task

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

I found the links at the top of search results relevant to the information I was looking for

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

It was easy to find the appropriate information on the search task

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

It was easy to navigate through the search results

- o Strongly Disagree
- o Disagree
- o Undecided
- o Agree
- o Strongly Agree

Explain the reasoning behind your choice (Optional)

Please answer this question after you have completed all the search tasks.

Did you like the way Carrot2 search engine presented the search results? Will you use Carrot2 or similar search engine in future? Why or why not?

Appendix C

Qualitative Feedback

1. “It is useful for organizing searches but it may detract from searches efficiency because of the visual aids. Takes some getting used to.”
2. “I really liked the way Carrot2 presented its results. I will probably try to use it more than google in the future because it gave me much more relevant results.”
3. “I had never heard of Carrot2 until today. I'm impressed. Organization is excellent. I will use it in the future.”
4. “Yes, Yes. I thought the visualization was very nice and easy to use.”
5. “yes, no i will not use it becouse im use to google and thats what i like to use.”
6. “I like Carrot2, but I don't know if I will change from Google because I am so accustomed to using Google.”
7. “I liked Carrot2 and will use it in the future. It separates your results into smaller sub-categories that make it easier to navigate.”
8. “I like that Carrot2 is suggestive and finds meaning to computer-generated relevance.”
9. “Yes it was very neat. It is a different way to search for things and have it presented to you. I really like the visualization wheel that is really cool.”
10. “I like the idea of how it searches, not necessarily how it presents results.”
11. “Yes, Yes, The visualization was very helpful to narrowing the results.”
12. “Very interesting UI. Text is sometimes more difficult to read on search results.”
13. “no. No becouse i am use to google and it works for me.”
14. “I may use Carrot2 in the future, but I like using Google and will maybe switch in the near future.”
15. “I did not like Carrot2's interface. It seemed to be a little bit more useful if what I was searching for returned varied results, but it was a little bit too distracting for me.”

16. “I liked the Carrot2 search engine but there's nothing wrong with google and Carrot2 doesnt do anything extraordinary, so ill stick to google.”
17. “yeah i liked the graphical display of the search results, i was counfused though why carrot2 and google did not duplicate their top hits in any of the catagories. i know google is the top search engine in the world and despite the fact that you may get un wanted information, it will still return your search with very reputable results. i have never heard of carrot2 before now and seeing that the top results were not close to the same puts me at unease in terms of using it for something more important.”
18. “Yes. It is highly organized and in order and categorized. I will definitely use it in the future.”
19. “Its a good idea and i liked the selection bar to the left side but i don't have any problems with the current search engines.”
20. “Yes I did like the way the search engine operated although the engine was slow. I feel you get the same information from refined searches on google.”
21. “Yes i would use Carrot2 in the future, because it divides the results into smaller, easy to search, categories.”
22. “Yes, it was much easier to get a lot of info without clicking several unwanted links.”
23. “The Carrot2 search engine was good, but the general catagories it found for me were not always what I was looking for leaving me with a lot of information I didn't want. Due to the size of the visualization, the top results were only able to display a small amount of text regarding the results. The tree was a good tab and allowed me to find what I was searching for more specifically, but I still believe that the visualizations and tree are unnecessary.”
24. “Yes I liked the presentation of Carrot2. It was nice to not only be able to scroll through the searches, but to see the top five search topics related to that topic to the left. I would use the Carrot2 search engine in the future, because its nice to be able to visualize the other search topics related to the search you typed in. It just simplifies the whole process.”

