2011

Exploring Digital Libraries through Visual Interfaces

Beomjin Kim
Indiana University - Purdue University Fort Wayne, kimb@ipfw.edu

Jon Scott

Seung Eun Kim

This research is a product of the Computer Science faculty at Indiana University-Purdue University Fort Wayne.

Follow this and additional works at: http://opus.ipfw.edu/compsci_facpubs

Part of the Computer Sciences Commons

Opus Citation

Exploring Digital Libraries through Visual Interfaces

Beomjin Kim[1], Jon Scott[1] and SeungEun Kim[2]
[1]Department of Computer Science, Indiana University-Purdue University Fort Wayne
[2]Department of Multimedia Engineering, Seoul Women's University
[1]USA
[2]South Korea

1. Introduction

Libraries are long standing institutions, providing an important service of making information widely available. So it is with Digital Libraries (DL), but this evolution into a computerized format does not come without its own unique challenges. The variety and quantity of information available in the digital space is truly astounding. However, as this growth continues, traditional methods for searching are becoming less effective to support the needs of users to find information quickly and easily.

The conventional library book search system provides several attributes associated with books as a response to the users' inquiry. This includes title, author, publication year, ISBN, page total, and similar information. While considering the increasing volume of data, the current text-based approach to result presentation is not an ideal solution for the modern digital environment. Particularly in the case of comparing a lengthy list of search results, this approach is ill-suited, as it is inefficient and non-intuitive (Good et al., 2005). Assistance, such as ranked results, can aid in such problems but the user will still be relied on to investigate the top results individually (Veerasamy & Heikes, 1997; Dushay, 2004). Additionally, the current popular approach of presenting a summary of content may not accurately reflect what is of value to the user.

The advancements and trends that allow for the rapid growth of DL also permit more elaborate interfaces with which to access them (Bertini et al., 2005). Information Visualization is one such avenue, which has proven to be an effective approach in acquiring information from a large compilation of data. By making use of users' perceptual cognition for navigating extensive digital workspaces, their ability to understand, and speed with which they review the information space is improved (Card et al., 1999). Previous studies have proven the significance of visualization in the users' information forage (Veerasamy & Heikes, 1997; Hawkins, 1999; Kim et al., 2002).

One common approach to assist users' search activities uses visualization techniques combined with information filtering. The users' interaction defines the attributes of interest that easily filter out unrelated data. The following visualization procedure transforms the remaining data into graphical illustrations. FilmFinder and HomeFinder are interactive visual interfaces which assist the user to narrow down the search scope and easily compare

results using the visualization (Ahlberg & Shneiderman, 1994; Williamson & Shneiderman, 1992). Another common approach focuses on presenting the underlying information through visualization. A novel text visualization interface, TileBars, shows the distribution behavior of a set of query terms (Hearst, 1995). This presentation allows users to compare multiple documents compactly and concurrently. Other visualization techniques in this category concentrate on showing a portion of the information at a great level of detail while maintaining the overall structure of the information (Lamping et al., 1995). Information clustering is another method for supporting navigation of a large data collection. Related documents are clustered together, whose notable characteristics are visualized using a mixture of attributes (Shneiderman et al., 2000; Au et al., 2000; Nowell et al., 1996). Visualization methodologies, such as those mentioned here, have shown that the illustration of data has contributed to improving the user's ability to comprehend information quickly. This, in turn, leads to increased speed and accuracy in finding desired information (Card et al., 1999; Kim, 2004).

We can apply these kinds of visual abstractions to enhance searches on different types of data domains. By presenting information in such a way, a large amount of content can be displayed in a format which is more intuitive. This has the benefit of allowing the user to analyze data more effectively, increasing the user's ability to comprehend results and make better content selections. Periscope, for example, is a visualization system targeted at web search results. It provides a series of different visualizations which users can utilize to analyze and explore the result set. A holistic interface can be used to organize documents into various categories, such as language and format, or web related attributes such as DNS domains. An analytical interface allows for up to seven attributes to be relayed at a time, through use of X, Y, Z axes, color, size, shape, and animation (Wiza et al., 2004).

