Interactive Visual Search Engine for Web Page Searching

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***ABSTRACT**: The volume of Web content is increasing and hence the heterogeneity also grows. The structure denies the understanding the content which leads to difficulty in obtaining effective results for the end users. Web research now becomes directed to get high relevancy in web searching. One important technique is the introductiopn of the interactive graphical and visualization techniques which enable to handle large numbers of results while simultaneously presenting several attributes for each Web page. Besides the query reformulation and reconstruction is usually controlled by the search engine. In many web search processes, the twin problems are the redundancy and/or irrelevancy. To ensure the effectiveness in the overall search relevance the user is integrated in the process of query reformulation. This study has used the Visual Search Engine (the VSE) where the query reformulation and results presentation are visualized. In the user study, the effectiveness of the VSE was demonstrated when compared to Google.*

Keywords: Interactive search enigne, Web page visualization, Search results, Query reformulation

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1. Introduction

In the last two decades, the major medium for the information access is the the web. The distribution of information in the web is so wide ([5], [9], [21]). Large pieces of the content are updated or or changed or added every day while others are removed ([8], [32]). The Web content is so complex, vast, dynamic, and heterogeneous. To ease the search process, the search engines are built in the web platform. The 'big' search engines, such as Google, produce thousands or even millions of results for compound queries. Nonetheless, relatively few items can be listed per screen; this is exacerbated by redundancy and irrelevancy in the results. The vast content and the differing formats of Web documents are factors that may contribute to irrelevancy in search results.

The rendering process in most conventional search engines presents a list of links per display with textual content attached to each link. The user may have to scroll over multiple pages to find relevant results. However, it has been shown that about 87% of Web search users do not look beyond the first three results ([12], [13], [28]). At which point, users either modify the search query or switch to a different search tool [27]. Although Web search engines have implemented different ranking techniques for the purpose of improving the relevancy of the first few ranked results, irrelevancy and redundancy are still major problems in Web Information Retrieval (Web IR).

Information visualization takes advantage of the innate abilities of users for perceiving, identifying, exploring, and understanding large amounts of data ([6], [10]). Visualization is of interest to research in Web information retrieval to improve users' interactions with Web search engines. We argue that utilizing search results' features such as document URL, title, summary, and thumbnail augmented with visualization and clustering may improve the effectiveness of users in searching the Web. Integrating visualization in the Web search process aims to combine computation and high bandwidth human

perception ([30], [31]). The VSE utilizes the users' visual capabilities to improve query construction and results presentation. The remainder of the paper is organized as follows. Section 2 illustrates previous related research. Section 3 explains the work motivation. Section 4 describes the design and implementation aspects of the VSE. Section 5 discusses the evaluation approach and the user study. Section 6 provides a discussion of the research findings. Finally, Section 7 concludes the paper and highlights future research directions.

2. Research Rationale

According to research in Web IR, visualization is usually incorporated in two stages of the Web search process, query reformulation and results presentation. The following sections discuss related research in each stage.

2.1 Visualizing Query Reformulation

The goal of providing a visual tool for query construction and reformulation is to involve the user more effectively. Kawano [15] designed a search engine that extends the original user query for enhancing the relevancy factor in the results. It extends the original query with keywords from a database of Web documents gathered by a Web crawler. The keywords are selected from metadata and other parts in the documents. The interactive graphical interface in this approach allows users to see the keywords with their associated weights. During the evaluation process, users were able to effectively utilize 45.5% of the suggested terms to construct alternate queries, and 84.8% of those queries consisted of more than two keywords. A similar idea can be seen in the search engine Quintura (www.quintura.com).

The overall relevance of search results to the user query has been used for ranking search results by most search engines. However, the contribution of each term in a multi-term query to the overall relevance of the results is not usually considered. Bonnel et al. [3] argued that permitting the user to assign ranks to query terms may provide more satisfactory results.m Consequently, Grewal et al. [11] presented a visualization technique called Result Wheel (*R-Wheel* for short). The purpose of this mechanism was to allow users to allocate a percentage of significance to each query term by shading the term's corresponding segment on the wheel. Experiments showed that using the R-Wheel approach resulted in correctly ranking Web documents.

