

# The Bohemian Bookshelf

## Supporting Serendipitous Discoveries through Visualization

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**Abstract**— Serendipity, a trigger of exciting discoveries when we least expect it, is currently being discussed as an often neglected but still important factor in information seeking processes, research, and ideation. In this paper we explore serendipity as an information visualization goal. In particular, we introduce the Bohemian Bookshelf visualization that aims to support serendipitous exploration of digital book collections. The Bohemian Bookshelf consists of five interlinked visualizations, each representing a unique (over)view of the collection. It facilitates serendipitous discoveries by (1) offering multiple access points by providing visualizations of different perspectives on the book collection, (2) enticing curiosity through abstract, metaphorical, and visually distinct representations of the collection, (3) highlighting alternate adjacencies between books, (4) providing multiple pathways for exploring the data collection in a flexible way, (5) supporting immediate previews of books, and (6) enabling a playful approach to information exploration. Our design goals and their exploration through the Bohemian Bookshelf visualization opens up a discussion on how to promote serendipity through information visualization.

**Index Terms**—Information Visualization, Serendipity, Visual Library Interfaces

### 1 INTRODUCTION

Information has become a part of our everyday life. It is no longer only scientists and information analysts who have to handle massive amounts of information. We all, on a day-to-day basis, encounter, search, and explore 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 on existing search approaches, which were designed to support the need for tools to perform exact information retrieval. In fact, many people, digital librarians included, have expressed concern over the possible loss of unexpected, yet valuable, discoveries that can be attributed to serendipity [13, 14, 38, 43, 47]. We introduce the Bohemian Bookshelf visualization, which we have designed to support serendipitous discoveries in digital book collections.

Consider this simple scenario. Lucy, after hard day’s work, is anticipating settling down with a good book for a relaxing read (see Fig. 1a). However, since she has just finished her last book, she needs another one. Upon entering the library she is faced with access to 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 bookshelves where she could have just browsed casually through books (see Fig. 1d). In creating the Bohemian Bookshelf visualization, our intention is to enable a similar open-ended “browsing the shelves” experience that has been shown to encourage serendipitous discoveries [14, 19, 29, 43]. The Bohemian Bookshelf consists of five interlinked visualizations that each offer a unique perspective

on a digital book collection. With this approach we aim to support serendipitous discoveries through information visualization by (1) offering multiple access points by providing visualizations of different perspectives on the book collection, (2) enticing curiosity through abstract, metaphorical, and visually distinct representations of the collection, (3) highlighting alternate adjacencies between books, (4) providing multiple pathways for exploring the data collection in a flexible way, (5) supporting immediate previews of books, and (6) enabling a playful approach to information exploration.

In this paper we explore serendipity as an information visualization goal. We first describe the concept of serendipity including its definition, influencing factors, and high-level recommendations that have been suggested in previous literature to support serendipity. This is followed by the presentation of six design goals that we have derived for promoting serendipitous discoveries through information visualization. We then introduce the Bohemian Bookshelf that exemplifies one interpretation of our design goals and discuss its design features and how they relate to serendipity in detail. We briefly describe related works from information visualization that inspired our work. A discussion of future research questions that this exploration raises concludes this paper.

### 2 THE CONCEPT OF SERENDIPITY

Literature from library and information sciences actively describes and discusses serendipity, covering its definition, delineating influencing factors, and offering suggestions on how serendipity might be nurtured in the development of traditional and digital libraries. In this section, we discuss the definition of serendipity and present a compilation of the influencing factors that have been discussed in the literature. Furthermore, we summarize recommendations from the literature of how serendipitous discovery can be promoted and encouraged.

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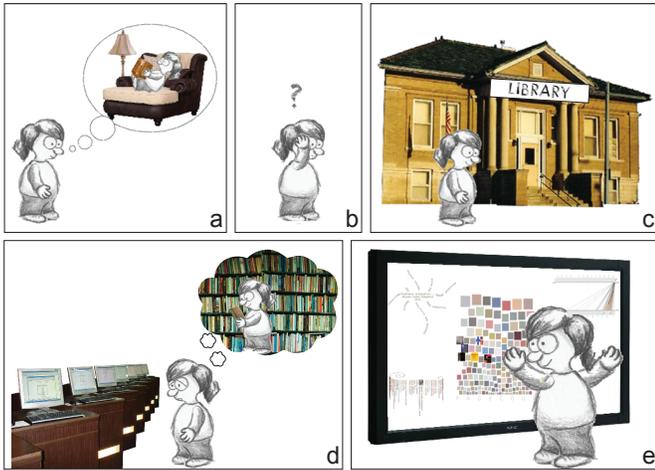


Fig. 1. Scenario.

## 2.1 Defining Serendipity

The term serendipity was coined by Horace Walpole in 1754 [37, 44] to characterize the discoveries made by The Three Princes of Serendip—the figures of an ancient fairy tale: “as their Highnesses travelled they were always making discoveries, by accidents & sagacity, of things which they were not in quest of” [37, 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” [35]. This definition 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.

## 2.2 Factors Influencing Serendipity

The concept of serendipity has been widely discussed for being a valuable part of discovery, creativity, and innovation in the humanities, sciences, art, and technology (e.g., [44, 40]). Different factors have been identified in the literature, that seem to favour serendipity beyond its coincidental aspect. Teasing out these factors brings to the fore additional aspects of serendipity that can be incorporated into design.

### 2.2.1 Personality Traits

One aspect of serendipitous discoveries can be attributed to an individual’s personality and knowledge, including special traits and attitudes. Austin coined the term *altamirage* that describes serendipitous discoveries as a result of chance paired with individual traits of the exploring person [2, 29]. Along these lines, Erdelez found that some people—“super-encounterers”—seem to be particularly talented in encountering information of interest unexpectedly [13]. These people embrace serendipitous discoveries as part of their research process. Talents or special traits that facilitate serendipity include observational skills [40], curiosity [29] and open-mindedness [1, 14, 29, 40, 44], knowledge [1, 29, 40], and perseverance [29].