The search based on the underlying content will increase the accuracy in finding targeted information from the available resources. Think for a moment how one might search a physical book for a topic of interest. The logical place to start would be the index. Indexes are valuable resources for referencing major terms which appear in a book. The categorical and hierarchical layout of terms in the index allows us to identify associated topics easily, along with their relationships without reading the underlying contents. The page numbers coupled with each entry makes it possible to estimate the amount information relating to a particular subject. The index will represent the overall layout of entire book contents. Due to a lack of readily available sources, this valuable information has been under utilized. The current trend of digitizing books in recent years allows us to exploit content in searches, instead of just depending on superficial book attributes. The visualization techniques utilizing this information will further enhances the user's search on the DL system.

The main objective of this book chapter is on the utilization of visualization techniques for exploring the DL system. The following chapter will survey and summarize various visualization approaches which applied to DL. We will introduce a visual interface which presents general book information through iconic representations. This chapter also proposes a novel visualization which utilizes the book index for mimicking the content analysis. It will allow for detailed comparison of index-based information between selected works. Two different visualizations for this detail view are implemented, each with different strengths. The procedure and analysis of results for a usability test follow, along with discussion and future possibilities, and final conclusions.

2. Related works

The efficacy of visualization in searching a large information space has been proven in many previous studies (Veerasamy & Heikes, 1997; Kim et al., 2002). DL are one promising area that should exploit visualization techniques in searching on various forms of archived information, such as text, imagery, multimedia, citations, and even computer mediated communication (Abbasi & Chen, 2007). The 3D Vase Museum is one example applying visualizations for browsing photographs in a digital library collection (Shiaw et al., 2004). A Focus+Context type visualization displays a set of Greek vases in the Perseus digital library in a simulated 3D virtual museum. By moving around the virtual space, users can appreciate vases with accompanying text data. Christel and Martin introduced visualization techniques for browsing and navigating another type of multimedia, video documents (Christel & Martin, 1998). Meanwhile, Chen proposed a novel approach utilizing a different side view of information in accessing the digital library (Chen, 1999). It visualizes semantic structures and co-citation networks extracted from a collection of documents. This method displayed the author co-citation networks in a 3D virtual space attempting to reveal the structure of a field of hyperlinks with co-citation patterns of authors.

Borner and Chen explained that there are three common usage requirements for visual interfaces to the DL: First, to support the identification of the composition of retrieval result. Second is to understand the interrelation of retrieved documents to one another. Lastly, to refine a search, gain an overview of the coverage of a DL and to visualize user interaction data in relation to available documents. The goal would be to evaluate and improve DL usage (Borner & Chen, 2002).

Clarkson et al. developed a visual interface emphasizing on the hierarchy of the repository in presenting the DL search results. They used the hierarchical representation in digital repositories for developing an interface for enhancing query-based search engines. A treemap, a well-known technique, is used to organize results in a space-efficient hierarchical display (Bederson et al., 2002). The system, known as ResultMap, maps each document in the hierarchical tree structures to a treemap where items matched with given query are highlighted. ResultMap presents the full contents of a hierarchical dataset while providing a view of underlying levels. The experimental results from two controlled lab studies showed that participants expressed preferences to use ResultMap system and produced comparable performance to a text-only engine (Clarkson et al., 2009).

When using physical books, people tend to view multiple at once. This is to better compare and review information across multiple sources, and to have a better overall understanding of the domain. In their study, Good et al, identify this to be a major weakness in current DL displays (Good et al., 2005). To address related issues, researchers have conducted studies applying visualization techniques for book searches and presenting various forms of search results for easy comparison (Shen et al., 2006; Silva et al., 2003). Envision is a visual interface presenting book search results in a rigid matrix (Nowell et al., 1997). The search results are presented as icons in a 2D grid where the visual attributes represent the characteristics of returned documents. Envision allows the user to organize the visualized output interactively based on their information needs.

The Graphical Interface for DL (GRIDL) and ActiveGraph adopted a similar approach in presenting search results. The GRIDL displays a hierarchical cluster of the relevant data to a query on two-dimensional display (Shneiderman et al., 2000). This system provides an interactive grid layout, the axes of which are selectable from a variety of different attributes.

Results were displayed within each cell as a collection of different size icons, color coded by document type. ActiveGraph presented search results based on scatter plots (Marks et al., 1996). ActiveGraph also provides similar functionalities to specify shape, color, and size of nodes representing various forms of digital resources. Because ActiveGraph system results in much more node clustering and overlap, a logarithmic transformation is provided, along with the ability to filter out unwanted items.

