# eBook meets Tabletop: Using Collaborative Visualization for Search and Serendipity in On-line Book Repositories


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## ABSTRACT

The ever-growing amount of digitized books and electronically published documents necessitates proper tools to search and explore such large digital information spaces. This paper presents the design of an interactive prototype for collaborative visual information seeking (VIS) in an on-line book repository. The main objectives of the prototype are a visual metaphor to query an on-line book repository and the facilitation of back-and-forth comparison of search results. Furthermore, an integrated cosine similarity search encourages for serendipitous discoveries while browsing through an information space.



## Categories and Subject Descriptors

H.3.3 [**Information Search and Retrieval**]: Search process

## Keywords

visual information seeking, serendipity, similarity search, scatter plot, multi-touch, tangible interaction, large database


## 1. INTRODUCTION

In recent years books are published electronically in addition to their physical counterparts. The ever-growing amount of eBooks and other digitized documents offer great potential for various profit or non-profit organizations (e.g., online bookstores or libraries). Despite the fact that eBooks empower digital functions such as searching or copy-and-paste as opposed to physical books, they lack implicit information. For instance, the evidence of loan frequency or usage can be seen easily on a physical book from the condition of its spine. Moreover such properties as, the book type, the amount of pages, or page size are not materialized or visually observable by a user. The libViewer [9] tries to compensate for those visual parameters by providing a user interface that implements a bookshelf metaphor.

Open Access Libraries such as the Library of the University of Konstanz organize books in a systematic order so that the spatial location of related books is the same. This enables users to make serendipitous discoveries such as finding additional relevant literature just by browsing the shelf. On the other hand, traditional Online Public Access Catalogue (OPAC) systems allow information seekers to efficiently query large digital libraries for relevant literature using terms such as keywords, book titles, or authors. This is sufficient if one knows what exactly to query for but will not work if vague terms are used for query formulation.



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Modern OPACs such as SerialSolutions' The Summon™ Service[1] provide supplementary facetted browsing facades to consecutively explore and browse through the subjacent information space. As output to the user, most systems provide a relevance-ranked one-dimensional result list, which can be manually analyzed by an information seeker. Although these OPACs are very powerful, they lack any instruments to compare not only the final search results but also different stages of a search, e.g., when a user progresses in query formulation and wants to compare two or more result sets while maintaining previous and current query formulations. In addition, a comparison of different result sets could be very beneficial especially to see if information items drop out when using too specific query terms or to see in what characteristics information items differ and in what characteristics information items are similar.

**Figure 1: The setting of the VIS system consists of a horizontal display for query formulation and a vertical display for data exploration. Digital pen and paper is used for keyword input.**

Furthermore, single point query formulation limits users in creating different search branches. Thus, applying different search strategies in parallel is particularly important in settings where multiple users work together on a common goal. Since tabletop and tangible interaction offer great support for co-located and collaborative activities such as travel planning [6], decision making, or purchasing products, we believe that interactive tabletops can also be used for collaborative exploration of on-line book repositories, especially for counseling interviews in book retail stores or libraries.

In this paper we describe a system for collaborative search and serendipitous discoveries in an on-line book repository using a post-WIMP user interface based on touch and tangible interaction (see Video[2]). It supports multi-user interaction that encourages information seekers to use well-known social protocols to communicate their search interests and to discuss search strategies among coworkers. Beyond that, the system offers a facility for

[1] http://www.serialssolutions.com/en/services/summon/

[2] http://youtu.be/2IKAoa6BIOw

serendipitous discoveries by seamlessly providing further related books to the user. The hardware setting of the system consists of two Samsung SUR40 with Microsoft® PixelSense™ (see Figure 1). The horizontal display is used for query formulation and the vertical wall-mounted display is used for data exploration.

## 2. SYSTEM DESIGN

To inform our project we conducted a study, which based on a questionnaire that was prompted to students and researchers from the University of Konstanz. The questionnaire was available online for 8 weeks (57 days) asking for common tasks in physical as well as digital libraries (e.g. *What tools do you use for literature search?*). At the end of the questionnaire participants could comment on existing systems and propose ideas to fulfill their current needs and requirements beyond the scope of tools they use. The total of 682 persons replied to the online questionnaire (599 students, 83 academic researchers) whereas our control sample reached 5.48% compared to the number of enrolled students at the University.

In the later analysis of the open questions we clustered similar needs and requirements and as an initial guideline, we took the two most promising clusters as input for designing a visual information seeking (VIS) system, which are:

- **Recommender System and Serendipity:** Provide additional recommendations and related literature while searching or browsing for results.
- **Data exploration:** Provide meaningful visualizations to compare results of different search queries and show relations between the result items.

