The Bohemian Bookshelf: Supporting Serendipitous Book Discoveries through Information Visualization

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ABSTRACT

Serendipity, a trigger of exciting yet unexpected discoveries, is an important but comparatively neglected factor in information seeking, research, and ideation. We suggest that serendipity can be facilitated through visualization. To explore this, we introduce the Bohemian Bookshelf, which aims to support serendipitous discoveries in the context of digital book collections. The Bohemian Bookshelf consists of five interlinked visualizations each offering a unique overview of the collection. It aims at encouraging serendipity by (1) offering multiple visual access points to the collection, (2) highlighting adjacencies between books, (3) providing flexible visual pathways for exploring the collection, (4) enticing curiosity through abstract, metaphorical, and visually distinct representations of books, and (5) enabling a playful approach to information exploration. A deployment at a library revealed that visitors embraced this approach of utilizing visualization to support open-ended explorations and serendipitous discoveries. This encourages future explorations into promoting serendipity through information visualization.

Author Keywords

Information Visualization; Serendipity; Library Interfaces.

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation: Miscellaneous

General Terms

Design.

INTRODUCTION

Information exploration is part of our everyday life. We all, on a day-to-day basis, search through and encounter volumes of information, whether that is via the web, in our music collections, or through increasingly common digital libraries. However, interfaces to this information tend to be modelled to perform targeted searches. This raises concerns over the possible loss of unexpected, yet valuable, discoveries that can be attributed to serendipity [13, 14, 39, 46, 50]. In this paper we discuss information visualization as a means to support serendipitous discoveries in digital data collections. As a case study we introduce the Bohemian Bookshelf, in which we have designed visualizations to support serendipitous book discoveries in digital library collections.

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Consider this simple scenario. Lucy has planned a summer vacation and wants to enrich her time at the beach with a relaxing read. However, since her local library has a large digital book collection and only few physical books on display, Lucy is faced with typical search engines that require specific input of keywords; a problematic starting point when she does not know what exactly she wants. Staring at the blinking cursor in an empty search field, she longs for the more traditional physical bookshelves where she could have just browsed casually through books. With the Bohemian Bookshelf, our intention was to create a digital parallel to the open-ended "browsing the shelves" experience that has been shown to encourage serendipitous discoveries [14, 19, 30, 46].

The Bohemian Bookshelf consists of five interlinked visualizations that each provide a unique perspective on the book collection based on attributes such as author names, keywords, cover colour, page count, and time. It is based on five design goals we derived from previous literature on information and library sciences: (1) offering multiple visual access points by providing visualizations of different perspectives on the book collection, (2) highlighting adjacencies between books, (3) providing flexible visual pathways for exploring the book collection, (4) enticing curiosity through abstract, metaphorical, and visually distinct representations of the collection, and (5) enabling a playful approach to information exploration.

The main contribution of this paper is our exploration of how serendipity can be supported through information visualization. As part of this we first introduce the concept of serendipity followed by our five design goals that specifically address visualization as a means to encourage serendipity. Second, we present the Bohemian Bookshelf as one possible implementation of these design goals. Third, we discuss findings from a deployment of the Bohemian Bookshelf at a university library. Our observations and visitor statements indicate that our design goals have largely been met and encourage further explorations into facilitating serendipitous discoveries and open-ended explorations of book collections through information visualization.

THE CONCEPT OF SERENDIPITY

In this section, we introduce the concept of serendipity as it has been defined in the literature from library and information sciences and present a compilation of the influencing factors gathered from this literature.

Defining Serendipity

Horace Walpole coined the term serendipity in 1754 [38, 47] to characterize the discoveries made by The Three Princes of Serendip—the figures of an ancient fairy tale: "*as their*

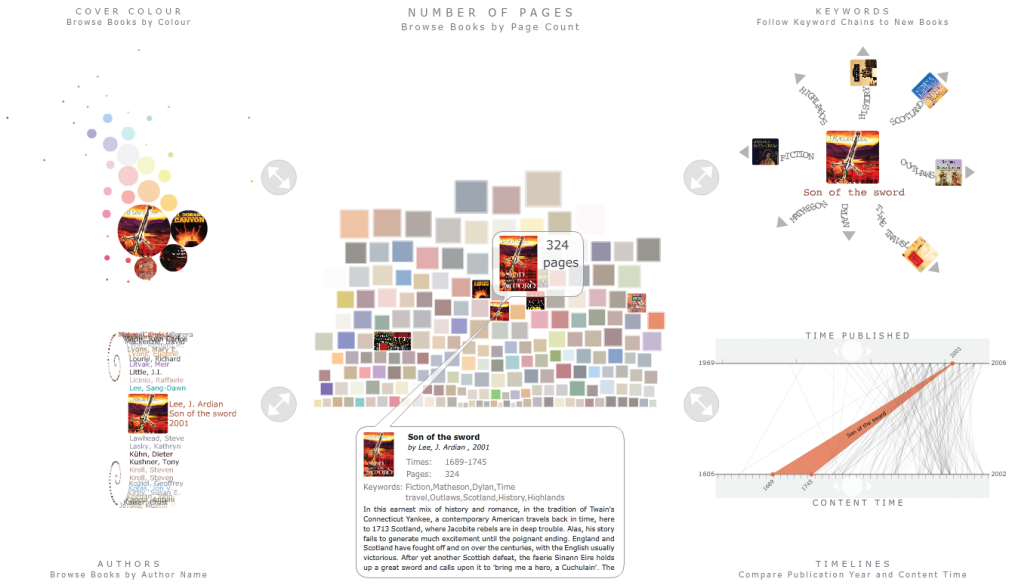

Figure 1. The Bohemian Bookshelf: five interlinked visualizations presenting different perspectives on a book collection.

Highnesses travelled they were always making discoveries, by accidents & sagacity, of things which they were not in quest of" [38, p.20]. Currently, variations of the Oxford English dictionary's definition are commonly used to describe the term serendipity: "*the faculty of making happy and unexpected discoveries by accident*" [36]. This definition, however, highlights the fortuitous and random aspect of serendipity while neglecting the existence of more strategic elements that Walpole has hinted at by mentioning the influence of sagacity on serendipitous discoveries.

Factors Influencing Serendipity

Different factors have been identified in the literature that can favour serendipity beyond its coincidental aspect. Here we tease out these factors to bring to the fore additional aspects of serendipity that can be incorporated into design.

Personality Traits

Serendipitous discoveries can be attributed to an individual's personality, knowledge, and attitudes. Austin coined the term *altamirage* to describe serendipitous discoveries as a result of chance paired with individual traits of the exploring person [2, 30]. Along these lines, Erdelez found that some people, "super-encounterers", are particularly talented in encountering information of interest unexpectedly [13]. These people embrace serendipitous discoveries as part of their life process. Talents or special traits that facilitate serendipity include observational skills [41], curiosity [30], open-mindedness [1, 14, 30, 41, 47], knowledge [1, 30, 41], and perseverance [30].