Many studies mainly focus on aiding the user in comparing the search results effectively by presenting book properties such as book title, author, publication, year, through various visual attributes, but they don't express in detail the amount of content related to user interest. Citiviz is a visual interface tool kit combining text mining and information visualization (Kampanya et al., 2004). In order to present the insight of similarity among documents as well as traditional document attributes, this system used two visualization techniques: an animated 2D scatter plot to represent document attributes and a dynamic hyperbolic tree to show hierarchical relationships among documents. By allowing users to manipulate the manner in which data is displayed, these visualizations provided a better chance to find patterns within the data that may not typically be apparent.

Lin proposed another approach through a graphical table of contents (GTOC) that tries to exploit a different perspective of underling information by utilizing the table of contents of the book. GTOC showed the dimension of items in the table of contents based on Kohonen's self organizing feature map algorithm (Lin, 1996). The paper introduces how documents can be organized and then visualized to allow the user easy access of underlying contents. The GTOC prototype describes various interactive tools to assist the user exploring document contents and analyzing relationships among terms in the table of contents.

Both the attributes associated with documents and its underlying contents are valuable resources finding the relevant information of the users' interest. The increasing computing power and performance of graphics devices make it possible to exercise these information in presenting search results. The following section introduces a newly developed visualization system that will assist the user's search while utilizing the book index, which has been underutilized as a visualization resource.

3. Method

The Visual Interface for Digital Library Search (VIDLS) system utilizes an Overview+Detail approach for presenting book search results. This is a visualization technique that uses multiple images to display the entire data space, as well as show an up-close, detailed view of the data (Baudich et al., 2002; Shneiderman, 1996). Similar to traditional library searches, the overview will present outline of the book search results through graphical illustration. The user interactively selects a subset of visualized icons that will allow them to execute content level exploration. When a user provides search terms of interests, the Detail view presents a visualization which relates, in depth, the information presented by the index. For our pilot study, we developed two possible visualizations for this view of the index, each with its own strengths. One emphasizes space utilization, whereas the other is designed to focus on clearly presenting term relationships.

3.1 Overview visualization
The Overview allows the user to perform a general search on the data space, similar to traditional library tools. This visualization utilizes a tabular layout which offers a familiar

spread-sheet style organization of book search results. The attribute of each axis can be independently selected by the user, allowing for a more targeted display and increasing the users' comprehension of the data set (Shneiderman et al., 2000). This functionality will assist the user in customizing the search based on their own judgment of which attributes are more important. In the Overview, each book is represented as a circular node, located in the appropriate cell based on the axes. To deliver the estimated amount of content, node size is determined by the normalized page count of the book compared to the rest. Books with a greater number of pages naturally map to the largest nodes. This will allow users to quickly identify the amount and distribution of content available.

Fig. 1. Overview interface displaying search results with tool-tip

The system presents other book attributes through a color coding scheme. The green component is derived through collaborative filtering. This is a content-filtering technique based upon the opinion of users whom have already evaluated the item in question (Resnick et al., 1994). This will be a valuable piece of information to know regarding the quality of the book. In the case of VIDLS, collaborative filtering would be done by collecting user reviews, much like you found find at a merchant website. Higher intensity of the green component would indicate a more positive response from reviews.

The accuracy of the content-filtering is highly correlated with the number of evaluators and their preferences. As an example: the mean score of a book which has a low number of reviews could potentially be misleading and unreliable (Allen, 1990). To account for this, the Overview associates the blue component with the number of unique evaluations given to a book. The publication year is a valuable attribute to find the most up to date information. This metric has been represented through the red component. With the utilization of the RGB color scheme, the larger more recent books with a solid review will be closer to white in intensity, while older, smaller, poorly reviewed works tend toward black. If the user needs to know more precise information for the components, or other detailed information of the work, the system provides this via a tooltip interface (figure 1).

3.2 Detailed visualization

Once a user makes a set of selections from the Overview, the system will provide a detailed view of those items. This display is tasked with presenting visualized index data for each book, allowing the user to perform more refined queries, and compare and contrast each work in detail. Two visualizations were implemented on a data model to present the same information while emphasizing different attributes: one a radial graph, and the other a sunburst-like display (Stasko et al., 2000).