**Observational Skills.** Observational skills have been discussed as one factor favouring serendipity. Rosenman emphasized how Flemming’s observational skills that he acquired in his training as an artist greatly contributed to his famous discovery of penicillin, which has been attributed to serendipity [40].

**Open-mindedness.** Numerous works on serendipity emphasized the importance of an *open* and *prepared* mind [1, 14, 29, 40, 44]. This recognizes that valuable insight from serendipitous discoveries requires a certain amount of receptiveness to unexpected information. In the words of the chemist and microbiologist Louis Pasteur: “chance only favours prepared minds” [44]. Such open-mindedness can manifest itself in curiosity [29], questioning previous assumptions, or deliberately looking at information from various perspectives [29, 40].

**Knowledge.** Knowledge, expertise, and the ability to make sound judgments can be also considered as part of a “prepared mind” and a key factor of serendipity in that they enable a person to draw connections between seemingly unrelated information [1, 29, 40, 43]. It is this kind of knowledge that Walpole described as *sagacity* in his definition of the term serendipity [37]. Without prior knowledge, certain serendipitous discoveries in science would not have been possible. For instance, Flemming’s previous knowledge about bacterial inhibitors helped him to recognize the potential value of the penicillin mould when he observed it for the first time [40].

**Perseverance.** It has been suggested that perseverant research of a certain topic or area favours the occurrence of serendipitous discoveries [29]. The more time and effort one invests, the more knowledge one aggregates, which, in turn, facilitates the discovery and recognition of unexpected valuable insights.

### 2.2.2 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, unexpected, or coincidental events [1, 14, 29, 44]. This is closely related to the notion of synchronicity where related ideas may manifest as simultaneous occurrences that seem acausal but still meaningful [29]. 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 or data collections that are explored on an everyday basis have 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 [29]. Library books, for instance, are usually categorized based on the Dewey Decimal Classification [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 also how they are presented.

## 2.3 Recommendations for Serendipitous Design

The factors listed above emphasize that, while coincidence plays a role, there is more to serendipity than mere chance. Studies have shown that traditional libraries with their racks of bookshelves can support serendipity through library organizational systems and catalogues, through books’ adjacencies on shelves, and through the possible paths one could take through the bookshelves [14, 19, 29, 43]. On the other hand, digital libraries with their continually improving search engines offer more and more support for targeted search. The question of how serendipitous discoveries can be supported in digital libraries has been much discussed in the context of library and information sciences [1, 4, 14, 47]. However, while these discussions include suggestions for integrating visual interfaces to support serendipitous discoveries [31], presently, this discourse still largely consists of rather vague hints, suggestions, and theory. Here we have distilled a list from a large number of general recommendations from the literature.

**Multiple Access Points.** Rice suggests supporting different access points to digital library catalogues to encourage serendipity [38]. This recommendation correlates with the idea of open-mindedness and the researcher’s willingness to “view data from several perspectives” [40]. An early study by Fox et al. revealed that people would actually like to explore library catalogues from different views [15].

**Juxtaposition of Information.** 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 information unexpectedly when browsing the library shelves in search of a book on a completely unrelated

topic [14, 19, 29]. The juxtaposition of information that traditional libraries offer to make their collections searchable can therefore (unintentionally) lead to serendipitous discoveries [43].

**Multiple Pathways.** Huwe suggests providing multiple pathways through digital book collections to preserve the opportunity for serendipitous discoveries in digital library systems [24]. While he does not specify how such pathways could be realized, this recommendation seems related to the call for more open-ended navigation strategies. Most search interfaces to digital libraries support targeted known-item-search in form of querying [30, 38, 43]. More open-ended search strategies known by the terms *exploratory search* [30, 43, 48], *browsing* [8, 33, 39], or *information encountering* [13] have been recommended as more appropriate when it comes to supporting serendipity. It has been suggested that such open-ended search strategies benefit from visual interfaces that allow for flexible, not predetermined visual navigation through data collections instead of relying on textual query editors and sequential result lists [30].

**Curiosity & Play.** The notion of serendipity has been discussed in relation to creativity and ideation [27]. Therefore, play as a facilitator of creativity [41, 45] might also stimulate serendipitous discoveries [1]. There is a close connection between playfulness and curiosity. Along these lines, some serendipitous discoveries have been attributed to curiosity [43, 44]. Similarly, Dörk et al. suggest considering information seeking as a pleasurable, inspiring experience [11].

### 3 DESIGNING FOR SERENDIPITY THROUGH VISUALIZATION

Previous information and library science literature has provided a set of highly general design recommendations for serendipity. From these, we have derived a set of design goals that demonstrate one possible interpretation of these recommendations from an information visualization perspective. First and foremost, these goals are intended to help guide the design of the Bohemian Bookshelf visualization. However, they can be considered as a starting point into the general discussion of promoting serendipity through information visualization.

#### 3.1 Complementary Access Points

In contrast to physical data collections where one item can only be located in a single place, digital collections allow items to be presented in any number of categories/locations at the same time and, therefore, to be explored from various perspectives. With regard to serendipity, providing different perspectives on a dataset can help people to build their knowledge along particular points of interest or reveal different, maybe unfamiliar and/or surprising, aspects of a known topic. We address this general recommendation by providing a variety of orthogonal access points to a book collection. We provide a variety of visual overviews, each focusing on different metadata of the collection. These overviews can be considered as visual and conceptual access points to the book collection that complement each other. They literally initiate exploration from different viewpoints that, in turn, can encourage serendipitous discoveries.

#### 3.2 Enticing Curiosity

Closely related to open-mindedness, curiosity can benefit people's perceptiveness to serendipitous discoveries. While curiosity may well be considered as part of the information seeker's personality, there are factors such as visual aesthetics and animation that can promote curiosity and initiate interaction [21, 20, 23, 46]. To this end, we intentionally focused on developing visualizations that are visually distinct from each other and that stand out from existing library search interfaces. We make use of abstracted real-world metaphors that reflect on the represented data. The idea is to introduce visual variance to promote curiosity while offering visual cues that help understand what is being represented.