2.2 Visualizing Results Presentation

To provide better perceptions of graphically rendered search results, Mukherjea et al. [24] presented a visualization technique that incorporates a *scatter plot* and a *bird's eye* view for a *tabular* visualization of search results. Although satisfaction with the presentation was recorded, the delay in manipulating the results was a significant shortcoming. Bonnel et al. [3] introduced clustering along with visualization in the presentation of Web search results. The goal was to obtain various search topics from the collection of returned results. They provided both 2D and 3D representations. A *3D City Metaphor* defined the layout that allowed users to see the different clusters based on color differences. Visualization was intended to show different features of the results in an easy-toperceivem manner. The overall assessment of this approach indicates above average satisfaction. However, it is worth mentioning that dealing with 3D metaphors may complicate the process of navigation and exploration.

Although techniques that use visual presentations as their standard rendering method, such as the search engine Kartoo discussed by Kunz and Botsch [19], to provide additional features over textual presentation-based approaches, these techniques are not yet widely adopted by users. Alonso and Baeza-Yates [2] argued that the familiarity of current Web search engines with text-based rendering is what causes users to avoid visualization-based techniques. Consequently, Alonso and Baeza-Yates [2] introduced a visualization method for Web search results that relied entirely on text rendering. Their technique provided two text views of the results: the *strip view* and the *thumbnail view*. Users see a large number of documents in the strip view listed by title, and magnify the document of interest in the thumbnail view. Although this technique is quite simple, further improvements in this case of text-only presentation are hard to envision. This is due to the limited characteristics of text compared to visual objects.

Cellary et al. [7] introduced a search interface that exploits varied characteristics in Web search results. In their system, *Periscope,* the 3D metaphor consists of multiple levels corresponding to different categorizations of the search results. Users could navigate and explore features of the search results such as document size and Web server source. Although a wide range of features is exploited in the categorization of results in Periscope, the display suffered from visual noise and clutter. Visual noise has been shown to degrade the effectiveness of visualizations for nonprofessional users ([1], [26]).

Joho and Jose [17] investigated the effectiveness of four presentation layouts for search results namely: text only, text accompanied with summaries (three 'bolded' Top Ranked Sentences within a page, TRS), text with thumbnails of the page, and text with TRS and thumbnails. The study showed that users found the presentation of text summaries accompanied with thumbnails and the TRS was the most effective. Teevan et al. [29] evaluated the effectiveness of visual snippets compared to text and thumbnail presentations. Visual snippets consist of thumbnails augmented with selected parts of the text on the Web page. They found that visual snippets permitted users to complete their search and re-search tasks faster and more effectively.

The findings of the relevant research show that several problems and disadvantages remain for users using visualized search techniques. In this research, our goal is to reduce those disadvantages by incorporating visualization and clustering utilizing document features obtained from search engines including URL, title, summary, size, last update, and page thumbnail in the design of the VSE. We hypothesize that such features—when presented visually—may enhance the effectiveness of query reformulation and result presentation.

3. Motivation

Relevant results for user queries typically reside somewhere among the list of hits provided by the search engine. The large number of matching documents and the textual list format make it hard for users to find such results. To further enhance the effectiveness in Web search, the VSE is guided by the following motivations:

• Visualization should make best use of the display to render results of large hit sets in an easily understood form.

• The use of visualization should incorporate features of Web documents such as the page size, last update, thumbnail, and the page similarity to other pages in the result set in order to provide detailed insights into the returned documents [18].

• The design of visualization techniques should consider the kind of user and the type of task. Most Web search users are casual users without specific search training [20].

4. Design and Implementation

The need for better presentations of search results has become increasingly important [14]. To improve access to Web search results and the effectiveness of users in gathering information on the Web, a prototype visualization tool (VSE) was designed and implemented. The design of the VSE relies on three main principles. First, the VSE uses two underlying search engines, namely Google and Microsoft's search engine, WindowsLive. Second, an alternate query is generated based on the user query. A single term query is augmented with additional terms to create an alternate query using the semantic network WordNet ([22], [23]). In the case of multiple term queries, an alternate query is generated by randomly reordering the keywords of the original query. The third principle is the incorporation of a query formulation area. The VSE infers keywords and complete phrases from the search results. These query components are presented along with the search results. The user can select terms and phrases in the reformulation area to build further queries.