3.2.1 Data model

The underlying model for the detailed visualizations relies on several important characteristics associated with a term in the index. These are: number of pages, number of occurrences, content density, and location relative to the parent term. Although this information is readily available in the index, it is unintuitive in a text format. Presenting these attributes via graphical illustration, the user should gain greater understanding of the content, and make more informed choices of which books to choose.

The number of pages associated with a term by the index is a potential indicator as to how much coverage a topic receives in a book. A work with a greater number of pages on a subject is intuitively going to have more potential value than one with less. Naturally, this attribute is represented by size in the visualizations. To assist the user in quickly making general comparison between each book, this attribute is further expanded to be a cumulative page total of the term along with its sub-terms.

The number of occurrences and content density are related through a color code. This is intended to give the user a better understanding of the comparative value of each term being displayed. Term occurrence within the book is related by the green component. Although one work may have more information referenced in a single index entry for a topic, that does not necessarily make it the better choice. If another book contained references of a particular term in many different locations within the index, that may be an indication of a greater breadth or complexity of coverage on that topic. The number of term occurrences are normalized across the display, with the instances of greatest coverage mapping to the highest green intensity, and the one with the fewest having no green intensity.

Although two books may have the same total of pages for a particular topic, this should not be taken to mean they have equal value. Consider the situation in which one index allocates ten pages for a topic, but they are separate and not listed as a single range of pages. Another index containing the same topic, but listed as a single range of ten pages, such as 152-161 may be more valuable to the user. The first may have fragmented references of the topic, but no detailed coverage, whereas the second may have a full section or chapter dedicated to the subject. To relate this information to the user, the content density is mapped to the blue color component. The value is given by calculating the ratio of page continuity to the total number of pages for a term. This is shown by equation 1, where C_{ib} is the blue intensity for term i, $\sum_{j=0}^{n} P_j^c$ is the number of individual page ranges for i, T_i is the total number of pages for the term i, and I_{max} is the brightest intensity of blue possible on the machine. This gives terms with more concentrated information a stronger representation in the visualization.

$$C_{ib} = \left(1 - \left(\frac{\sum_{j=0}^{n} P_j^c}{T_i}\right)\right) * I_{max} \tag{1}$$

The last attribute represents the relationship between a sub-term and its parent. Similar to the previous attribute, a sub-term which is located close to its parent within the book could be an indication of cohesive coverage of the topic. A user may regard such a case with more value than one where the sub-term is more removed from the parent's location. The value of this attribute is calculated by equation 2.

$$D_j = ABS\left(\frac{NORM\left(\sum_{k=0}^{n} (P_j^k - \overline{Root_i})\right)}{N}\right) \tag{2}$$

D_j is a normalized distance between the root node and associated sub-node j; P_j^k is the page number contains sub-term j; $\overline{Root_i}$ is the mean page number having the root word i; and *NORM* and *ABS* are a normalization and absolute function respectively.

3.2.2 Visualizations

The two visualizations share several aspects, in addition to the attributes described previously. Each displays the matching term of the search prominently in the center, with the sub-terms radiating outward. Since each term is sized based on the cumulative page count of itself and sub-terms, the root node will give users a quick guidance as to which book has more content. Additionally, each graph has a context side-bar that indicates which term is currently moused-over, along with a histogram displaying its color components. The similarities end here for the two visualizations.
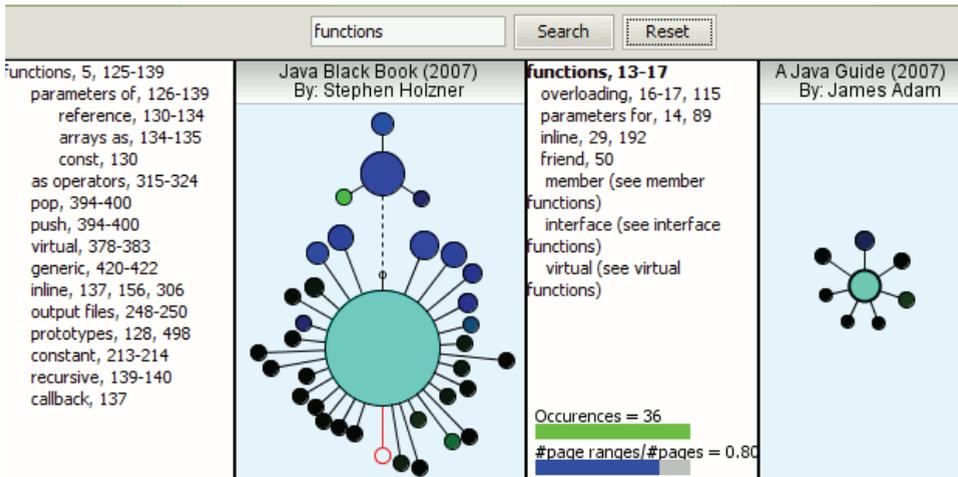