Observational Skills. Observational skills can favour serendipity. For example, Rosenman emphasized how Flemming's observational skills, acquired during his arts training, contributed to his famous discovery of penicillin, which has been attributed to serendipity [41].

Open-mindedness. Numerous works on serendipity emphasize the importance of an *open* and *prepared* mind [1, 14, 30, 41, 47]. This recognizes that valuable insight from serendipitous discoveries requires receptiveness to unexpected information: "*chance only favours prepared minds*"(Louis Pasteur) [47]. Open-mindedness can manifest itself in curiosity [30], questioning previous assumptions, or deliberately looking at information from various perspectives [30, 41].

Knowledge. Expertise and the ability to make sound judgements, as part of a "prepared mind", also are considered key factors of serendipity in that they enable drawing connections between seemingly unrelated information [1, 30, 41, 46]. Walpole described this as sagacity in his definition of the term serendipity [38]. Without prior knowledge, certain serendipitous discoveries in science would not have been possible. For instance, Flemming's knowledge about bacterial inhibitors helped him to recognize the potential value of the penicillin mould when he observed it for the first time [41].

Perseverance. It has been suggested that perseverant research of a certain topic favours the occurrence of serendipitous discoveries [30]. The more time and effort one invests, the more knowledge one aggregates, which, in turn, facilitates the discovery and recognition of unexpected valuable insights.

Environmental Factors

Besides the personal factors described above, there are some outside factors that can favour serendipity. These factors are independent of the person researching the information.

Coincidence. As previous work points out, serendipity is most commonly discussed in relation to fortuitous, accidental, or coincidental events [1, 14, 30, 47]. This is closely related to the notion of *synchronicity* where related ideas may manifest as simultaneous occurrences that seem acausal but still meaningful [30]. The prevalence of these ideas of chance, fortuity, and coincidence in the discussion around serendipity has led to a tendency to trivialize this complex concept by assuming that serendipity can be supported simply through the introduction of randomness.

Influence of People & Systems. Most information that is explored on an everyday basis has already been classified, organized, or laid out for us by others in advance. This prior categorization by other people, systems, or processes can lead to serendipitous discoveries by making relations explicit [30].

Library books, for instance, are often classified by the Dewey Decimal System [9] which determines how books are grouped on the shelves. It is therefore not only the personal interests, characteristics, or search strategies of a patron that influence what books are being encountered while browsing the library shelves but the system used to organize them.

While the specific impact of each of the factors listed above on serendipity is unknown, it becomes clear that there is more to serendipity than mere chance and coincidence.

DESIGN FOR SERENDIPITY THROUGH VISUALIZATION

The question of how serendipitous book discoveries can be facilitated through information technology is much discussed in library and information sciences [1, 4, 14, 50]. However, while these discussions include recommendations toward visual interfaces [32], presently, this discourse largely consists of rather vague suggestions and theory. We have distilled the general recommendations from the information and library science literature into a concise list that includes an interpretation from an information visualization perspective. The resulting set of visualization design goals can be considered a starting point for promoting serendipity through information visualizations in future case studies.

Multiple Visual Access Points

Rice suggests supporting different access points to digital library catalogues to encourage serendipity [39]. This correlates with the idea of open-mindedness and a person's willingness to "view data from several perspectives" [41]. Fox et al. found that exploring library catalogues from different views appealed to people [15]. Unlike in physical libraries where one book can only be located in a single place, digital collections allow multiple groupings at the same time. Utilizing this characteristic, we suggest providing different *visual* perspectives on a collection to help people conduct explorations from distinct viewpoints, revealing different, maybe unfamiliar or surprising, aspects of a known topic. This could be realized by providing a variety of orthogonal access points to books in form of different overview visualizations.

Highlighting Adjacencies

When browsing through data collections, it is often items in close proximity that draw people's attention and trigger serendipitous discoveries. For instance, people have described finding interesting books unexpectedly when browsing the library shelves in search of a book on an unrelated topic [14, 19, 30]. The juxtaposition of books in traditional libraries both makes their collections searchable and, unintentionally, can lead to serendipitous discoveries [46]. Visualization techniques offer the opportunity of visually highlighting multiple, co-existing alternate adjacencies. For example, books can be adjacent in terms of their genre, topic, or publication year.

Flexible Visual Pathways

Huwe suggests providing multiple pathways through digital book collections to preserve the opportunity for serendipitous discoveries in digital library systems [25]. This recommendation is related to the call for more open-ended navigation strategies. Most search interfaces to digital libraries support targeted search in the form of querying [31, 39, 46]. More open-ended strategies such as *exploratory search* [31, 46, 51], *browsing* [8, 34, 40], or *information encountering* [13] have been recommended as more likely to support serendipity.

It has been suggested that open-ended search strategies may benefit from visual interfaces that allow for flexible, rather than predetermined navigation through data collections as commonly supported by current textual query editors and sequential result lists [31]. Visualizations can offer pathways through digital book collections, as suggested above, by providing multiple interactive overviews as visual guides through the collection and by offering many possible adjacencies that can act as visual signposts suggesting alternative exploration routes. Additional pathways can be indicated by emphasizing cross-visualization attributes by mutual highlighting as in coordinated views [3, 7]. It is important to note that these pathways do not have to be predetermined but can instead offer constantly changing series of crossroads. By enabling options for multiple pathways the support of fluid transitions between visualizations and changing exploration foci becomes important. It is the variety of visual pathways and their flexibility that can serve to enhance serendipity.

Enticing Curiosity

Some serendipitous discoveries have been attributed to curiosity [46, 47]. Similarly, Dörk et al. suggest considering information seeking as a pleasurable, inspiring experience [11]. While curiosity may well be considered as part of a person's personality, there are factors such as visual aesthetics and animation that can promote curiosity and initiate interaction [20, 21, 23, 49]. Specific factors to be considered include: visually distinct interfaces, visual metaphors, the representation of unusual data facets, and the incorporation of visual cues to facilitate the interpretation of the presented data.

Playful Exploration

The notion of serendipity has been discussed in relation to creativity and ideation [28], suggesting that play as a facilitator of creativity [43, 48] might also stimulate serendipitous discoveries [1]. Walk-up-and-use information visualizations can encourage a playful, pleasurable and, in turn, more thorough and perseverant approach to information exploration.