#### 3.3 Alternate Adjacencies

In a traditional library, adjacency between books on shelves is perhaps the most discussed promoter of serendipity. A traditional library can show one such organization that highlights one type of relation

between books. A digital library offers the opportunity of showing multiple, co-existing alternate adjacencies between books. Books can be adjacent, for instance in terms of their genre, topic, author, or publication year. On a higher level, we reveal different book metadata adjacencies visually in the overview visualizations of the book collection by positioning books with similar attributes in closer proximity. In addition, we emphasize different types of adjacencies on book-level: we highlight groups of related books, aiming for a similar experience that people might have when browsing physical bookshelves.

#### 3.4 Visual Pathways & Crossroads

An interactive visualization can be considered not only an access point to a dataset but also a pathway through the data. It can be quite overwhelming to start exploring a large data collection, in particular, when one does not know exactly what to look for. The design of the Bohemian Bookshelf offers multiple pathways through the book collection by (1) providing multiple interactive overviews of the book collection that can guide the information seeker into different and interesting directions, (2) the presentation of adjacent data that can act as visual signposts providing alternatives for the viewer to move through the dataset by following up on related books, and (3) emphasizing cross visualization attributes by mutual highlighting as in coordinated views [3, 7]. It is important to emphasize that these pathways are not predetermined but full of crossroads. We were careful to design the Bohemian Bookshelf in a way that enables people to fluidly switch back and forth between visualizations and change their exploration focus as needed. It is the variety of pathways and their flexibility that can serve to enhance serendipity.

#### 3.5 Immediacy of Previews

All visualizations are designed so that, upon selection, a book can readily move from being in the background, to being in focus. This enables people to follow up on serendipitous discoveries without much effort.

#### 3.6 Playful Interaction

From an interaction perspective, it was our goal to design for playful walk-up-and-use exploration techniques. We aimed for making the exploration of a book collection a pleasurable experience to encourage a more thorough and perseverant approach to exploration and, in turn, increase people's knowledge as well as the chance of serendipitous discoveries.

### 4 THE BOHEMIAN BOOKSHELF VISUALIZATION

The Bohemian Bookshelf is a visualization prototype developed to explore how serendipitous discoveries—as part of open-ended data exploration—can be supported through information visualization. The design of this visualization prototype reflects in particular on the goals discussed in the preceding section.



Fig. 2. The Bohemian Bookshelf: five interlinked visualizations presenting different perspectives on a book collection.

The Bohemian Bookshelf (see Fig. 2) consists of five individual visualizations: the Cover Colour Circle, Keyword Chains, Timelines, the

Book Pile, and the Author Spiral. Each of the five visualizations provides a unique overview of the dataset from a particular perspective, as we will describe below in more detail. At the same time, the individual visualizations are interlinked with each other: the selection of a book in one visualization changes the views of the other four visualizations to in relation to the newly selected book (see Fig. 2).

The visualization is based on a dataset of books retrieved from the Open Library<sup>1</sup> project. To develop the prototype of the Bohemian Bookshelf we decided to work with a sample dataset that is characterized by attributes similar to those that would be available in library collections on a larger scale. The metadata provided for each book in our dataset includes the book title, author, publication year, a thumbnail image showing the book cover, the time period the book focuses on (start year–end year), general keywords characterizing the book’s content, and its number of pages. The images for this paper were generated with a sample set of 300 books. In this section we describe the visualizations that together compose the Bohemian Bookshelf. This is followed by a discussion of the Bohemian Bookshelf design and how it supports serendipity.

### 4.1 Cover Colour Circle

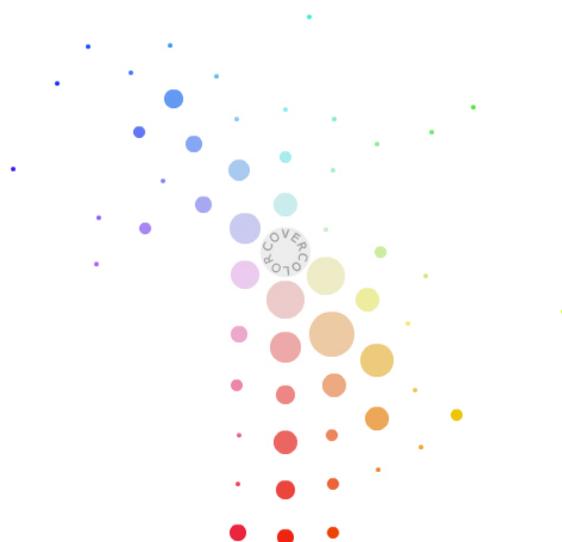


Fig. 3. Cover Colour Circle visualization.

When browsing through books on a traditional shelf, a book’s cover is one of the first things noticed; in fact covers are carefully designed by publishers specifically to catch attention and sometimes even reflect the genre of the book (e.g. science fiction). The Cover Colour Circle focuses on this prominent aesthetic quality of books by providing a visual overview based on their cover colour (see Fig. 3). For each book, we generated an average colour 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.

In the Cover Colour Circle visualization all books are grouped by their colour and distributed in a circular layout based on the HSV model (hue, saturation, value). We make use only of hue and saturation (HS) from the 3D HSV model (see Fig. 4(a)) and divide the HS circle into discrete colour points that are distributed in concentric circles where each point is equidistant from its neighbouring points (see Fig. 4(a)). Books are placed in the resulting HS circle according to their colour’s HS value. Each book is assigned to the colour point that is closest in distance to the position of the book’s colour in the

<sup>1</sup><http://openlibrary.org>

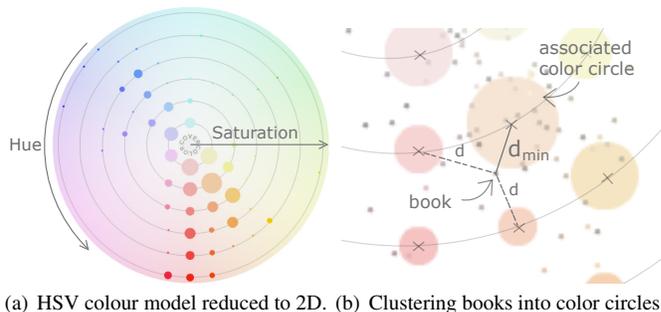


Fig. 4. Calculation of the Cover Colour Circle.