Fig. 2. Diagram shows two books being compared in the Detail View. The left shows expanded sub-terms and an overflow node. The right has context highlighting of text list (bold-face font) and bar display from user interaction

The first visualization approach employs a radial graph layout; with each term presented as a circular node branching off the parent. Sub-terms are sized in the same way as the root, with node size directly correlated to the total number of pages. The largest sub-terms start from the top toward the bottom of the visualization. This is done to prevent over-crowding of the display. Terms with the fewest pages are considered less important, and are collapsed into a single node, indicated by a red outline, if not enough space is available. Another way in which space is conserved is by displaying only the first level of sub-terms. A node with hidden sub-terms has a ridged outline. These along with the red 'overflow' node can be clicked show the hidden terms (figure 2).

In contrast, the second visualization follows a sunburst-like design. Sub-terms are displayed in concentric sections around the center, extending from their parent term. Each sub-term 'slice' is sized as a percentage of its page allocation from the parent's. This has the benefit that all terms can be displayed compactly without hiding any. No additional user interaction would be required to explore the full term hierarchy. One potential downside of this design, compared to the previous one, is that terms are crowded together. This may cause difficulty in picking them out from their neighbors.
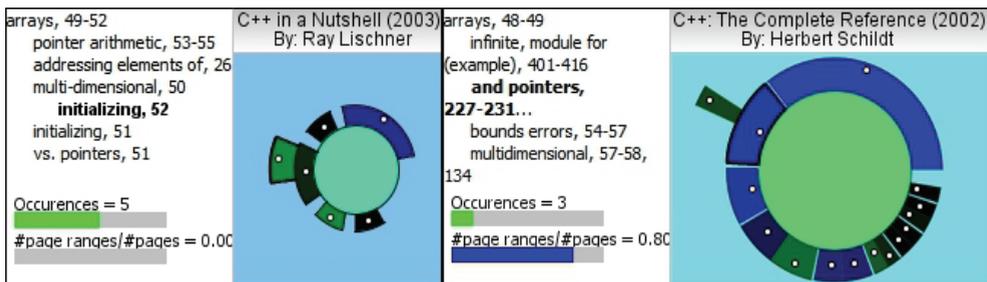

Fig. 3. Alternate sunburst detailed view

In the radial graph, the relation between a sub-term and its parent is indicated by the branch length. Terms which appear on pages near those of the parent naturally are drawn with shorter branches. Since the sunburst approach has forgone branches to conserve space, a different analogue is required. Each slice instead contains a bubble, which will relate this information (figure 3). As the closeness to parent is normalized, the term with the closest relationship has a bubble at the base of the slice, while the term with the most distant has a bubble on the outer edge of its slice.

As was previously noted, the chief difference between the two visualizations is their concern for space conservation. With its emphasis on the term relation branch, and distinct nodes, the radial graph may have more clarity, but at the cost of poorer space utilization. This results in the need to hide terms considered less important. The other visualization puts more value in making better use of space, and is able to display all terms efficiently. However, when many terms are displayed at once, the resultant crowding could make smaller slices difficult to see. The addition of the bubble overlay to each slice can add to this difficulty.

4. Experiment

To measure the effectiveness of VIDLS, a series of usability tests were performed to compare it to more traditional text-based interfaces. In this set of experiments the VIDLS system, using the radial graph detailed layout, was used in conjunction with a text-only interface for the same information.

Each usability test consisted of a small group of three to five students, comfortable in the use of computers, whom had no prior experience with VIDLS. Each group was given a brief orientation presentation, and then allowed to acclimate to the functionality of both applications for a few minutes. The tests then began, with each user asked to search for books and information with the text-only application and then with the visualization based approach. Once the test concluded, participants then filled out a survey to measure their quantitative and qualitative feedback of VIDLS in comparison to the text-based format.