RELATED VISUALIZATION APPROACHES

The Bohemian Bookshelf, a visual exploration tool for digital book collections, represents a first exploration into the use of information visualization to support serendipity. It exemplifies one interpretation of our design goals that have been described above. Here, we discuss previous work on visual interfaces for document collections, coordinated views, and public information displays that has influenced the Bohemian Bookshelf design.

Visualization of Document Collections

Some tools visualize search results in relation to the entire document collection (e.g. [6, 16, 44]). These visualizations require querying before a visual exploration can begin. This dismisses parts of the document collection and disagrees with the notion of "maximizing the number of possibly relevant objects" that has been suggested to support serendipity [31]. We deliberately designed the Bohemian Bookshelf to provide multiple overviews of the entire book collection to provide opportunities to discover unexpected trends and relations

within the collection. Existing tools that currently provide such overviews, include traditional visualization techniques such as scatter plots, tree maps, or pie charts to offer an efficient and analytical view on documents [12, 17, 26, 27]. Others make use of metaphors that realistically mimic the look and feel of traditional bookshelves to leverage people's familiarity with physical libraries [5, 37]. In contrast, our choice of visual representations in the Bohemian Bookshelf exemplifies an abstract, metaphoric approach that aims to evoke curiosity and promote a playful exploration of book collections to encourage serendipitous discoveries. With the intention to offer a child-friendly interface, the International Children's Digital Library supports open exploration based on the physical characteristics of books such as cover colour [24]. With the Bohemian Bookshelf we aim at encouraging open-ended explorations of book collections and serendipitous discoveries for library audiences at large.

Coordinated Views for Document Exploration

Coordinated views provide multiple interlinked visualizations that are used in relationship to one another [7]. They lend themselves well to visualizing document collections such as library catalogues that are characterized by a variety of attributes [3]. North and Shneiderman highlight multiple views to benefit the "discovery of unforeseen relationships" [35]; serendipitous discoveries, in other words. Coordinated views have been utilized to support the exploration of brief texts (e.g. [10, 21]). However, they have not been applied or discussed in the context of serendipity.

Public Information Displays

Some public ambient information displays address the concept of unexpected discoveries by emphasizing information randomly in the hope that some of it meets the interest of passers-by. The News Wall traverses through recent news ordered by topic [33]. "Making Visible the Invisible", an ambient display installation at the Seattle Library, cycles through different visualizations of media being checked out of the library during the past hour [29]. ResearchWave, an ambient visualization, animates through publications to maintain a casual awareness of activities within large research organizations [20]. The InfoGallery is a large information display that aims to promote awareness of libraries' digital collections that otherwise have no presence in the physical library space [18]. Through the use of visual interfaces and animation these approaches can trigger serendipitous discoveries in a coincidental way. In contrast, the Bohemian Bookshelf exemplifies how to encourage serendipitous discoveries through information visualization more systematically, beyond concepts of fortuity and coincidence.

THE BOHEMIAN BOOKSHELF VISUALIZATION

One of the best known ways of finding books serendipitously is through location and proximity to a given book on a bookshelf [14, 19, 46]. Furthermore, previous literature [42, 45] as well as our informal discussions with librarians revealed that physical and visual attributes play a big role during open-ended explorations of book collections. This guided our choice of book attributes to visualize in the Bohemian Bookshelf: we aimed at providing a variety of perspectives or *facets* [52] on the book collection to increase the number of possible adjacencies by leveraging content-related as well as physical characteristics of books. We included one attribute commonly used for physical adjacencies (ordering by author), one commonly used for digital search (content-related keywords), one physical attribute often neglected in digital libraries (page count), one emphasizing the visual appearance of the book (cover colour & thumbnail image), and one that juxtaposes books' temporal aspects (content era and publication year). Thus, the Bohemian Bookshelf (see Fig. 1) offers five possible adjacencies between books, instead of just one as in physical bookshelves, any of which might offer disparate types of serendipitous discoveries.

The Bohemian Bookshelf is based on a collection of 250 books retrieved from the Open Library[1] project and covers mostly the genres history and fiction. We decided to work with a sample book collection with attributes similar to those available in large library collections. The book attributes we chose to focus on—book title and author, content keywords, page count, cover colour extracted from a book's cover image, publication year, and content era—are each represented by one of five individual visualizations: the Author Spiral, Keyword Chains, the Book Pile, the Cover Colour Circle, and Timelines. Each visualization provides a unique overview of the book collection from a particular perspective. All five of them can be considered as→*Multiple Visual Access Points*; one of our design goals. The individual visualizations are interlinked: the selection of a book in one visualization changes the views of the other four visualizations in relation to the newly selected book,→*Highlighting Adjacencies* across visualizations. The visual emphases of cross-visualizations adjacencies can be considered as crossroads to different→*Visual Pathways* through the collection that can be followed by flexibly switching back and forth between different visualizations. Of course, other book attributes could be visualized and interlinked in a similar way. The Bohemian Bookshelf exemplifies one possible implementation of our design goals.

The Bohemian Bookshelf prototype was implemented in Adobe Flash. The visualizations and corresponding interaction techniques were designed with a large touch-interactive display in mind. However, they could also be integrated in a web-based interface. The following describes the visualizations that define the Bohemian Bookshelf in detail.

Cover Colour Circle

When browsing through books on a traditional shelf, a book's cover is one of the first things noticed. Covers are often designed specifically to attract attention; previous research has found them to be decisive for the anticipated reading experience [42]. The Cover Colour Circle (see Fig. 2) focuses on this aesthetic quality of books by providing an overview of cover colours as they occur in the book collection. This overview can be considered a→*Visual Access Point*,→*Enticing Curiosity* with its prominent visual features. For each book, an average colour is generated by calculating the mean pixel colour from the book's cover image. In the remainder of the paper we will refer to a book's average cover colour simply to as its colour. This colour is used consistently throughout all visualizations in the Bohemian Bookshelf.

[1] http://openlibrary.org

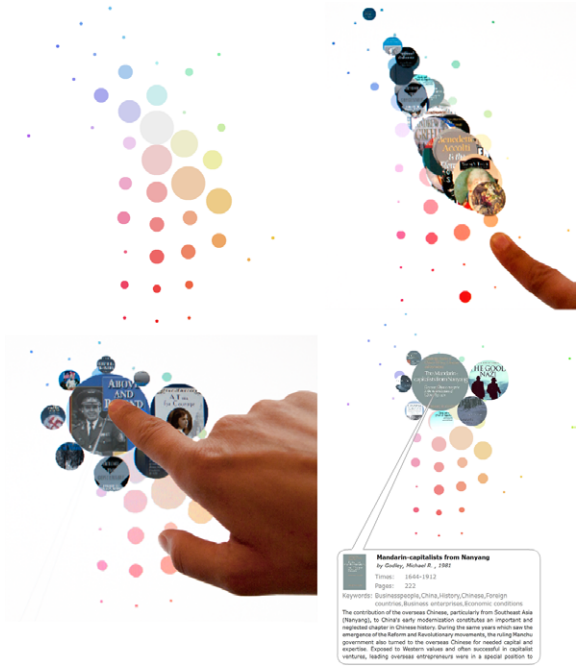

Figure 2. Cover Colour Circle: browsing through book covers (top), selection with adjacent books (bottom).