25. “Yes the clusters were fairly helpful. I may use Carrot2 in the future.”
26. “I just think the graphics take too long. We are on high speed internet and it was a little slower than Google. I didn't see a noticeable difference in the accuracy of the search. I think it is a good idea. My brain works in categories though. I also do more searches for standards though and hard to find stuff. Like the diameter of a typical 2002 Civic LX counter bore. Its hard to find anyway So I want to use the search engine that pops up the fastest.”
27. “Yes, I loved Carrot2 because it seem more efficient and gave better information. It's easier and it gives you better options on the side. This was way better than google and all it's mishaps.
28. I found my self not using the features in Carrot2 at all. I don't like how it dosn't spell check as you type and the shortness of each site description.”
29. “Carrot2 was nice, I like the cluster idea it makes narrowing searches much easier than following links in google. I wouldn't be opposed to using Carrot2 in the future, it seems to work really well and usually found what I wanted.”
30. “Carrot2 seems to have almost exactly the same search results as Google, but the categorizing could be useful in some situations. I may use Carrot2 occasionally.”
31. “I will stick with Google. I like how Google helps me finish my search statement. Carrot2 brought up the same sites as Google for the tornadoes search, however it was presented better on Google. Google also had better travel sites, instead of leading me to random searches or questions posted by people.”
32. “No I did not like the way it worked or the way in which it was layed out for the user. I prefer the google layout where the user can type in the info desired and it scrolls through possibilities as you type.”
33. “I liked Carrot2 search engine results very much. I will use Carrot2 in the future because it organized the results very well.”
34. “Yes, because I like the way Carrot2 broke down the search options even further to help you find the information quicker and easier.”

35. “It was more visual, and got to topics that I needed to get, but in the idea that I'm trying to find an article, I don't want to have to look at two different places to see results. Google gets straight to the links. But, it is more festive and gets to the point like google as well.”
36. “Yes I liked it.”
37. “Yes. Yes. I like the way it categorized everything so I could choose exactly what I was looking for.”
38. “I did like carrot, but I did not like the url. I am comfortable using yahoo, but I may use carrot. There is not a big chance however.”
39. “Yes, I thought it was a new way of doing search engines and I really enjoyed it.”
40. “Yes because I like the clustering strategy that it uses.”
41. “it is interesting to use and the user interface is fun to play with. I may use it when i have time to play around otherwise i may use what i know.”
42. “I did not like how Carrot2 Search Engine presented the results. I felt like it was really hard to read through the results that we crammed very tiny on the right side of the page. They should utilize the entire screen space.”
43. “Carrot2 was okay, but I am happy using Microsoft Bing. I have no complaints with Bing and as long as it meets my needs I see no reason to learn another search engine.”
44. “no, i don't need things grouped together, I know how to refine my searching to produce the information and results I require for the information i'm trying to obtain.”
45. “No, The information presented after the search was too cluttered without an east distinction between random websites and government/scholastic websites.”
46. “I liked the search engine, but its something different and things that are different are hard to get used to when you already have something like google that works just fine. In the future I will probabaly not use carrot2 in the future.”

47. “Carrot2 was an effective way to find the relevant information I needed. When comparing this search engine to google I still preferred google because it seemed to be a little more user friendly in the way that it brings up suggestions in the search bar.”
48. “Yes, Carrot2 might be the next generation of search engine and I find it pretty useful. However I will still use Google for the general searching since I'm used to it. I'll try Carrot2 if I need more analyzing on the topic I'm searching.”
49. “I like Carrot2 because it was different and it gave the option of choosing multiple topics within one search engine, however, it was a little bit more complicated and not as user friendly as Google. I would use Carrot2 in the future but maybe not as much as Google because it is too broad and it suggests a lot of information that could be completely irrelevant to the research topic.”
50. “Yes I like the way Carrot2 presents search results. I will use Carrot2 because I like the grouping feature that it has.”
51. “I did not like it. It didn't produce desirable results and the user interface was annoying.”
52. “I did like it, and it provided useful results. I may use it, but I am much more comfortable with Google because I'm already used to how it works and how to sort through it. However, if Google fails me I would certainly use Carrot2 as a back up search engine.”
53. “Yes I liked the way it presented the information. It was very organized and I would use it further.”
54. “I like the way results are presented in the cluster format. I may begin to use Carrot2.”
55. “I don't like that the carrot wheel takes up a significant portion of my searching space. it distracts from looking at results so I will probably not use Carrot2 in the future.”