The questionnaire has 14 questions which utilize a 5 point Likert scale; 5 indicating the highest level of satisfaction, and 1 the lowest. Table 1 shows the survey results that summarizes the user's feedback to VIDLS over a text-based library search system. Participants overall found the VIDLS system to be satisfactory, with some comments highlighting that unfamiliarity with the visualizations led to preference of the text-based design.

The Overview visualization was well received, with 82% of testers responding that it improved their ability to quickly identify desirable books. This was supported through the exploratory aspects of the system, which participants indicated positively as giving meaningful result displays, and facilitating better understanding of the information.

The radial graph visualization of index level information was also seen in a positive light, as 65% found it to be a useful representation, and only 11% preferring the familiar text-only listing of results. As with the Overview, testers considered the Detail View to also be useful in expressing the concentration of information, and improving selection among the results. Table 1 shows a summary of survey results.

Question	Pos.	Neut.	Neg.
VIDLS overall was preferable to a text-based search	53%	35%	12%
The Overview improved identification of desirable books	82%	6%	12%
Use of the selectable axis facilitated a better understanding of a set of books.	71%	24%	5%
The Overview helped in selecting a subset of books.	65%	29%	6%
It was easy to discern book attributes based on node color	53%	18%	29%
The Detailed view was preferable to a text approach	65%	24%	11%
It was easy to discern term attributes based on node color	47%	24%	29%
The Detail view made relevant book selection easier	88%	12%	0%
The relation between a term and it's child was understandable	65%	35%	0%
The Detail view helped identify terms related to the search	94%	6%	0%

Table 1. Post experiment survey results

5. Discussion and future work

Overall, feedback was positive toward the VIDLS system. Users indicated it was a helpful and effective alternative to more traditional search utilities. Among the responses, familiarity with text-based result displays was a common explanation for favoring it over a new approach. It is promising that the majority of participants still showed preference for the visualized prototype.

One of the chief strengths of VIDLS highlighted by the usability tests is its exploratory nature. The customization afforded by the selectable axes in the overview, and the interactive nature of the detailed view greatly enhanced users search activity. Many felt that their understanding of the information was improved by these traits. This aspect of the system is also important, in that it may help lead users to other terminology related to their goal, but exempt from their initial search vocabulary.

Although most were comfortable with it, the color-coded attributes proved to be the main area of difficulty for users. The primary issue highlighted by the experiment is user difficulty with interpreting the color codes of both views. Although around half in both instances were comfortable with this aspect of the system, around 30% had trouble with it. The post-experiment interviews provided two main causes for the diverging opinions. First, the RBG color model was not familiar to some. These users cited heavy exposure to the RYB (primary color pigments) model as being a source of confusion when interpreting the displays. The increased unfamiliarity left those individuals feeling more comfortable using a text-based search.

The other difficulty reported by users was in determining the relative value of one result with another. This could be, in part, a result of the human eye being more sensitive to some colors rather than others. For example, green-yellow colors have the strongest reception, which could mislead a user into considering a result with this color to have more overall value than another when that may not be the case (Foley et al., 1996). Researching and examining alternate color models will be one of the challenging task for future work on the VIDLS system.

While users found the graph approach to be effective, it has plenty of room for improvement. The issue of overlapping prevents showing all information at once. If possible, it would be preferable to avoid that situation, as it may reduce the effectiveness of the visualization. As stated earlier, the layout does give the graph design more clarity and makes it easy to pick out individual items; however some users found it difficult to compare two nodes which aren't adjacent to each other.

The sunburst layout could improve upon these points. The compact design greatly reduces the need to hide information for typical indexes without extensive hierarchies. It may also cut down on unnecessary competing visual information created by the empty space seen in the graph layout. Another possibility is that the slice shape of sub-term nodes is more distinct, and may afford more visual context when making comparisons.

Though small in size, the experiment supported the viability of VIDLS as a search utility. Still, larger experiments will need to be planned in order to better understand how the prototype compares against existing search methodologies. Testing will also need to be done to confirm how the sunburst and radial visualizations differ in effectiveness. These will be key topics as future work on VIDLS continues.