Fig. 5. Covers bubbling up when browsing the Cover Colour Circle.



Fig. 6. Selecting a book in the Cover Colour Circle.

HS-circle (see Fig. 4(b)). Thus, each discrete colour point may correspond to a number of books of similar colour. Consequently each colour point is represented by a circle with the radius proportional to the number of books that are associated with the colour.

Browsing through the Cover Colour Circle reveals books grouped according to their colours. Moving the mouse pointer or finger across the Cover Colour Circle reveals a circular preview of book covers whose colour corresponds to the current position in the HS circle. This preview of the covers is temporary: cover previews directly under the interaction point are shown in largest scale and slowly shrink as the interaction point moves away (see Fig. 5). This behaviour creates the impression of book covers bubbling up to the surface and disappearing again (inspired by the Etsy “Shop by color”<sup>2</sup>).

Selecting a cover enlarges its circular preview and shows a maximum of eight cover previews of other books with similar cover colours (see Fig. 6(a)). These adjacent books can be selected as well. In this case, an enlarged preview of the newly selected book comes into focus along with a new selection of adjacent books. Selecting a book cover that is already in focus brings up a full cover view and more detailed information such as the book title, author, and year of publication (see Fig. 6(b)).

<sup>2</sup><http://www.etsy.com/>

## 4.2 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. 7). Starting with one book of interest people can browse the book collection following from one keyword to the next. Unlike the Cover Colour Circle,

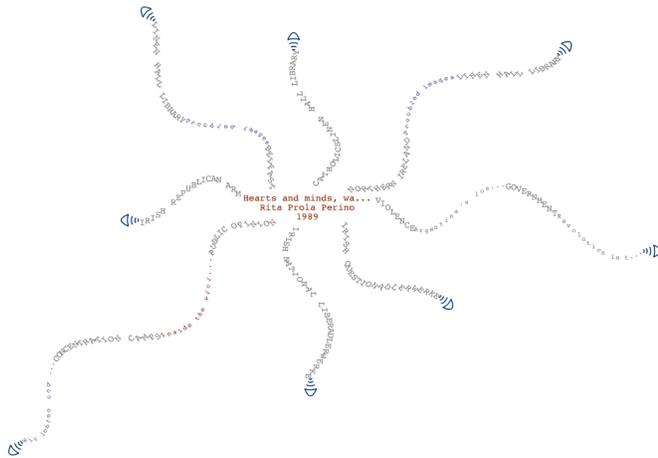


Fig. 7. Keyword Chains visualization.

the Keyword Chains visualization does not provide an overview of the whole book collection. Instead, it shows a vignette of up to 17 books connected through their keywords. The Keyword Chains visualization always displays the selected book at the centre. This book's title, author, and publication year (e.g. "Hearts and minds" by "Rita Prola Perino" in Fig. 7) are shown in the book's colour. From there, eight keywords that characterize this particular book branch out like tentacles (e.g. "violence", "Northern Ireland", etc.) as shown in Fig. 7. These keywords  $k_{1i}$  each form the start of one *Keyword Chain*. Keyword Chains alternate between keywords and book titles: each keyword  $k_{1i}$  is followed by a book title  $t_{1i}$  of another book that shares keyword  $k_{1i}$  with the book in focus. In turn, the book title  $t_{1i}$  is followed by one of  $t_{1i}$ 's other keywords  $k_{2i}$ . This keyword  $k_{2i}$ , again, is followed by a new book title  $t_{2i}$  that shares the keyword  $k_{2i}$  with  $t_{1i}$  (see Fig. 8).

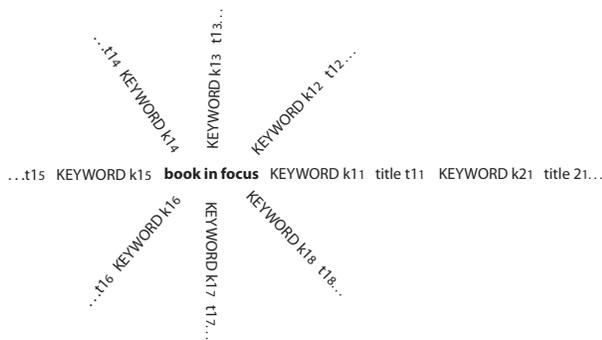


Fig. 8. Keyword Chains alternate between keywords and book titles.

Note that keywords are rendered in capital letters to distinguish them from book titles that are shown in a smaller font. Book titles and keywords that appear in a Keyword Chain are selected on a random basis from the data collection as long as they fit the criteria of connecting one book title with a corresponding keyword and vice versa.

To avoid repetitions of book titles or keywords within one Keyword Chain, we exclude items that have already been used within this chain. A Keyword Chain ends either after the second book title ( $t_{2i}$ ) or if one of the keywords has no more associated books that have not already been shown. For instance, there is no book that has the keyword "Irish Republican Arm" other than the book in the centre (Keyword Chain pointing to the left, see Fig. 7).

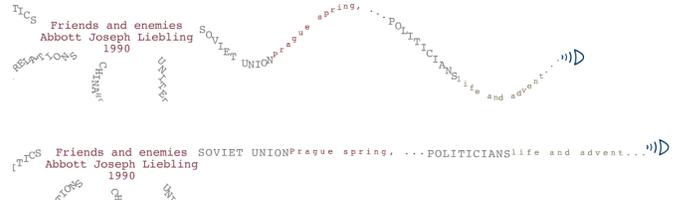


Fig. 9. Keyword Chains—animation and interaction.