Based on the user feedback of the two clusters we, then, deduced the three different design goals *Visual Query Formulation*, *Search Result Comparison*, and *Similarity Search* as important elements of a VIS system and used these as input for the design of an interactive prototype. The design goals are described in the following subsections.

### 2.1 Visual Query Formulation

Most users are familiar with traditional query composition interfaces such as Google's search mask displaying a single search field where one or multiple keywords are entered successively to formulate a query. Those keywords express search terms that are connected automatically by Boolean AND operator except when other logical operators are entered explicitly (e.g. negating a search term by a prefixed minus character). Those expressions need to be known in advance or learned as otherwise queries will just presume Boolean AND operators.

Traditional search interfaces, especially browser-based search, do not optimally support collaborative information seeking. Recent work shows, however, that there is great potential for systems that support collaborative and visual information seeking [2, 5–7]. Jetter et al. [6] developed a visual "pipe-and-filter" metaphor for faceted-browsing through a dataset of hotels. Although they use it intentionally for faceted-browsing, it seems very promising to apply a similar visual metaphor also for the formulation of keyword search queries. Such a query formulation on an interactive tabletop enables both loosely-coupled parallel work as well as tightly-coupled collaboration (see Figure 2).

With our approach, users can phrase search requests by writing keywords on paper strips using digital pen & paper technology and aligning them in the query network according to the "pipe-and-filter" metaphor. The system transforms the digital pen strokes to machine readable characters and, if such a paper strip is placed on the tabletop surface, it queries automatically for authors, titles, abstracts, and full-texts that contain the specified keyword. A simple menu is visualized next to the paper strip so the user can select or deselect an item to search more or less specifically.

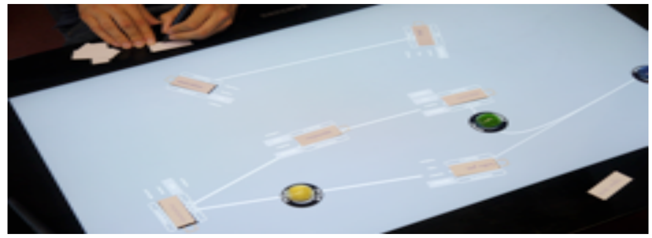

**Figure 2: A view of a query network that contains different search branches and the three result tokens put on different edges on the network (yellow, green, and blue).**

A feature of the materialized keywords is that a paper strip can either be placed on to the interactive surface of the tabletop to query the on-line book repository with a keyword or put aside on the rim of the tabletop to store a keyword for later usage. The latter enables a seamless undo or redo of a query formulation since the user can switch back-and-forth between the different search stages. Moreover, a written keyword can be handed over to a coworker to instruct for a specific search strategy. Multiple keywords can be concatenated by edges using the "pipe-and-filter" metaphor. The arrow on an end of an edge indicates the flow direction. This way, Boolean AND can be visually expressed. In contrast to [6], we changed the behavior for the Boolean OR operator since the system is designed for back-and-forth comparison of search results and not for consensus finding. A Boolean OR operator is applied on keywords with multiple incoming edges.

Aside from the visual metaphor and since a tabletop is used for query formulation, users can learn search strategies from coworkers and immediately apply them to their current search.

### 2.2 Search Result Comparison

The comparison of multiple search results can be very beneficial particularly in a collaborative setting where multiple users initial search independently and then want to compare for equality or differences in the search results. For instance, visualizing the complement of two search branches to check for keywords that are contained just in one of the two result sets. The gained information can be applied to a different branch of the ongoing search.

Current collaborative and VIS systems focus on co-located and parallel search and do not provide any computer-supported facilities to compare different result sets. To compare multiple results on traditional desktop computers, multiple browser tabs or windows are needed to execute multiple queries in order to compare the result sets of different queries. The evaluation of relationships needs to be done manually by the user in a sequential order comparing the various result lists.

In our system, the result visualization is shown on an additional vertical display to avoid mode switches and allow continuous reformulation and refinement of search queries. Separated views provide awareness to coworkers as for the materialized branches of search, taken search strategies and the intermediate and final query results. Furthermore, the text on the vertical display can be read more easily by all coworkers compared to a horizontal display. To show the result on the vertical display, a user puts a colored result token (yellow, green, blue) on an edge of the query network (see Figure 2). This triggers the corresponding query to the database and updates the visualization on the vertical display accordingly. The system allows putting result tokens on multiple edges of the query network. Since each result token has a unique color, the corresponding data items in the visualization are also in the token color highlighted (see Figure 3). If an item occurs in multiple results, it will be visualized according to the 7 glyphs of Figure 3 on the bottom (e.g., a blue/green glyph if an item occurs in both the blue and the green token result set).