Other areas for future work include investigating content analysis. Although indexes proved to be a useful foundation for visualization, these are limited to books. Other media lack such precompiled information. VIDLS would need to integrate methods to examine document content in order to extract the information it presents. This is a very ambitious topic, but could expose additional attributes for expressing to the user, as well as allowing for a more universal application of the system. Similarly, enhancing VIDLS to have thesaurus-like capability to identify similar topics would be another valuable addition. Grouping such items together would further improve a users understanding of which work has more comprehensive coverage on a topic.

6. Conclusion

The emergence of the Digital Library provides an interesting dichotomy: effortless access to a large compilation of data, but increased challenges in finding a few specific works of interest. Having effective mechanisms for exploring this space is both an important and also demanding research topic. Information visualization can be one possible solution in addressing these difficulties presented by digital library systems. This chapter surveyed existing approaches, applying a range of visualization techniques for querying information in the digital library system with a focus toward books. The developed interfaces presents multiple attributes associated with books through visual icons on a table. This simple graphical illustration assists the user to compare and contrast search results intuitively. The chapter also introduces a novel method that utilizes book indexes for enhancing searches. The exploitation of indexes will further enhance search activities, making them more efficient and effective. The conducted survey-based usability tests that compared the proposed system over traditional text-based approaches showed the efficacy of the visual interfaces as a search supporting tool on digital libraries. This chapter concludes with the belief that visualizations will be a promising approach to address current issues in the digital library system suffering from the complexity and volume of its sources.

7. References

Abbasi, A. & Chen, H. (2007). Categorization and Analysis of Text in Computer Mediated Communication Archives Using Visualization, *Proceedings of the 7th ACM/IEEE-CS Joint Conference on Digital Libraries*, pp.11-18

Ahlberg, C. & Shneiderman, B. (1994). Visual information seeking using the FilmFinder, *Proceedings of the ACM Conference on Human Factors in Computing Systems*, pp.433-434

Allen, R. (1990). User Models: Theory, Method, and Practice, *International Journal of Man-Machine Studies,* Vol. 32, pp. 511-543

Au, P.; Cary, M.; Sewraz, S.; Guo, Y. & Rüger, S. (2000). New Paradigms in Information Visualization, *Proceedings of the 23rd Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*, pp. 307-309

Baudich, P.; Good, N.; Bellotti, V. & Schraedley, P. (2002). Keeping Things in Context: A Comparative Evaluation of Focus Plus Context Screens, Overviews and Zooming, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems,* pp. 259-266

Bederson, B.; Shneiderman, B. & Wattenberg, M. (2002). Ordered and Quantum Treemaps: Making Effective Use of 2D Space to Display Hierarchies, *ACM Transactions on Graphics*, Vol. 21, No. 4, pp. 833-854

Bertini, E.; Catarci, T.; Di Bello, L. & Kimani, S. (2005). Visualization in Digital Libraries, *Lecture Notes in Computer Science*, Vol. 3379, pp. 183-169, Springer-Verlag, Berlin

Borner, K. & Chen, C. (2002). Visual Interfaces to Digital Libraries: Motivation, Utilization, and Socio-technical Challenges, *Lectures Notes in Computer Science*, Vol. 2539, pp. 1-9 Springer-Verlag, Berlin Heidelberg New York

Card, S.; Mackinlay, J. & Shneiderman, B. (1999). *Readings in Information Visualization Using Vision to Think*, Morgan Kaufman

Chen, C. (1999). Visualizing Semantic Spaces and Author Co-citation Networks in Digital Libraries, *Information Processing and Management: an International Journal,* Vol. 35, No. 3, pp. 401-420

Christel, M. & Martin, D (1998). Information Visualization Within a Digital Video Library, *Journal of Intelligent Information Systems*, Vol. 11, No. 3, pp. 235-257

Clarkson, E.; Desai, K. & Foley, J. (2009). ResultMaps: Visualization for Search Interfaces, *IEEE Transactions on Visualization and Computer Graphics,* Vol. 15, No. 6, pp. 1057-1064

Dushay, N. (2004). Visualizing Bibliographic Metadata - A Virtual (Book) Spine Viewer. *D-Lib Magazine*, Vol.10, No. 10

Good, L.; Popat, A.; Janssen, W. & Bier, E. (2005). Fluid Interface for Personal Digital Libraries, *Proceedings of the 9th European Conference on Research and Advanced Technology for Digital Libraries*, pp. 162-173

Hawkins, D. (1999). Information Visualization: Don't Tell Me, Show Me!, *Online*, Vol. 23, No. 1, pp. 88-90