In the Cover Colour Circle books are grouped by colour and distributed in a circular layout based on the HSV model (hue, saturation, value). We make use only of hue and saturation (HS) and divide the HS circle into discrete colour points that are distributed in concentric circles where each point is equidistant from its neighbouring points. Books are placed in the resulting HS circle according to their colour's HS value. Each discrete colour point in the HS circle corresponds to a number of books of similar colour, represented by a circle whose radius is proportional to this number of books.

Moving the finger across the Cover Colour Circle reveals a circular preview of book covers whose colour corresponds to the current position in the HS circle (see Fig. 2, top right). This cover preview is temporary: previews directly under the touch point are shown in the largest scale and slowly shrink as the touch point moves away. This behaviour, inspired by Etsy's "Shop by color"[2], creates the impression of book covers bubbling up to the surface and disappearing again (→*Playful Exploration*).

Touch-and-release interaction selects a cover and enlarges its preview. In addition, a maximum of eight cover previews of other books with similar cover colours are shown (see Fig. 2, bottom;→*Highlighting Adjacencies*). Selecting one of these adjacent books brings it into focus as an enlarged preview along with a new selection of adjacent books.

Keyword Chains

Digital libraries commonly make use of general terms or keywords that describe the content of books to facilitate categorization and search. Searching for a certain keyword in a digital library catalogue usually produces a list of books that share this particular term but can be otherwise quite different in content. The Keyword Chains visualization picks up on this common notion of categorizing books: it shows relations between books based on their keywords (see Fig. 3). Unlike the Cover Colour Circle, the Keyword Chains visualization does not provide an overview of the entire book collection but shows a vignette of up to nine books represented by their covers and connected through their keywords (→*Visual Access Point*). A cover thumbnail of the selected book is always displayed at the centre. From there, eight keywords that characterize this particular book branch out (e.g. "History", "Political Activity", etc., see Fig. 3), and each of them is attached to another book that shares this keyword (→*Highlighting Adjacencies*). Books that appear in a Keyword Chain are randomly selected from the book collection as long as they fit the criteria of connecting one book title with a corresponding keyword and vice versa. If one of the keywords has no more associated books, this particular Keyword Chain ends.

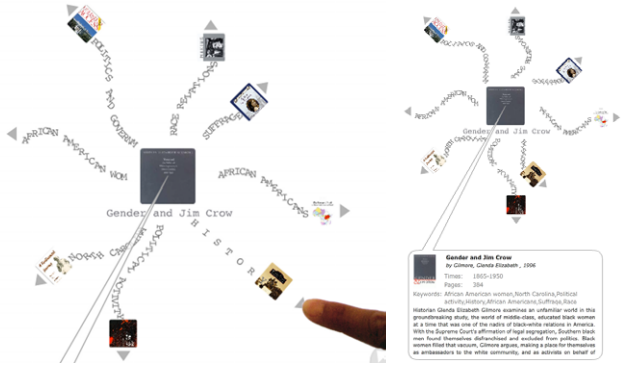

Figure 3. Keyword Chains visualization.

The arrangement of keywords and book titles along sine-based curves is reminiscent of a starfish meandering on the ocean bed. This organic appearance is enforced by subtle animations that cause each Keyword Chain to undulate (→*Enticing Curiosity*). To facilitate reading, Keyword Chains can be stretched by dragging the marker at the end of the chain (see Fig. 3.left, →*Playful Exploration*).

Selecting a cover thumbnail in a Keyword Chain causes the associated book to move into the centre of the visualization and new keywords form around it. This transition is animated, creating the impression of tentacles growing out of the selected book cover in the centre.

Timelines

Two important aspects of books are the publication year and the time period that the book discusses. The Timelines visualization shows the relationship between these temporal characteristics of books (→*Visual Access Point*). It consists of two parallel horizontal timelines (see Fig. 4) corresponding to the books' publication years (upper timeline) and content eras (lower timeline). Each book is represented by a line that connects both timelines, showing the relation between its publication year and the time period in focus. The pattern of lines between the timelines provides an overview of the range and density of publication dates and time periods covered by the entire book collection. Trends can easily be identified: prominent publication years or time periods with particular coverage are visible by dense line clusters (see Fig. 4),→*Enticing Curiosity* and inviting for further exploration.

[2]http://www.etsy.com/

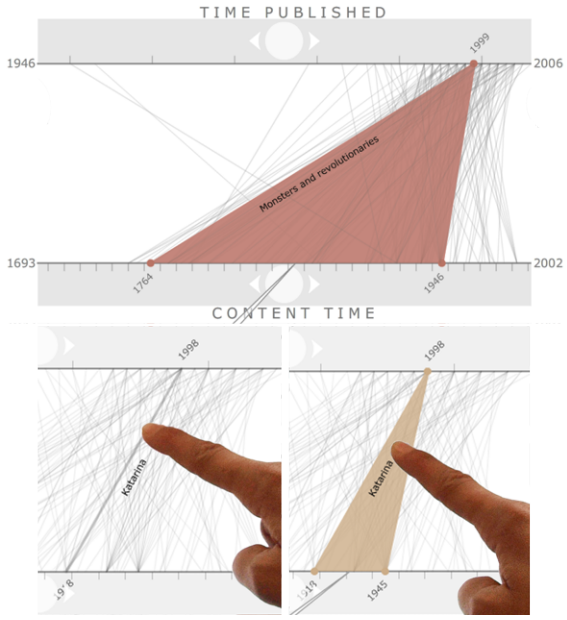

Figure 4. Timelines visualization: overview (top), browsing and selecting books (bottom).

Running a finger across the connecting lines between the two timelines reveals the title of each book and highlights labels on both timelines to indicate the exact publication year and the start year of the time period in focus (see Fig. 4, bottom left). This enables lightweight browsing through the book collection (→*Playful Exploration*). Releasing the finger from a selected line shows a triangle in the book's colour determined by the book's publication year and start and end date of the time period in focus (see Fig. 4, bottom right). This triangle is slightly transparent to allow visibility of lines indicating other adjacent books (→*Highlighting Adjacencies*).