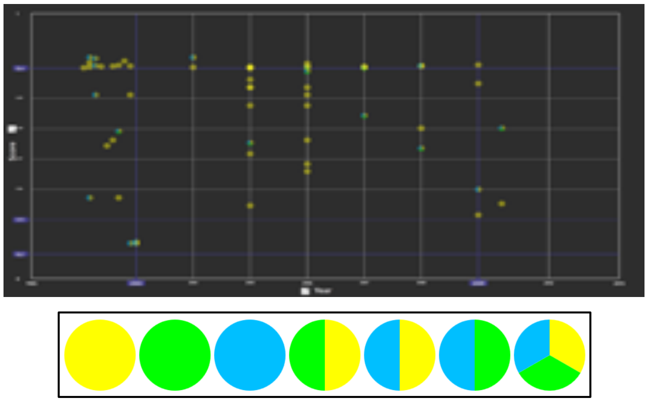

**Figure 3: The 2-dimensional scatter plot (top) visualizes data items of multiple search branches. Each item is encoded in one of the 7 glyphs (bottom) according to the result containment.**

Ahlberg and Shneiderman argue that color coding combined with proximity coding "[…] enable users to explore large information spaces rapidly and reliably" [1]. Therefore, a 2-dimensional scatter plot is used to visualize the data. Visual clutter that can occur when displaying a large amount of data can be reduced by the user using multi-touch interaction similar to the concepts proposed by Heilig et al. [3].

Moreover, the visualization conforms to the VIS Mantra "Overview first, zoom and filter, then details-on-demand" by Shneiderman. Thus, the information items are displayed as small points indicating two values (x- and y-coordinate) at the first sight to minimize visual clutter. Then, a user can straighten out interesting regions of the scatter plot to get more details about the axis values and to reduce overlap. If a specific data item comes to the interest of a user, a finger tap animates to the detail view (semantic zooming) showing information such as the title, authors, abstract, and similar articles in an additional 2-dimensional scatter plot.

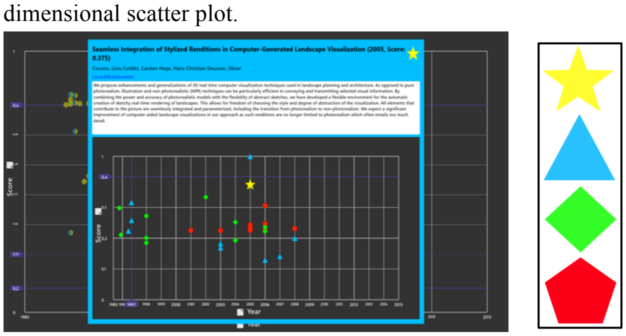

**Figure 4: A detail view of an information item displays the title, authors, abstract and similar documents in an additional 2-dimensional interactive scatter plot (left). The relations are encoded in 4 glyphs (right).**

## 2.3 Similarity Search

The search for appropriate material in on-line book repositories is mostly triggered by a limited set of search terms. Users seeking for useful and valuable material use their previous knowledge to formulate search terms and run queries against the digital archives and library catalogs. This practice leads to a limited set of results returned to the users. For example, a search for a specific term mostly returns material that contains the term in the title, abstract or full-text. Additionally to the simple search approach, we extended our system to display documents related to the documents in the result set in order to encourage for serendipitous discoveries [11]. The relationship between documents is calculated on the basis of the three elements, namely the author, the title and the abstract. This information is displayed in an additional 2-dimensional scatter plot (see Figure 4). Relations are encoded as follows:

- **Yellow Star** = **self-reference** (not calculated)
- **Blue Triangle** = **author relation**
- **Green Diamond** = **title relation**
- **Red Pentagon** = **abstract relation**

We calculate the cosine similarity of all pairs of documents by these three factors. The user is able to see the documents, related based on the similarity measure in the content of the author, title or abstract field. Hereby we support the results found by chance that would probably never be found by entering keywords into the query interface.

# 3. SYSTEM IMPLEMENTATION

The interactive prototype is implemented in C#/WPF with the Microsoft .NET 4.0 Framework and the Microsoft Surface 2.0 SDK[3]. We use BaseX[4] as data backend for the VIS system since XML offers a solid base for semi-structured data. For the keyword input we printed a unique dot pattern (Anoto[5]) on the front and a unique optical marker (Microsoft Byte Tag) on the back of each physical paper strip (2.4 x 1.0 inch). Our software connects the dot pattern and the Byte Tag and uses the Windows 7 SDK to transform pen strokes into machine readable characters, which are then assigned to the corresponding Byte Tag virtually.