Hearst, M.A. (1995). Tilebars: Visualization of term distribution information in full text information access. *Proceedings of the ACM Conference on Human Factors in Computing Systems*, pp. 59-66

Kampanya, N.; Shen, R.; Kim, S.; North, C. & Fox, E. (2004). Citiviz: A Visual User Interface to the CITIDEL System, *Lecture Notes in Computer Science*, Vol. 3232, pp. 122-133, Springer-Verlag, Berlin

Kim, B.; Johnson, P. & Huarng, A. (2002). Colored-sketch of Text Information, *Journal of Informing Science*, Vol. 5, No. 4, pp. 163-173

Kim, B. (2004). Visual Interface for Evaluating Internet Search Results, *Lecture Notes in Computer Science*, Vol. 2973, pp. 533-542, Springer-Verlag, Berlin

Lamping, J.; Rao, R. & Pirolli, P. (1995). A Focus+Context Technique Based on Hyperbolic Geometry for Visualizing Large Hierarchies, *Proceedings of the ACM Conference on Human Factors in Computing Systems*, pp. 401-408

Lin, X (1996). Graphical Table of Contents, *Proceedings of the 1st ACM International Conference on Digital Libraries*, pp.45-53

Marks, L.; Hussel, J.; McMahon, T. & Luce, R. (1996). ActiveGraph: A Digital Library Visualization Tool, *International Journal on Digital Libraries*, Vol. 5, No. 1, pp. 57-69

Nowell, L.; France, R.; Hix, D.; Heath, L. & Fox, E. (1996). Visualizing Search Results: Some Alternatives to Query-Document Similarity, *Proceedings of the 19th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*, pp. 67-75

Nowell, L.; France, R. & Hix, D. (1997). Exploring Search Results with Envision, *Proceedings of the ACM SIGCHI*, pp. 14-15

Resnick, P.; Iacovou, N.; Suchak, M.; Bergstrom, P. & Riedl, J. (1994). GroupLens: An Open Architecture for Collaborative Filtering of Netnews, *Proceedings of the ACM Conference on Computer Supported Cooperative Work,* pp. 175-186

Shen, R.; Vemuri, N.; Fan, W.; Torres, R. & Fox, E. (2006). Exploring Digital Libraries: Integrating Browsing, Searching, and Visualization, *Proceedings of the 6th ACM/IEEE-CS Joint Conference on Digital Libraries*, pp. 1-10

Shiaw, H.; Jacob, R. & Crane, G. (2004). The 3D Vase Museum: A New Approach to Context in a Digital Library, *Proceedings of the 4th ACM/IEEE-CS Joint Conference on Digital Libraries*, pp. 125-134

Shneiderman, B (1996). The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations, *Proceedings of the IEEE Symposium on Visual Languages,* pp.336-343

Shneiderman, B.; Feldman, D.; Rose, A. & Grau, X. (2000). Visualizing Digital Library Search Results with Categorical and Hierarchical Axes, *Proceedings of the 5th ACM Conference on Digital Libraries*, pp. 57-66

Silva, N.; Sánchez, A.; Proal, C. & Redbollar, C. (2003). Visual Exploration of Large Collections in Digital Libraries, *Proceedings of the Latin American Conference on Human-Computer Interaction*, pp.147-157

Stasko, J.; Catrambone, R.; Guzdial, M. & McDonald, K. (2000). An Evaluation of Space-Filling Information Visualizations for Depicting Hierarchical Structures, *International Journal of Human-Computer Studies,* Vol. 53, No. 5, pp. 663-694

Foley, J.; Van Dam, A.; Feiner, S. & Hughes, J. (1996) *Computer Graphics: Principles and Practice*, 2nd ed. Addison-Wesley Publishing Company

Veerasamy, A. & Heikes, R. (1997). Effectiveness of a Graphical Display of Retrieval Results, *Proceedings of the 20th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*, pp. 236-245

Williamson, C. & Shneiderman, B. (1992). The dynamic HomeFinder: evaluating dynamic queries in a real-estate information exploration system, *Proceedings of the 15th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*, pp. 338-346

Wiza, W.; Walczak, K. & Cellary, W. (2004). Periscope: A System for Adaptive 3D
     Visualization of Search Results, *Proceedings of the ninth international conference on 3D
     Web technology, pp. 29-40*