4.1 Search and Response

Each time the user submits a new user query, an alternate query is created as discussed above. Both queries are submitted to both Google and WindowsLive. The resulting documents are examined to eliminate repeated matches. Then, the derived results are further manipulated to build clusters of similar documents using agglomerative hierarchical clustering [21]. Document summaries are analyzed to infer keywords and phrases to be shown to the user in the query formulation area. For each document, the VSE derives a thumbnail from the publically available Google preview directory. The VSE uses thumbnails attached to titles as recommended in the work of Teevan et al. [29]. The system allows the user to enable/disable the use of alternate queries and page thumbnailsm and to set the document similarity threshold.

4.2 The Interactive Search Interface

The interactive interface was designed to enhance the user's ability to find relevant results for a search query. This is done based on two main principles: visualization and interactive query reformulation. On the left upper side of the VSE interface shown in Figure 1, results are presented as visual glyphs containing document titles and webpage thumbnails. Similar documents are connected via edges on the display. The VSE implements a simple content-similarity-based clustering that utilizes document summaries provided by the underlying search engine. Users can click on any glyph to either open its corresponding page in the Web browser or hide the glyph from the display to reduce clutter. Moreover, the system provides drill-down capabilities. Users can hover over s glyph to magnify its content and reveal the document statistics, summary, and

URL. Document statistics include size, PageRank value, and last update. The right side of the VSE interface in Figure 1 provides a view of the document statistics. Moreover, the interface offers the user the ability to search within the results.

The second principle is interactive query reformulation. Along with search results, the VSE presents users with alternate query terms and phrases as shown on the lower part of the VSE interface in Figure 1. The VSE selects terms and phrases from the document summaries returned by the underlying search engines. The terms and phrases are presented to the user in a separate view on the display. The interface provides immediate search and response. It allows the user to enable and disable several parts such as document statistics, document thumbnail, edges representing content similarities, and the display of results derived for either the alternate queryn or the original one. In addition, users can see the actual content of a page in the Web browser. As a result, users with different query building skills can easily use the VSE.