The following subsections give insights into the data source used to showcase the prototype, benchmarks indicating the performance of the data backend, and the implemented communication framework that was used to connect the two interactive surfaces.

## 3.1 Data Source

The dataset used for this work contains more than seven thousand digitally available documents such as books, publications, or theses. Each document consists of the meta-data elements *title*, *authors*, *publication year*, and *language* and content elements *abstract* and *full-text*. The full-text is extracted from the PDF documents and is also structured as XML hierarchy to maintain the structure of the original document. In addition to these elements we analyzed the content of the titles, authors, and abstracts to calculate the cosine similarity between all pairs of documents contained in the database. We added new elements with the Top One Hundred related documents for title, authors and abstract to the corresponding document entry. With this additional meta-data we are able to recommend related works in three categories (title, authors, abstract) to the users. To support an easier and faster evaluation of the results, which may be represented in large numbers, we additionally add scoring values for the hits to the result set. This enrichment is done on-the-fly by using the internal advanced scoring model of BaseX. Hereby we

[3] http://www.microsoft.com/en-us/download/details.aspx?id=26716

[4] http://www.basex.org

[5] http://www.anoto.com/

calculate a score, which reflects the importance of single documents in contrast to other documents in the result set.

## 3.2 Real-time Result Feedback

It is a mandatory requirement for a query interface, which supports parallel and collaborative searches on a multi-touch surface, to deliver results in a real-time or near real-time manner.

In order to guarantee this requirement we tested the performance of the underlying database system and query processor with some default search queries. For our test cases we used BaseX 7.3 and a 64-bit Windows 7 operating system running on an Intel Core i7 processor with 3.40 GHz and 16 GB RAM installed. The following table contains results of a preliminary benchmark:

| Query | Time | Results |
|---|---|---|
| //Title contains text “human” | 90.52 ms | 123 Hits |
| //Abstract contains text “methods” | 109.36 ms | 415 Hits |
| //Fulltext contains text “index” | 210.44 ms | 1676 Hits |
| //Fulltext contains text “methods” and //Title contains text “gene” | 159.79 ms | 31 Hits |
| //Abstract contains text “methods” or //Title contains text differential” | 135.54 ms | 440 Hits |

**Table 1: Results of preliminary performance tests.**

## 3.3 Communication Framework

With the usage of a database as the central component in our system, we also introduced a communication framework, which supports the direct execution of queries for each query token in the query network and the synchronization of various clients (e.g. large vertical display, tablet, or smartphone).

The synchronization of clients is realized by using an event mechanism, which sends notifications to the registered clients. If a client activates a defined event, all of the clients registered for that event get notified and receive the results of the event definition. In our use case, all result tokens are able to activate events in the database and the 2-dimensional scatter plot visualization is listening for incoming results. If a result token fires an event the scatter plot receives the result and displays it on the screen. This could also be used in the opposite direction or to synchronize results with further devices connected to the database.

# 4. CONCLUSION

We identified needs and requirements for literature search gained from an initial questionnaire that was prompted to students and academic researchers. The most promising needs and requirements led to the three design goals *Visual Query Formulation*, *Search Result Comparison*, and *Similarity Search*, which were used to implement an interactive prototype that enables for back-and-forth comparisons of search results and encourages serendipitous discoveries by providing additional results based on a pre-calculated cosine similarity measure.

# 5. FUTURE WORK

The integration of serendipity at certain stages of a VIS process can be very beneficial to the user. For instance, related keywords such as synonyms, hyponyms, or hypernyms pop up visually while placing a keyword on the interactive surface that could help to refine or enlarge a query result. Another possible integration of serendipity could be a function that recommends eBooks in the following manner “users read this eBook also read this eBooks”.

The use of keywords for the exploration of the subjacent information space is aggravated since the user needs to know matching keywords in advance. Therefore, a combination of attribute-based browsing [6] and keyword-based search could help to improve a seamless transition between searching and exploration.

As mentioned previously, the communication framework enables connections between multiple devices. Thus, it will be possible to transfer the desired eBooks to a tablet, a pad, or an eBook reader so a user can obtain it and read and annotate the document in a more comfortable way (e.g. in a nice armchair [10]).

Since the system was designed on the basis of related work and an informal questionnaire, we plan an exploratory study to investigate whether users understand the visual query formulation metaphor and how different search results can be compared.

# 6. ACKNOWLEDGMENTS

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