Zooming is supported on both timelines independently to review time periods of interest more closely. Moving the finger in the light-grey area of one timeline to the left, causes the start year of this timeline to increase—the timeline stretches. The overall time frame of the timeline is shortened and books within this shorter time period become dispersed. Moving the finger toward the right loosens the tension in the timeline: the overall time frame enlarges and the density of books increases again. The Timelines Visualization only shows books that are fully visible within the time frames of both timelines.

Book Pile

The thickness of a book and, related to this, its weight, are physical characteristics that influence not only its appearance but also the reading experience. For example, extremely large books can be attractive for their prominent physical appearance. The Book Pile visualization focuses on this physical aspect of books (→*Visual Access Point*). It is based on the metaphor of a physical pile of books (→*Enticing Curiosity*). Each book is represented by a square where colour reflects the book's colour and edge length represents its page count. A square's position is dependent on this page count: books with fewer pages trickle through to the bottom of the Book Pile while thicker books get stuck more toward the top. We use a stacking algorithm to position books. First, books are categorized based on their page count in intervals of 100 pages. Within each interval books are stored in random order. We then position the books starting from the bottom centre of the visualization canvas working our way upwards. Books with the smallest number of pages are positioned first, alternating between the left and right of the canvas' centre to achieve a balanced pile. The random order of books within the page count categories visually strengthens the pile metaphor.

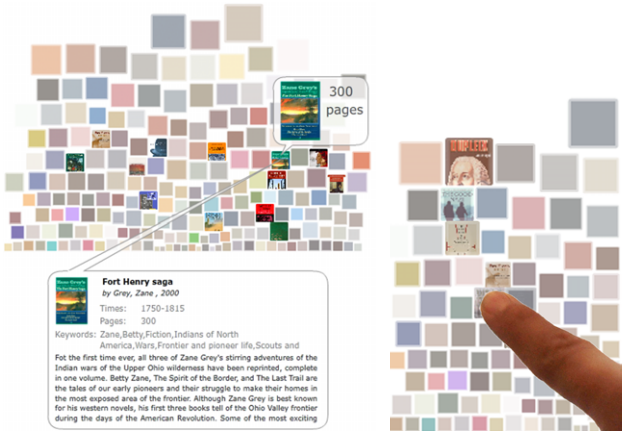

Figure 5. The Book Pile visualization.

Touching a square in the book pile reveals the corresponding book cover and page count. Books with similar page counts (±5 pages) are emphasized by showing their covers, →*Highlighting Adjacencies* (see Fig. 5). Continuously moving the finger across the book pile also temporally reveals the corresponding book cover (→*Playful Exploration*).

Author Spiral

Many libraries and bookstores organize books alphabetically by author name. With the Author Spiral visualization we adopt this common way of alphabetical organization (→*Visual Access Points*). To provide space for various sized collections, the author list rolls up into spirals toward both ends, similarly to a parchment role (see Fig. 6,→*Enticing Curiosity*); only the stretched part of the Author Spiral shows books in form of an author label in the book's colour. Toward the spiral-shaped ends of the list, books are represented by circles in the book's colour. Circles become smaller the closer they are to the spirals centre. The size of the spirals is adjusted depending on the number of books listed on each side while the number of books shown in the stretched middle of the parchment remains constant.

Touching an author label or circle moves the corresponding book into the centre of the "parchment stretch" and reveals its cover preview, title, author, and publication year. Due to the alphabetical ordering, books with same or similar author names line up below and above (→*Highlighting Adjacencies*). To facilitate their selection, author circles enlarge underneath the finger. People can smoothly scroll through author names by running their fingers across the Author Spiral (→*Playful Exploration*).

Interlinked Visualizations in the Bohemian Bookshelf

Together, all visualizations described above form the interface of the Bohemian Bookshelf with one visualization in the centre and the others surrounding it (see Fig. 1). The centre

Figure 6. The Author Spiral visualization.

visualization is 20% larger than the peripheral visualizations. A visualization can be brought into the centre of the display by touching a small arrow button beside it. All visualizations can be explored independently as described above, no matter if they are in the centre or in the periphery. This can facilitate flexible changes of exploration paths through the collection (→*Visual Pathways*). A detail view in the bottom centre of the display provides textual information about the book that is currently selected, including all attributes also shown by the visualizations and a brief abstract (see Fig. 1, 2, 3, 5, and 6). All visualizations are interlinked in that a selection made in one visualization is reflected in the others. For instance, Fig. 1 shows the Book Pile as the central visualization through which the book "Son of the Sword" has been selected. Therefore, all other visualizations highlight this particular book and present adjacent books according to their own perspective. This concept of interlinked visualizations enables browsing through the book collection based on a perspective of particular interest (e.g. keywords) while still offering different perspectives in the periphery (→*Visual Pathways*). If a peripheral visualization catches someone's attention, it can easily be brought to centre for further exploration. When switching a visualization's position from periphery to centre and vice versa, current selections within the visualizations remain unchanged to maintain the search context and provide people with a familiar reference point within the new visualization now in focus. Together, the visualizations of the Bohemian Bookshelf can provide a synergistic experience that can propagate serendipity by encouraging viewers to experience the collection from a variety of perspectives.

LIBRARY DEPLOYMENT OF THE BOHEMIAN BOOKSHELF

We installed the Bohemian Bookshelf on a tilted, touch-interactive display (31.1 by 18.8 inches) for eight consecutive workdays at a central location at the University of Calgary library (see Fig. 7) to explore how library visitors would experience this visual and open-ended, serendipitous way of browsing book collections. Library visitors were able to spontaneously approach the display in a walk-up-and-use manner without any instructions or prior training. We took field notes of visitors' interactions and interviewed 11 visitors (6 male, 5 female; age approx. 20 to 60) who had interacted with the display for at least 30 seconds. The interviews included questions regarding visitors' initial motivations to approach the Bohemian Bookshelf; their overall experience of the visualizations; fulfilment of eventual expectations; potential book discoveries; and general book browsing and information seeking habits. All interviews were transcribed and coded independently by two researchers for visitors' thoughts on: using the Bohemian Bookshelf for the exploration of book collections, differences to other search interfaces they were familiar with, and the role of visualization, visual aesthetics, and display technology for browsing book collections. During the deployment, 129 library visitors approached the Bohemian Bookshelf: 94 visitors interacted with it while 35 just took a brief look without interacting. Average interactions times were 1:06 min (interviewed visitors: 1:59 min) with a maximum interaction time of 6:26 min (interviewed visitors: 3:39 min). Such seemingly brief interaction times are realistic in libraries where visitors often approach information displays spontaneously.

SERENDIPITY AND THE BOHEMIAN BOOKSHELF

In the following we discuss visitors' reactions to the Bohemian Bookshelf in the light of our five design goals for encouraging serendipity through information visualization.