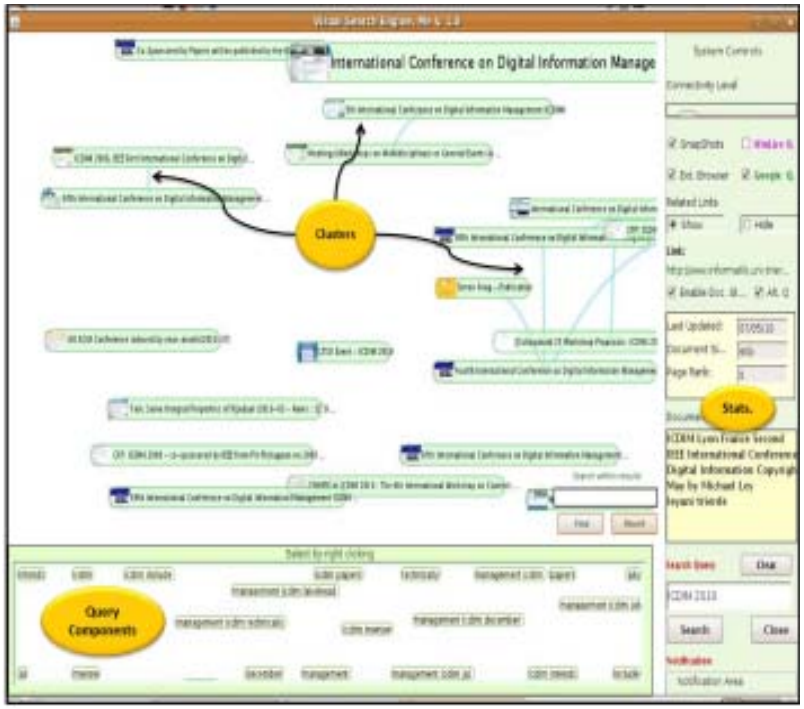

Figure 1. Interface for Visual Search Engine

5. VSE Evaluation

To evaluate the VSE, a user study was conducted. The study investigated the ability of the VSE to improve the effectiveness in performing information-gathering tasks on the Web. Kellar et al. [16] classified web tasks as fact-finding, information gathering, and navigation. In both fact finding and navigation tasks, the documents sought by the user are usually specific and they require some previous knowledge about the document content. Therefore, the results are usually either relevant or non-relevant. Information-gathering tasks, on the other hand, achieve results that depend on the user's search expertise. This study investigated four main factors: the ability of users to find relevant results effectively and efficiently, the number of topics (types of information) covered in the results, the number of queries needed by the user, and the number of pages the user opened. In the study, the VSE was compared to Google, considered to be most frequently used search engine (www.searchenginewatch.com).

5.1 Study Location and Population

The user study was carried out in the Faculty of Computer Science at Dalhousie University using a Linux machine loaded with the Chromium Web browser and the VSE. The Chromium Web browser was chosen because of its ability to record the data required in the study. Fourteen participants took part in this study. The participants were mainly computer science students including five undergraduate and nine graduate students. The participant set was comprised of nine males and five females.

5.2 Study Design
The design of the study was complete factorial in which all combinations of the tasks and the two systems (Google and VSE) were used. The study design was within-subjects and counterbalanced so that each participant experienced all conditions in different random orders. This design limits the effect of order.

5.3 Study Tasks
The search tasks were information gathering intended to encourage participants to find as many pages related to the task as needed. The following is a description of one of the tasks used in the study:

"Use the given Search Engine to gather Web pages that include information about how to use the java programming language in transforming html documents into images. The pages you find should give someone a good idea about the task's topic. You can submit up to five queries only, and you should not go beyond one page of results for each query you submit. You can also view results in the Web browser."

5.4 Study Methodology
To ensure fairness in the comparison between the VSE and Google, WindowsLive was not used during the study and the number of results was restricted to 20 hits per query for both the VSE and Google. Each participant received a short training session using one demonstration task on the VSE. Then, each participant was asked to perform the information-gathering task using both the VSE and Google. The two search engines had the same chance of being used first to eliminate any learning effect. After performing the search task, each participant was asked to report the number of relevant results and the number of topics (or types of information) covered by those pages. Each participant was asked to state their confidence level (on a Likert scale) with the results.

After performing the task on both the VSE and Google, each participant was asked to complete a post-study survey. In this survey, the participants were asked to answer questions in which the VSE and Google were compared. Finally, participants were asked to provide their own comments regarding the VSE and possible improvements. The participants spent a total of 20 minutes on average to complete the study.

5.5 Study Data
The data collected in the study included logged data as well as surveys' data. The log data included the time on task and the number of pages opened on the Web browser using both the VSE and Google. While participants were working on their tasks, the machine logged all search queries. The survey data included answers to questions in the surveys. The questions were used to compare the VSE to Google with respect to the ease of use, the effectiveness with respect to finding relevant pages, and the effectiveness of the query reconstruction feature as well as other visual features of the VSE. The survey data was collected using a five-point Likert scale (1 for worst and 5 for best). The analysis of the data considered answers of 1 and 2 as negative choices and answers of 4 and 5 as positive. Finally, the data involved qualitative comments reported by the participants.

5.6 Study Results
1) *Efficiency:* With respect to efficiency, the task completion time was less using the VSE with an average task time of 6.5 minutes compared to Google with an average of 8.2 minutes. Although these results are not statistically significant, there is a good indication that the more familiar the users become with the VSE, the faster they will perform.

2) *Effectiveness (Quantitative Performance Results):* Effectiveness was measured with regard to the number of relevant pages located for the task on each search engine, the number of topics (information types) discovered in the results, the number of pages participants had to open on the browser (click behaviour), and the number of queries they had to submit in order to achieve the task. The VSE was shown to be more effective than Google with respect to those criteria. The quantitative results are shown in Table 1. The ANOVA results showed a significant difference between the VSE and Google ($F=41$, $\alpha < 0.003$) with respect to all of the above evaluation metrics.