56. “I did not like the way carrot2 operated or presented my search results. It was more confusing with the addition of the GUI.”
57. “I do like the search engine results. However with googles reputation i will probably stick with google becuase im used to the interface and its more common.”
58. “Yes, I liked the way the wheel appeared and gave me almost exactly what I was looking for. I would like to use something like Carrot2, or I guess learn how to use something similar to Carrot2.”
59. “It was different. It is something I would have to get used to using.
60. Yes I liked the way that carrot broke the results into different categories
61. I did like how it represented the results, but the results did not seem to match what the cluster said they were.”
62. “Yes I do but I don't like how it doesn't have suggestions like on Google. I might use it in the future. The GUI doesn't look that appealing though. It's too bland. Needs some color.
63. I think it is a little bit different. I would have to get used to using it. I would use it in the future because it seemed like it is a good search engine.”
64. “One feature that i did like from carrot 2 was the feature that it showed when you looked up the vacations. you could choose from various things that would be needed at the destination, like car or hotel. but overall google is the better of the two in my opinion.”
65. “I really liked how the Carrot2 Search engine worked. It was very helpful by how it grouped the results. I would like to use Carrot2 more in the future. It will take a bit of using before I get the hang of the program.”
66. “Yes, instead of just listing web sites to visit, Carrot2 actually separates results into relevant categories. Just makes searching and obtaining information easier.”
67. “I really liked the graphic representation of Carrot2. I will use it again just so I can get a good Idea of how it works. That being said, I feel the the people who are not as computer savy will use google only because it has a simpler

layout and presentation. Yes you may be flooded with paged you don't need, but you eventually find something. However I definitely see myself using this search engine in the future."

68. "i liked it but i will probably not use it to often, because most web browsers have google search bars in the toolbar, its easier."
69. "yes, i liked how you could type in a key word in the search engine and the red wheel would give you different options to choose from. It was easier to see more in depth topics when there is a wheel with related information for you to choose from on it."
70. "Maybe. Google is far too easy to use, has too many advantages, far more popular; which will hamper the likelihood of me using it in the future. The one advantage was the visual aspect of the search results, splitting it up into categories. Great idea."
71. "I like the way that it presented results. I'm not sure it is particularly better then google or other such engines. I might. I like the ease and speed of google as a start page. If this page ran faster then maybe."
72. "Yes, i will use Carrot2 as a search engine because it was easy to use and very efficient."
73. "At first I didn't know how to use it but once I figured it out, it made searching for things much easier. I will probably use this in the future because it saves time."
74. I liked how it presented the search results and I will most likely use Carrot2 again because of how it presented the information
75. "When I hit the back button after a site, I had to click through the cluster interface to get back to the filtered results I was at before. It would be nicer if the back button took me straight back to that point instead of having to click through all the filters again."
76. "Yes, I like the Carrot2 search engine because it breaks down the results into categories so that you can pinpoint what you are looking for. I think it gives more accurate results. I will use this in the future."

77. “No, I prefer using either google or yahoo.”
78. “It was pretty simple and user friendly. I would probably use something like this in the future.”
79. “I thought the graphical interface that divided the results was very nice. I would consider using this search engine.”
80. “it is a good search engine. seems to give a lot of relevent information.”
81. “Not Really, It complicates things too much, its easier to see bold words than a slice of a pie graph.”
82. “No. I dont know what that big wheel was. I prefer google. It is better in every way.”
83. “No. I didn't prefer to use the Carrot 2 search engine because I have grown accustom to using going my whole life, and I am not a very big fan of change. I dont like things to be new and different. I also like google because it does SO much more then just let me search for things.”
84. “yea it found what i needed”
85. “I did like the way Carrot2 worked. I would probably use it in the future as it categorizes things that Google would not otherwise.”
86. “I like the way the results are presented. But, the accuracy is much lower as compared to google.”