Visitors often mentioned that they appreciated the Bohemian Bookshelf as a way for finding new books that they did not know of before as the following statements demonstrate: *"I have a set of interests or topics that I'd rather read about. So I think that [using the Bohemian Bookshelf] would be a good way of finding new books. [...] You get to see more different books that you might find interesting later, which you otherwise would never see because you wouldn't be looking for them."* [V4]; *"I think it will actually help me discover more authors and provoke people to read, like encourage them to read.* [V11].

Visitors also appreciated the way the Bohemian Bookshelf presents books compared to common search interfaces such as digital library catalogues: *"It's just the way information is presented is different than on the computer [the library catalogue]. That opens up different possibilities for finding out about the different books."* [V9]. Although the interface of the Bohemian Bookshelf does not resemble existing search interfaces commonly used in libraries and we did not provide any instructions regarding its purpose or possible interaction techniques, visitors quickly figured out how to control it. The following statement echoes common opinions regarding the interface: *"I like the fact that it is fairly intuitive. [...] I liked that it was very simple and easy to get used to in that way."* [V4]. Our interviews also revealed that it was the visualizations that helped visitors to get an idea of what the Bohemian Bookshelf is about and how to use it: *"I'd say like*

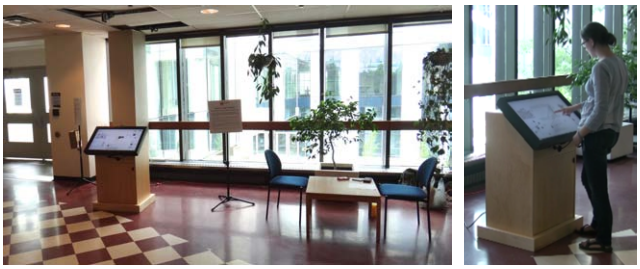

Figure 7. The Bohemian Bookshelf at the University of Calgary library.

90% of the understanding of it is the visual component. [...] I read the labels, but after [looking at] the visuals." [V8].

Providing Multiple Visual Access Points

The Bohemian Bookshelf presents a variety of different perspectives on the book collection, each providing different access points for exploration. Our interviews and observations of visitors' interactions revealed that the personal preferences regarding search criteria and the visualizations of the Bohemian Bookshelf were diverse. Providing a variety of different overviews can help addressing the individual preferences and interests of different patrons. Visitors also appreciated the variety of visual representations for gaining a general idea of the collection and potential starting points for exploration. For example, visitors explained: *"The way things are presented here [the Bohemian Bookshelf] also puts things in perspective. It just gives you a little bit of a different angle of seeing things."* [V9]; *"It gives you more options. [...] So if you have more information, it is easier to have a starting point."* [V8]; *"I'm sure each element [the visual overviews] works differently for different people. I like having it all together. [...] It kind of promotes curiosity."* [V11].

Enticing Curiosity through Visual Aesthetics

All visitors we interviewed stated that the visual aspect of the interface in combination with the touch interactive display evoked their curiosity. Visitors in particular mentioned the colours and cover images as visually attractive and as motivating them to take a closer look and to touch the interface even if they first did not know what it was about or how it worked. Many visitors appreciated the Cover Colour Circle with its focus on books' visual aesthetics. Comments that describe serendipitous discoveries within this visualization, such as *"I picked my favourite colour. I picked pink and then I found a book that I liked."* [V7] were common. Visitor statements suggest that our focus on visual aesthetics was not only important for evoking curiosity but also in providing a starting point for more elaborate explorations that can potentially lead to serendipitous discoveries: *"First of all it [the Bohemian Bookshelf] catches interest. [...] I don't know the cover colours, what it is for exactly, but it makes it more interesting and then if you stumble upon something, you might want to read it. And that's a good way to get people to actually want to read."* [V5].

Highlighting Adjacencies

The visualizations in the Bohemian Bookshelf highlight adjacencies along different dimensions such as colour, time, page count, keywords, and authors' names. Each visualization provides a visual overview where adjacent books are presented in close proximity. In addition, adjacent books are individually emphasized in response to current selections. This combination of visual overviews and emphasis of individual books aims to parallel a "browsing the shelves" experience which has been shown to support serendipitous discoveries [14, 19, 46]. Our interviews indicate that highlighting adjacencies encouraged new discoveries by promoting new or different associations between topics or books. For instance, visitors stated: *"I like the different criteria; that it is all on the same screen. [...] It [the Bohemian Bookshelf] is a cool tool to discover something new through different associations."* [V5].

Flexible Visual Pathways as Serendipitous Guides

It can be overwhelming to start exploring a large book collection when one does not know exactly what to look for. With the Bohemian Bookshelf we aimed at providing multiple flexible pathways through the book collection to guide people in potentially interesting directions that they did not think of in the first place. We approach this goal in three ways. First, we provide multiple interactive visual overviews of the collection that can help steer people's explorations. Several visitors appreciated these overviews to help guide their exploration and prevent them from *"getting lost"* [V3] in the collection. We also observed visitors deliberately steering their exploration along "outlier" books that visually stood out within the visualizations. For instance, visitors frequently explored particularly large or small books in the Book Pile or isolated connecting lines in the Timelines visualization. Second, the emphasized adjacencies between books can act as visual signposts that can guide the exploration. For instance, some visitors browsed through the Keyword Chains, following up on thematically adjacent books: *"[...] the current way of searching for a book is, you have to know what it is or just browse through an alphabetical list like an author list. But here [with the Bohemian Bookshelf] you can kind of branch off by keyword and find similar books in the same type of topic."* [V4]. Similarly, visitors explored books about particular time periods in the Timelines visualization.

The interlinking of visualizations is a third way of promoting visual pathways through the collection, in that every book selection in one visualization can be considered a cross road to other visualizations that highlight the book in a different context. We observed that visitors fluidly switched back and forth between visualizations, changing their exploration direction on a whim as one visualization caught their interest.

Playful Exploration to Encourage Browsing

The design of the Bohemian Bookshelf is strongly focused around the use of playful interaction to not only evoke curiosity and initiate exploration but also to make book exploration a pleasurable experience. Visitors found that the combination of interactive visualizations and touch-interactive display technology encouraged book exploration and enhanced the general browsing experience: *"I think it makes it very interesting to actually look for books. [...] It is visual and it's high tech."* [V5]; *"You have the touch screen with all the different covers that open up and you can [...] just pick them. That's sort of like browsing. [...] It's more satisfying than sitting on the computer clicking through a whole bunch of stuff."* [V9].