Overall, the arrangement of keywords and book titles along sine-based curves (see Fig. 9(a)) provides a visualization reminiscent of a starfish meandering on the ocean bed. This organic appearance is enforced by subtle animations that cause each Keyword Chain to undulate. To facilitate reading, Keyword Chains can be stretched (see Fig. 9(b)) by selecting the marker at the end of the chain.

Selecting a book title in a Keyword Chain causes this book to move into the centre of the visualization and new Keyword Chains form around it. This transition is animated, creating the impression of tentacles growing out of the selected book title in the centre. Selecting a keyword in a Keyword Chain causes the first corresponding book in the collection to appear in the centre of the visualization.

## 4.3 Timelines

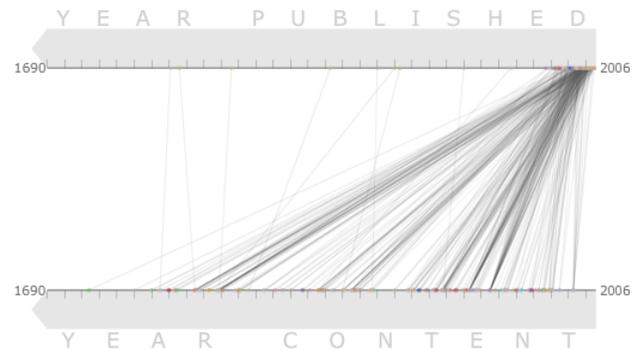


Fig. 10. Timelines Visualization.

Two important temporal aspects of books are the publication year and the time period that the book discusses. The Timelines visualization shows the relation between both of these temporal aspects of books.

The Timelines visualization consists of two parallel horizontal timelines (see Fig. 10): the upper timeline corresponds to the year of the books' publication and the lower one indicates the time periods that are the focus of the books' content. Each book is represented on both timelines by a circle coloured in the book's colour: a circle on the year-of-publication timeline indicates the book's publication year (see Fig. 11); a circle on the time-period-in-focus timeline indicates the starting point of the time period that the book focuses on (see Fig. 11). For each book, a line connects these two circles showing the relation between the book's publication year and the time period in focus. Books that focus on past times are represented by lines pointing from the year-of-publication timeline to the left, contemporary books are represented by more or less vertical lines, and books about future events are shown by lines pointing from the year-of-publication timeline to the right (see Fig. 10). Furthermore, the pattern of lines pro-

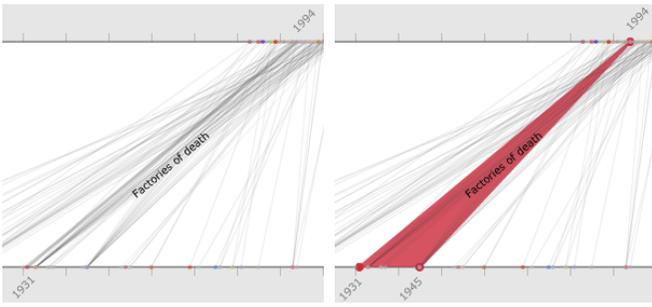


Fig. 11. Browsing and selecting books in the Timelines visualization.

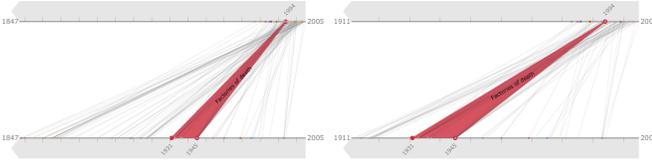


Fig. 12. Stretching the timelines shortens their time frame and spreads out books.

vides 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 years of publication or time periods with particular coverage are visible by dense line clusters (see Fig. 10).

Moving the mouse or finger across the connecting lines between the two timelines reveals the title of each book and highlights labels on both timelines, indicating the exact year of publication and the start year of the time period the book focuses on (see Fig. 11, left). This enables lightweight browsing through the book collection. Selecting a line highlights the book's publication date as well as start and end date of the time period in focus showing the resulting triangular shape in the book's colour (see Fig. 11, right). Note that this triangle is slightly transparent to prevent the complete occlusion of lines indicating other adjacent books located underneath.

With many books and a wide range of publication dates and time periods in focus, the line density increases making it difficult to select particular books of interest or to review certain time periods. We therefore provide a simple mechanism to zoom into both timelines simultaneously, making use of a rubberband metaphor. We assume that both timelines are fixed on their right end. Moving the cursor or finger in the light-grey area of one timeline to the left, causes the start year of both timelines to increase—the timelines stretch. While the overall time frame of both timelines (start and end time) is shortened, book items within this shorter time period become dispersed (see Fig. 12). Moving the mouse cursor or finger toward the right loosens the tension in the stretchy timeline: the overall time frame enlarges and the density of books in certain time periods increases again.

In some use cases, it might be desirable to zoom into both timelines independently. However, this would jeopardize the easy distinction of books focusing on the past, the present, and the future in relation to the book's publication date. In general, zooming can cause the problem of cutting off the timelines so that certain books might still be visible in one timeline but not in the other. Currently, we only display books that can be fully visible in the time frames of both timelines.

#### 4.4 Book Pile

Similar to colour, the thickness of a book and, related to this, its weight, are prominent physical characteristics that influence not only its appearance but also the reading experience. How often have you picked up a book only because it was extremely thin and quickly flipped through to see what was discussed in so few pages? Alternatively, we likely all have sought out extremely large books, not necessarily for their content but for their prominent physical appearance. We have fo-

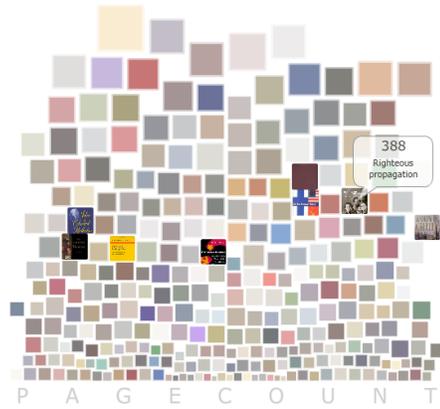


Fig. 13. The Book Pile visualization.