3) *Effectiveness (Survey Results):* Regarding confidence with the results, the study showed that the participants were more confident with their choice of pages using the VSE than they were with Google. Figure 5 shows the effectiveness of the VSE compared to Google with respect to user confidence. In addition, analyzing the data of the questionnaires showed that 65% of the participants reported that the VSE is better than Google, that the VSE makes it easier to find the intended results, and

that it makes query reformulation more efficient. Finally, 71% of the participants considered the VSE as a more helpful search tool. Figure 6 shows the subjective ratings. A one-tail z-test results show no significant difference between the two proportions of ratings of the VSE and Google ($z = 1.42$, $\alpha = 0.08$).

System		VSE	Google
Time (Mean)		*6.5*	*8.2*
Submitted queries	μ	2.5	3.5
	σ	1.5	1.6
Pages opened on the browser	μ	2.1	9
	σ	1.5	11
Relevant pages found	μ	6.5	4.5
	σ	2.7	2.1
Covered topics	μ	3	2
	σ	1.4	1.3

Table 1. Web page search results

Where (μ) is the Mean and (σ) is the Standard Deviation.

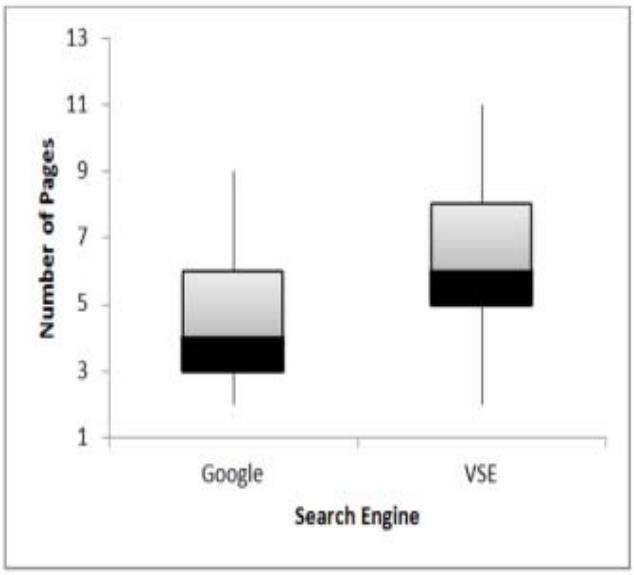

Figure 2. Pages Located for the task

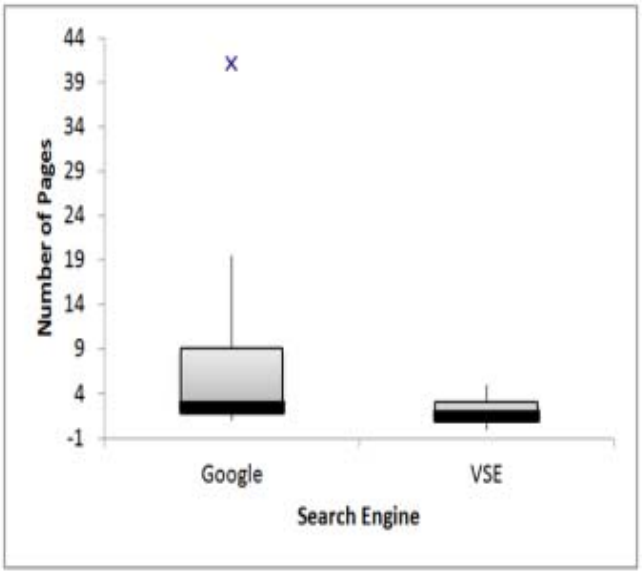

Figure 3. Opened pages in the web browser

4) *Effectiveness (Subjective Comments):* The last part of effectiveness-related results was the qualitative comments provided by the participants. Participants provided 40 comments, which were categorized by the researchers into four types namely: comments related to the query reconstruction area, comments about the visual view of the results, comments regarding visual clustering, and comments related to finding relevant results. The comments regarding the VSE were 80% positive. The first set of comments concerned the query reconstruction aspect of the VSE. All of those comments were positive. The visual view of the results showed that 70% of the participants regarded the VSE as better for viewing Web search results. The

negative comments expressed concerns with the result presentation layout and the slow movement of the glyphs on the display. One participant stated, "*The VSE keeps me focused and interested in what I am doing, but I do not like the slow movement of the connected glyphs*". According to the one-tail z-test, there was a significance difference between the two proportions of comments ($z = 2.79$, $\alpha < 0.004$).