Serendipitous Book Discoveries

Six of the visitors we interviewed explicitly mentioned that they made personal serendipitous discoveries while interacting with the Bohemian Bookshelf. Three participants explained that they found a book by selecting their favourite colour. Others stated that a book's cover, title or author caught their eye when browsing the visualizations: *"I had no expectations and I just saw a [author] name that seemed familiar to my language, and then I thought, well, why not check it [the book] out."* [V11]. The participants named book titles they found interesting and sometimes wanted to check them out from the library. This is remarkable considering visitors'

spontaneous use of the Bohemian Bookshelf and the short interaction times. These encouraging initial results indicate that visitors embraced the concepts inherent in the Bohemian Bookshelf of supporting open-ended browsing of book collections and serendipity through information visualization.

DISCUSSION

Initial reactions of library visitors toward the Bohemian Bookshelf have been encouraging. Visitor statements not only reveal that our design goals have largely been met, but they also demonstrate a high level of excitement toward the use of information visualizations for supporting open-ended explorations of library collections and promoting serendipitous discoveries: *"It [the Bohemian Bookshelf] gives you a chance to kind of explore at your leisure and to discover new artists or topics you might like, so it's something I'd definitely be looking forward to using at the library."* [V4]. However, the Bohemian Bookshelf, as a first exploration in this direction, also raises some questions to be explored in the future.

Scalability. The Bohemian Bookshelf prototype that we installed at the library included a collection of 250 books to ensure fluid real-time interaction. Of course, this number does not come even close to most library collections. While the performance of our prototype can easily be improved by applying more potent implementation strategies, some of the visualizations have to be adjusted to allow for larger data sets. The Book Pile and the Author Spiral, for instance, could be redesigned to show books in an aggregated form, similar to the Cover Colour Circle. Common visualization techniques such as edge bundling [22] could be used to avoid clutter within the Timelines visualization.

Combining Open-Ended & Targeted Search Strategies. While we designed the Bohemian Bookshelf to support open-ended explorations of book collections, library visitors made use of some visualizations in a rather targeted way. For instance, many visitors appreciated the Book Pile visualization as a useful way to find particularly short books on a topic. Furthermore, visitors frequently asked for possibilities to filter and specify the books displayed to certain topics of interest. It seems that the boundaries between open-ended and targeted browsing are fluid and people make use of both when exploring book collections. This raises the question of how to combine targeted and open-ended *serendipitous* exploration strategies using information visualization. One obvious step in this direction would be the integration of a textual query interface into the Bohemian Bookshelf visualization.

Distraction through Complexity. Providing several visual overviews that point to other, potentially interesting, books not only facilitates unexpected, valuable discoveries but also the possibility of getting distracted from the actual topic of interest and, at worst, getting lost in the book collection. Visitors seemed ambivalent about this potential problem. Some liked the approach of having several interlinked visualizations in one single view and even asked to add more visual perspectives to further reflect on the content of books or to integrate ratings and reviews of other readers. Other visitors, however, were concerned about the visual complexity of the interface and suggested showing only one visualization at a time. It would be interesting to explore the impact of different layouts that include varying numbers and sizes of interlinked visualizations. The problem of loosing track of previously discovered books and the overall exploration path was also mentioned. This reveals the integration of visual "bread crumbs" to help people trace back their exploration path and mark books or views on the collection that they may want to get back to as another important research direction.

CONCLUSIONS

Introducing the Bohemian Bookshelf as a case study, we have discussed how serendipitous book discoveries can be supported through information visualization. While serendipity has been found to be an important factor in information seeking, research, and ideation, the approach of most search interfaces to digital data collections is targeted toward "minimizing the number of possibly *irrelevant* objects" rather than "maximizing the number of possibly *relevant* objects" [31]. This does not specifically encourage serendipitous discoveries. We have presented five design goals derived from previous literature that can guide the design of visualizations to facilitate serendipitous discoveries. As an interpretation of these design goals we have introduced the Bohemian Bookshelf, which aims to support serendipitous discoveries in the context of digital book collections. A deployment of this prototype at a university library and interviews with the library visitors who interacted with it suggest that our design goals were largely met. Beyond this, they indicate considerable excitement of visitors toward visualizations of library collections that facilitate open-ended exploration and serendipitous discoveries. Our findings encourage future case studies that address serendipity as a goal in information visualization. There are many digital data collections that could benefit from a serendipitous approach to information exploration such as news feeds, photos, videos, or music collections. The case study presented in this paper can be considered as a first step into exploring information visualization as a means to encourage serendipitous discoveries. While our design goals are applicable to a variety of different scenarios and datasets, future case studies will help to evaluate and further expand these goals and recommendations for serendipity support through visualization.

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REFERENCES

1. André, P., schraefel, m. c., Teevan, J., and Dumais, S. T. Discovery is never by chance: Designing for (un)serendipity. In *Proc. of Creativity and Cognition* (2009), 305–314.
2. Austin, J. H. *Chase, Chance, and Creativity. The Lucky Art of Novelty*. The MIT Press, 2003, ch. Altamirage, 84–86.
3. Baldonado, M. Q. W., Woodruff, A., and Kuchinsky, A. Guidelines for Using Multiple Views in Information Visualization. In *Proc. of AVI'00* (2000), 110–119.
4. Blandford, A., and Buchanan, G. Usability of digital libraries: a source of creative tensions with technical developments. *IEEE Technical Committee on Digital Libraries Bulletin 1*, 1 (2003).