Fig. 14. A selected book in the Book Pile and adjacent books.

used the Book Pile visualization on exactly this aspect of books. This has strong ties to the physical properties of the book and can point the viewer toward more playful exploration approaches.

The Book Pile visualization is based on the metaphor of a physical pile of books. Each book is represented by a square. The colour of the square reflects the book's colour while its edge length represents the book's page count. The position of a square is dependent on this page count: books with fewer pages are organized at the bottom of the Book Pile while thicker books appear more toward the top. We use a stacking algorithm to position books. First, books are categorized based on their page count using 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. We place books 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.

Selecting a book's square reveals its cover. A label shows the book title and the actual page count. Furthermore, books with a similar page counts (plus/minus five pages) are highlighted by changing the colour of the book's square to a cover texture (see Fig. 14).

#### 4.5 Author Spiral



Fig. 15. Author Spiral visualization

Many libraries and bookstores organize books alphabetically by author name. With the Author Spiral visualization we adopt this common way of alphabetical organization. We added the minor variation that books are alphabetized according to Firstname, Lastname instead of the more common Lastname, Firstname. To provide space for various sized collections, the author list rolls up into spirals toward both ends, similarly to a parchment role: the stretched part of the Author Spiral shows books in form of an author label, once again using the book's colour (see Fig. 15). Toward both ends of the list, books are represented by filled circles of book's colour positioned in form of a spiral. Circles become smaller the closer they are to the spiral's centre. The size of the spirals is adjusted depending on the number of books listed on each side. The number of books shown in the stretched middle of the parchment stays constant. This makes it possible to determine if a selected book is located more at the beginning or more at the end of the book collection. Figure 16 shows the Author Spiral with different selected books and exemplifies how the spirals change accordingly.

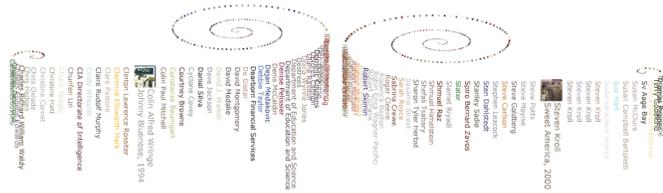


Fig. 16. Selected books close to the beginning and end of the collection sorted by author name.

Selecting a book (text label or circle) moves this book into the centre of the “parchment stretch” and reveals a squared preview of the book's cover, as well as its title, author, and year of publication. Since circles within the spiral can be small and hard to select, they enlarge underneath the selection (by cursor or finger) to facilitate the selection process (see Fig. 17, left). To provide feedback about selections while moving the cursor or finger across the author labels, the author label directly below the selection point is slightly indented (see Fig. 17, right).

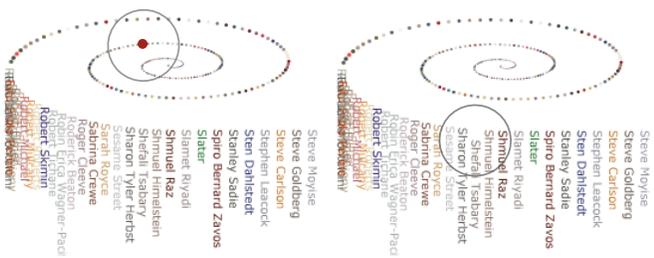


Fig. 17. Selected books from the Author Spiral.

#### 4.6 Interlinked Visualizations in the Bohemian Bookshelf

Together, all visualizations described above form the Bohemian Bookshelf and are displayed at all times. However, to provide sufficient space for the visualization at the focus of the current interaction, it is centred and enlarged while the others are shown in miniature (see Fig. 2). These peripheral visualizations change according to selections that are being made in the central visualization. For instance, Figure 2 shows the Book Pile as the central visualization through which the book “Righteous Propagation” has been selected. Therefore, the Keyword Chains visualization also shows this particular title and its eight characterizing keywords (see Fig. 2). The Timelines visualization highlights the book by showing a coloured triangle consisting of this book's publication year and start and end of the time period it focuses on. The Book Pile emphasizes the page count of the selected book and highlight books with similar page counts, and the Author Spiral highlights the book embedded in the alphabetical author list. All

visualizations look and react exactly as they would if the book would have been directly selected within them, except the Keyword Chains visualization that, due space constraints, is limited to showing only one set of keywords.

The concept of a single, central interactive visualization and several peripheral visualizations enables browsing through book items in one visualization while still offering different views and representations of these items in the periphery. If a peripheral visualization catches someone's attention, it can easily be selected and made the central visualization to explore it further. With this selection an animation occurs where the former central visualization shrinks and moves to the outside while the selected visualization enlarges and moves to the centre of Bohemian Bookshelf. Furthermore, current selections remain unchanged to maintain the search context and provide people with a familiar reference point within the new visualization in focus.

### 5 SERENDIPITY SUPPORT IN THE BOHEMIAN BOOKSHELF

The Bohemian Bookshelf represents a rather unorthodox take on the exploration of digital book collections. In the following section we discuss the features of the Bohemian Bookshelf in the light of our design goals for encouraging serendipity through information visualization.

#### 5.1 Providing Complementary Access Points

On a conceptual level, books provide many attributes that can be leveraged for organization in a variety of ways. However, digital library catalogues commonly focus only on content-related attributes of books (most particularly the author, title, and genre). The tangible and aesthetic qualities of books that come across on a physical bookshelf are often lost. When designing the Bohemian Bookshelf we aimed for organizing the book collection based on content-related metadata as well as attributes that emphasize the physical appearance of books. The resulting interlinked overview visualizations of the Bohemian Bookshelf offer multiple perspectives or *facets* [49] on the digital book collection that can act as starting points for the exploration.

Individually the visualizations that make the Bohemian Bookshelf provide limited explorations of the book collection. However, together these visualizations provide a synergistic experience that can propagate serendipity by encouraging viewers to experience the collection from a variety of perspectives and viewpoints.