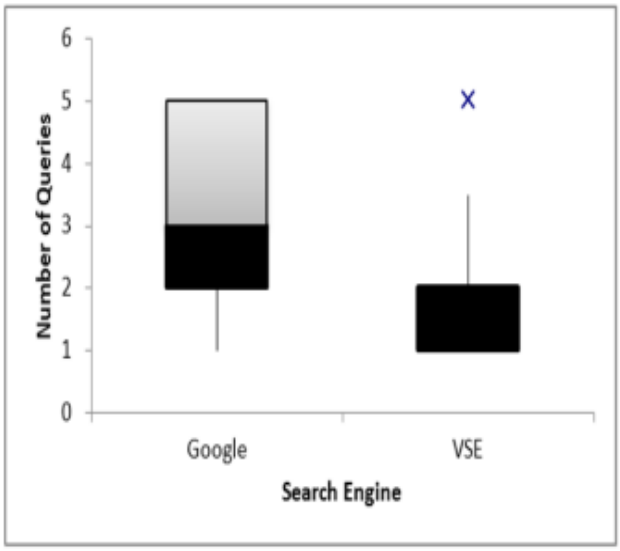

Figure 4. Submitted queries

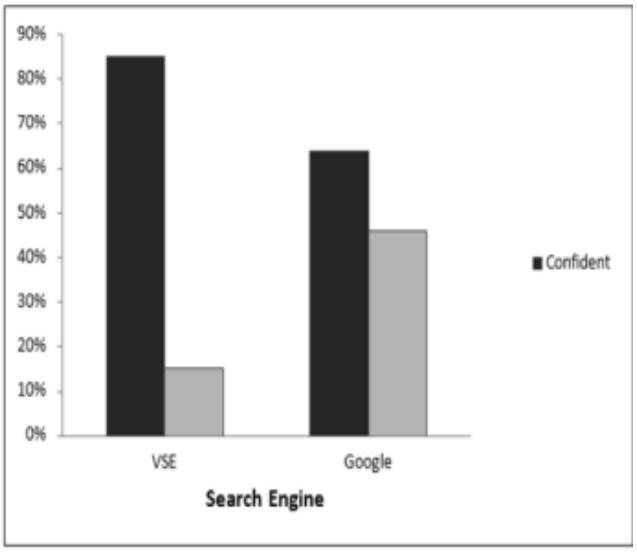

Figure 5. Users' preference for Google and Visual search enginer

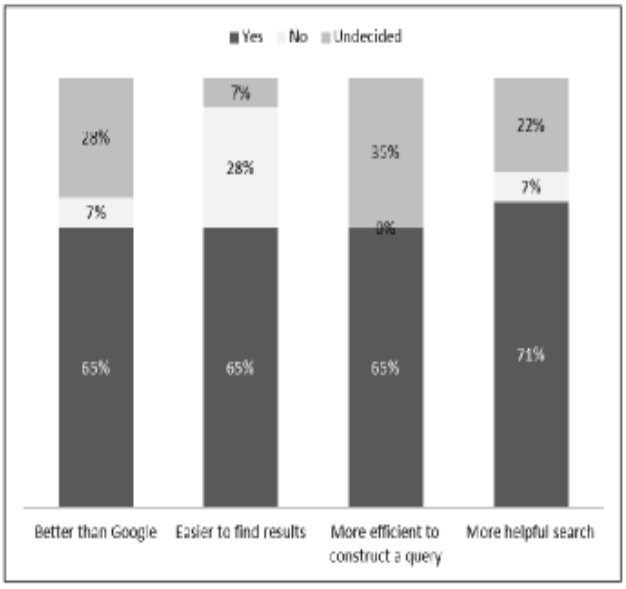

Figure 6. Questionnaire ratings of the VSE compared to Google

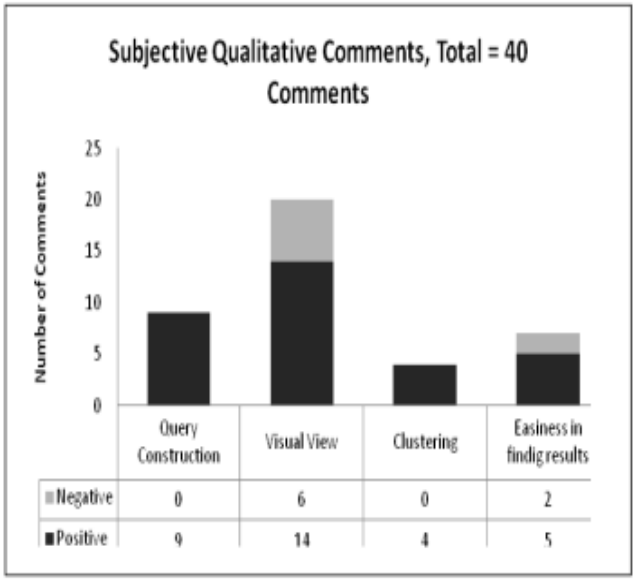

Figure 7. User perceptions of the VSE

Clustering documents based on their content similarity received all-positive comments. The last group of comments was on the easiness in finding relevant results. Only 28% of the qualitative comments were negative One of the participants stated, "*I would like to set and learn more about everything in the VSE so that I can use it in a more effective way*". The qualitative comments indicated that the VSE was more efficient with respect to allowing its users to quickly spot relevant documents on the display without having to open each document in the Web browser. Figure 7 shows the distribution of the qualitative comments among the four groups.

5.7 Study Limitations

Due to limited resources, the study was conducted with the participation of computer science students only. In addition, the number of participants was limited to only fourteen individuals who may reflect early adopters. Also, the choice of information-gathering tasks does not allow generalization of the study results to other task types.

6. Discussion

The study, while small, showed that presenting Web search results visually accompanied with query reconstruction components (keywords and phrases) and document information required submitting fewer queries, viewing fewer pages on the browser, and spending less time on the task. In addition, the exploitation of document features provided by the VSE's underlying conventional search engine including the page URL, title, summary, thumbnail, and document statistics in addition to the visual clustering of similar pages lead to improving the effectiveness in gathering information on the Web.

The effectiveness of the VSE was based on the number of pages found by the user for the task, the number of topics (or types of information) in those pages, the number of queries submitted, and the number of pages opened by the user in the Web browser. Utilizing visualization in addition to providing different features of the search results along with query construction components created a better environment for the user to find relevant results for the task.