5. Christoffel, M., and Schmitt, B. Accessing libraries as easy as a game. In *Visual Interfaces to Digital Libraries [JCDL 2002 Workshop]*, Springer-Verlag (London, UK, 2002), 25–38.
6. Clarkson, E. C., Desai, K., and Foley, J. D. ResultMaps: Visualization for Search Interfaces. *IEEE TVCG 15*, 6 (2009), 1057–1064.
7. Collins, C., and Carpendale, S. Vislink: Revealing relationships amongst visualizations. *IEE TVCG 13*, 6 (2007), 1192–1199.
8. de Bruijn, O., and Spence, R. A new framework for theory-based interaction design applied to serendipitous information retrieval. *ACM Transactions on Computer-Human Interaction 15*, 1 (2008).
9. Dewey, M. *A Classification and Subject Index for Cataloguing and Arranging the Books and Pamphlets of a Library (Dewey Decimal Classification)*. Kingsport Press, Inc., 1876.
10. Dörk, M., Carpendale, S., Collins, C., and Williamson, C. Visgets: Coordinated visualizations for web-based information explorations and discovery. *IEEE TVCG 4*, 6 (2008), 1205–1212.
11. Dörk, M., Carpendale, S., and Williamson, C. The information flaneur: A fresh look at information seeking. In *Proc. of CHI* (2011). to appear.
12. Dushay, N. Visualizing metadata : A virtual book spine viewer. *D-Lib Magazine 10*, 10 (2004).
13. Erdelez, S. Information encountering: It's more than just bumping into information. *Bulletin of the American Society for Information Science 25*, 3 (1999), 25–29.
14. Foster, A., and Ford, N. Serendipity and information seeking: An empirical study. *Journal of Documentation 59*, 3 (2003), 321–340.
15. Fox, E., Hix, D., Nowell, L., Brueni, D., Wake, W. C., Heath, L. S., and Rao, D. Users, user interfaces, and objects: Envision, a digital library. *Journal of the American Society of Information Science 44*, 8 (1993), 480–491.
16. Fox, E. A., Neves, F. D., Yu, X., Shen, R., Kim, S., and Fan, W. Exploring the Computing Literature with Visuailzation and Stepping Stons & Pathways. *Communications of the ACM 49*, 4 (2006), 53–58.
17. Good, L., Popat, A. C., Janssen, W. C., and Bier, E. UC: A Fluid Treemap Interface for Personal Digital Libraries. In *Proc. of JCDL'05* (2005), 408–408.
18. Grønbæk, K., Rohde, A., and Bech-Petersen, S. Infogallery: Interactive art services for physical library spaces. In *Proc. of JCDL'06* (2006), 21–30.
19. Gup, T. Technology and the end of serendipity. *The Education Digest 6* (1998), 48–50.
20. Hinrichs, U., Fisher, D., and Riche, N. H. ResearchWave: An ambient visualization for providing awareness of research activities. In *Proc. of DIS* (2010).
21. Hinrichs, U., Schmidt, H., and Carpendale, S. EMDialog: Bringing information visualization into the museum. *IEEE TVCG 14*, 6 (2008), 1181–1188.
22. Holten, D. Hierarchical edge bundles: Visualization of adjacency rlations in hierarchical data. *IEEE TVCG 12* (2006), 741–748.
23. Huang, E. M., Koster, A., and Borchers, J. Overcoming assumptions and uncovering practices: When does the public really look at public displays. In *Proc. of the conf. on Pervasive Computing* (2008).
24. Hutchinson, H., Bederson, B., and Druin, A. Supporting elementary-age children's searching and browsing: Design and evaluation using the international children's digital library. *Journal of the American Society of Information Science and Technology* (2007).
25. Huwe, T. K. New search tools for multidisciplinary digital libraries. *Online 23*, 2 (1999), 67–74.
26. Johnson, D. K. Knowledge mining with VxInsight: Discovery through interaction. *Journal of Intelligent Systems 11*, 3 (1998).
27. Klein, P., Reiterer, H., Müller, F., and Limbach, T. Metadata visualisation with VisMeB. In *Proc. of IV'03* (2003), 600–605.
28. LeClerc, A. Seeking serendipity: The inspiration hunt of a creative professional. *Faculty of Information Quarterly 2*, 3 (2010).
29. Legrady, G. Making visible the invisible. http://www.mat.ucsb.edu/g.legrady/glWeb/Projects/spl/spl.html, 2005. Website visited Sept. 2011.
30. Liestman, D. Chance in the midst of design: approaches to library research serendipity. *RQ 31*, 4 (1992), 524—536.
31. Marchionini, G. Exploratory search: From finding to understanding. *Communications of the ACM 49*, 4 (2006), 41–46.
32. Merčun, T., and Žumer, M. Visualizing for explorations and discovery. In *Proc. of the conf. on Libraries in the Digital Age* (2010), 104–115.
33. Moghnieh, A., Arroyo, E., and Blat, J. The news wall: Serendipitous discoveries in dynamic information spaces. In *Proc. of IUI'08* (2008).
34. Morse, P. M. On browsing: The use of search theory in the search of information. *Bulletin of the Operations Research Society of America 19* (1971).
35. North, C., and Shneiderman, B. A Taxonomy of Multiple Window Coordinations. Tech. Rep. CS-TR-3854, Univ. Maryland Computer Science Dept., 1997.
36. Oxford English Dictionary. http://www.oed.com/view/Entry/17638-7?redirectedFrom=serendipity#eid. Website visited Sept. 2011.
37. Rauber, A., and Bina, H. A metaphor graphics based representation of digital libraries on the world wide web: using the libviewer to make metadata visible. In *Proc. of DEXA'99* (1999), 286–290.
38. Remer, T. G. *Serendipity of the Three Princes, from the Peregrinaggio of 557*. Norman, OK: University of Oklahoma Press, 1965.
39. Rice, J. Serendipity and holism: the beauty of opacs. *Library Journal 113*, 3 (1988), 38–41.
40. Rice, R. E., McCreadie, M. M., and Change, S. L. *Accessing and Browsing Information and Communication*. MIT Press, Cambridge, 2001.
41. Rosenman, M. F. Serendipity and scientific discovery. *Journal of Creative Behavour 22* (1988), 132–138.
42. Ross, C. S. Finding without seeking: the information encounter in the context of reading for pleasure. *Information Processing and Management 35*, 6 (1999), 783–799.
43. Russ, S. W. *Affect and Creativity: The role of affect and play in the creative process*. Lawrence Erlbaum, 1983.
44. Shneiderman, B., Feldman, D., Rose, A., and Grau, X. F. Visualizing Digital Library Search Results with Cathegorical and Hierarchical Axes. In *Proc. of Digital Libraries* (2000), 57–65.
45. Spiller, D. The provision of fiction for public libraries. *Journal of Librarianship 12*, 4 (1980), 238–265.
46. Toms, E. Serendipitous information retrieval. In *DELOS workshop on "Information seeking, searching and querying in digital libraries"* (2000), 17–20.
47. van Andel, P. Anatomy of unsought finding. serendipity: Origin, history, domains, traditions, appearances, patterns, and programmability. *The British Journal for the Philosophy of Science 45*, 2 (1994), 631–648.
48. Vandenburg, B. Play, problem-solving and creativity. *New Directions for Child and Adolescent Development 9* (1980), 49–68.
49. Viégas, F., Perry, E., Howe, E., and Donath, J. Artifacts of the presence era: Using information visualization to create an evocative souvenir. In *Proc. Of the IEEE Symp. On Information Visualization* (2004), 105–111.
50. Walton, C., Williamson, S., and White, H. D. Resistance to online catalogs: A comparative study at bryn mawr and swathmore colleges. *Library Resources and Technical Services 30*, 4 (1986), 388–401.
51. White, R. W., Kules, B., Drucker, S. M., and Schraefel, M. Supporting exploratory search. *Communications of the ACM 49*, 4 (2006), 37–39.
52. Yee, K.-P., Swearingen, K., Li, K., and Hearst, M. Faceted Metadata for Image Search and Browsing. In *Proc. of CHI'03* (2003), 401–408.