#### 5.2 Enticing Curiosity through Visual Aesthetics

Each individual visualization was designed to visually reflect on the data attributes they represent. The Book Pile is reminiscent of an actual pile of books, the Author Spiral plays with the idea of a parchment roll, the Cover Colour Circle highlights the aesthetics of book covers, the Timelines visualization resembles a classical timeline, and even the Keyword Chains visualization brings to mind a word map assembled from linked terms. While the Bohemian Bookshelf may not resemble existing interfaces that people have experienced, the design of the visualizations makes use of familiar metaphoric connections to assist in learning their use.

#### 5.3 Highlighting Alternate Adjacencies

The spatial arrangement of books that all visualizations of the Bohemian Bookshelf provide, makes different types of adjacencies within the book collection implicitly visible: related books (books with similar colour, temporal dimensions, page count, or authors names that start with the same letter) are positioned in close proximity—in the Cover Colour Circle even in aggregated form. An exploration of the Author Spiral, for instance, shows books of the same author next to each other. Similarly, the patterns within the Timelines visualization provide an overview of the distribution of books over time. People who are interested in a certain time period will find a number of books that focus on this period from different perspectives (e.g., history, art, or fiction). Regarding serendipity, making adjacency-based patterns in large data collections visible can lead to general insights about the collection and may lead to new ideas on how to approach a new topic or reveal surprising aspects of a known topic.

In addition, the Bohemian Bookshelf emphasizes adjacencies within the collection on book-level. For instance, upon the selection of a book, the Cover Colour Circle brings up cover thumbnails of other books related by colour (see Fig. 6(a)). The Keyword Chains visualization shows individual book titles that share at least one keyword and emphasizes connections between keywords that characterize the same books (see Fig. 9). The latter can be useful when researching a broader topic: one keyword of interest might be related to another one in an unexpected way and lead to a new interesting topic for exploration. The combination of visual overviews and emphasis on individual books aims to mimic several different “browsing the shelves” experiences that have been shown to support serendipitous discoveries [14, 19, 43].

#### 5.4 Visual Pathways as Serendipitous Guides

The visualizations of Bohemian Bookshelf offer multiple pathways through the book collection that can provide guidance in a serendipitous way. The visual overviews can provide one way of exploring books. For instance, visitors can systematically browse through all books of their favourite colour and, in this way, possibly encounter books that are of interest to them but that they did not think of to search for directly. Furthermore, emphasizing adjacent books can be considered as visual signposts. For instance, following up on highlighted books in the Book Pile is likely to rapidly guide people serendipitously to different topical areas of the book collection. As a third approach to multiple pathways, all visualizations of the Bohemian Bookshelf are interlinked with each other. Therefore, every selection of a book in one visualization can be considered a cross road to the other visualizations that highlight this selection as well in their particular context. A person, for instance, being interested in the medieval, might start her exploration with the Timelines visualization. She selects a book of potential interest, and finds it highlighted in the Author Spiral. While she did not know the author of this book before, and had no intention to search for him, she decides to switch her focus on the Author Spiral to check out more of his books.

#### 5.5 Immediacy of Previews

Highlighting adjacencies on book-level, is particularly important for visualizations such as the Cover Colour Circle that provides an overview of the collection in aggregated form. Showing the cover thumbnails of related books, makes individual books accessible. In this way, people can quickly follow up on a potentially valuable discovery and decide if they would like to examine a particular book in more detail or move on with their general exploration. While the Bohemian Bookshelf enables this quick investigation on book-level, it does not provide elaborate details for each book such as a table of contents or a content summary. Such details could be integrated into the visualization directly, or, alternatively, provided through links that guide visitors directly to the book listed in the library catalogue.

#### 5.6 Aesthetics & Playful Interaction: An Invitation to Dwell

The design of the Bohemian Bookshelf is strongly focused around the use of aesthetic visuals and playful interaction to not only evoke curiosity and initiate exploration but also to promote pleasurable experiences when exploring book collections. With the choice of unusual visuals we aim to support a presentation that prepares and encourages people to explore books from unusual perspectives and to be open for serendipitous discoveries. In addition, we aim to encourage prolonged interaction that, enhances the chances of serendipitous discoveries.

The Cover Colour Circle in particular exemplifies visual aesthetics and playful interaction. The circular layout of different sized circles ordered by colour provides a visually pleasing overview that evokes curiosity. Most people have a preference for particular colours, which may initiate interaction. Every interaction with the Cover Colour Circle is rewarded with immediate, at times animated, visual feedback. On the one hand this feedback enables people to learn how to interact with the Cover Colour Circle without prior instructions. On the other hand, the visual feedback has an aesthetic quality that can promote further interaction. In similar ways, all visualizations in the Bohemian

Bookshelf have aesthetic and interactive features that make them distinguishable and provide for a unique exploration experience. At the same time, visual variables are used consistently. For example, colour, in all visualizations refers to books’ cover colour. This consistency helps the interpretation of the visualizations and draws connections between them. Furthermore, while all visualizations are rather abstract, the thumbnail view of books used by the Cover Colour Circle, the Book Pile, and the Author Spiral provides a familiar representation.

## 6 RELATED VISUALIZATION APPROACHES

To our knowledge, serendipity has not been addressed as a goal in information visualization. Yet, different approaches exist that we leverage in the design of the Bohemian Bookshelf to support serendipity.

### 6.1 Visualization of Document Collections

Some tools have been developed that visualize search results in relation to the whole document collection (e.g. [6, 16, 42]). 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 [30]. 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 [12, 17, 25, 26]. Such visualizations can offer an efficient and analytical view on data. Other visualizations of book collections make use of metaphors that realistically mimic the look and feel of traditional bookshelves to leverage people’s familiarity with physical libraries [5, 36]. 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 document collections to encourage serendipitous discoveries.