Furthermore, that the view of the search results found in the VSE was more effective than the presentation of Google was demonstrated in the survey results and the qualitative user comments. For example, the participants' ratings favored the VSE presentation over Google's. In addition, participants were more confident in their decisions regarding the task results with the VSE than they were with Google. The qualitative comments showed a significant difference between the two tools with regard to the query construction and results presentation approaches.

Previous research has investigated visualization and clustering in Web results presentation and query formulation. However, most evaluations have been concerned with the effectiveness of the search technique in simple query-response contexts. In Web information gathering, the user may haveto gather different sources of information, find further related information to the located sources, and re-find information that was previously located ([4], [16], [25]). The implementation of the VSE took these activities into consideration. The visual view included document statistics, categorization of similar documents, and query components. Consequently, users found it more effective to gather information using the VSE. However, the results also indicate that further improvements to the layout of the visualized clustering are needed.

7. Conclusion

In this paper, an interactive graphical presentation model (the VSE) that utilizes multiple underlying search tools to provide visual search results, Web document statistics, and query reconstruction components was presented. A user study was conducted to evaluate the effectiveness of the VSE. The results of the study showed that the VSE model for presenting Web search results improves effectiveness. Future research would focus on testing different layouts for presenting search results. Future studies will also investigate the effectiveness of the VSE in subtasks that comprise the overall task of Web information gathering such as locating information sources and re-finding Web information.

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