### 6.2 Coordinated Views for Document Exploration

Coordinated views provide two or more 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 and accessed by a diverse audience [3]. North and Shneiderman even highlight multiple views as beneficial for the “discovery of unforeseen relationships” [34]—serendipitous discoveries, in other words. Coordinated views have been used for text or document exploration before. VisGets, for instance, can facilitate the exploration of blog entries by time, geographic location, and tags [10]. EMDialog uses two interlinked visualizations to visualize the discourse around the life and work of an artist along temporal and contextual dimensions [21]. However, the use of coordinated views has not been discussed in the context of serendipity.

### 6.3 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 photographs and keywords to represent the most recent news ordered by topic [32]. “Making Visible the Invisible” is an ambient large display visualization installed at the Seattle Library that cycles through different visualizations of media being checked out of the library during the past hour [28]. ResearchWave is an ambient visualization that represents different aspects of publications to maintain awareness of activities within large research organizations in a casual way [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 design of the Bohemian Bookshelf exemplifies how to encourage serendipitous discoveries through information visualization in a more systematical way that goes beyond fortuity and coincidence.

## 7 DISCUSSION

With the Bohemian Bookshelf we explore a first approach to encouraging serendipitous discoveries through information visualization. As a first prototype it raises some interesting questions to be explored in the future.

### 7.1 Serendipity at the Appropriate Time

The highly open-ended exploration approach that the Bohemian Bookshelf offers may appear as distracting or even misleading in the scenario of a targeted search. It is therefore important to consider the appropriate time and context when serendipity can hit fertile ground. André et al. suggest to present potentially serendipitous content upon request so that people can engage with it, for instance, during idle moments [1]. However, this requires people to consciously decide between targeted search and more open-ended information exploration. Another strategy could be to offer textual query-based search and open-ended exploration strategies side-by-side. Visualization systems such as the Bohemian Bookshelf can be applied as a web-application where people can use it solely or in addition to query-based interfaces. It can also be integrated on a large direct-touch display in a physical library. Many libraries have started to move toward digitizing their collections. Visualizations such as the Bohemian Bookshelf could offer a replacement for traditional bookshelves in an attractive way that still supports serendipitous discoveries. Similarly as with physical bookshelves, patrons could casually engage in book explorations.

### 7.2 Scalability

The images of the Bohemian Bookshelf visualizations that we included in this paper are based on a set of 300 books. Adding larger datasets leads to performance issues with the current version of our visualization prototype that was implemented in Adobe Flash®. While the performance could be easily improved by applying more potent implementation strategies, the question arises how scalable the visualizations of the Bohemian Bookshelf are from a design perspective. To make the visualizations scalable to thousands of books—a realistic number for most library collections—some of the visualizations, including the Book Pile and the Author Spiral would need to be adjusted 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 keep line patterns within the Timelines visualization visible even with much larger amounts of books.

### 7.3 Alternate Visualizations & Datasets

The Bohemian Bookshelf currently offers five different visualizations that focus on our diverse selection of book metadata. However, there are many options to extend our approach to (1) other types of visualizations, (2) other types of metadata, and (3) combinations with different search strategies. For instance, we can imagine many different ways to visualize keywords of books. Also, there are other metadata that could be integrated as alternate visualizations into the Bohemian Bookshelf, for instance, the popularity of books based on their number of check-outs. Furthermore, the idea of the Bohemian Bookshelf can be combined with more targeted search strategies while still offering some room for serendipitous discoveries. While we decided to focus on providing overviews of the entire collection, an additional query interface could be provided that allows people to narrow down the visualizations to reflect book collections that fit particular search terms.

There are many datasets that could benefit from the serendipitous approach to information exploration that the Bohemian Bookshelf aims to support. Many people own large digital music collections and oftentimes do not even remember the huge variety of albums they actually own. Visualizations such as the Bohemian Bookshelf could help them to serendipitously (re)discover forgotten items in these collections. Other possible datasets that this approach to information visualization might be applicable to include news feeds, photos, videos, or digitized paintings (see [21]).

## 7.4 Evaluation

The design of the Bohemian Bookshelf follows from the highly general recommendations on how to encourage serendipity provided by existing literature. Many of these recommendations follow from studies on how serendipitous discoveries have happened in the past (e.g., [13, 14, 43]). Our design goals for supporting serendipity through information visualization and, in turn, the design of the Bohemian Bookshelf, are therefore not fabricated but grounded in literature from information and library sciences as well as information visualization and human-computer interaction. However, we of course realize that studying the Bohemian Bookshelf in use will provide insights on how people make use of the provided visualizations and whether they actually support serendipitous discoveries as anticipated. More generally, such a study will assist in refining our design goals for supporting serendipity through information visualization and help to ground our design goals empirically. While the targeted audience for the Bohemian Bookshelf is the library going public, we also consider librarians an important, less direct, audience for the Bohemian Bookshelf. The librarians of our local university library have selected the Bohemian Bookshelf for use in their entrance foyer of the new “Digital Library” building on campus. The selection for such a venue is a validation in itself of both the Bohemian Bookshelf and its underlying concepts. Further, it will allow us to conduct a study in collaboration with a university library where the Bohemian Bookshelf will be installed on a large touch interactive display.

## 8 CONCLUSIONS

In this paper we have discussed serendipity as an information visualization goal. Serendipity has been found to be an often neglected but important factor in information seeking, research, and ideation. However, the approach of most search interfaces to digital collections is targeted more toward “minimizing the number of possibly *irrelevant* objects” rather than “maximizing the number of possibly *relevant* objects” [30]. This does not specifically encourage serendipitous discoveries. We have introduced the Bohemian Bookshelf that exemplifies how serendipitous discoveries can be supported through information visualization in the context of digital book collections. We have presented a list of design goals that have guided the design of the Bohemian Bookshelf. This list was derived from previous literature that has provided high-level recommendations for encouraging serendipity. We have discussed how our design goals are met through the Bohemian Bookshelf. These goals can be considered as a first step into exploring information visualization as a way to encourage serendipitous discoveries. While these goals are applicable to a variety of different scenarios and datasets, future case studies will help to evaluate and further expand these goals to a solid set of recommendations for encouraging serendipity through information visualization.

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