

Reading Traces: Scalable Exploration in Elastic Visualizations of Cultural Heritage Data

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Figure 1: Reading Traces is a visualization of the reference library of Theodor Fontane. The “distribution mode” (left) represents the frequency of reading traces along the linear reading order of the books, and the “similarity mode” (right) arranges books and authors based on similarity measures. Both modes offer the possibility to navigate between granularity levels (top down and reverse).

Abstract

Through a design study, we develop an approach to data exploration that utilizes elastic visualizations designed to support varying degrees of detail and abstraction. Examining the notions of scalability and elasticity in interactive visualizations, we introduce a visualization of personal reading traces such as marginalia or markings inside the reference library of German realist author Theodor Fontane. To explore such a rich and extensive collection, meaningful visual forms of abstraction and detail are as important as the transitions between those states. Following a growing research interest in the role of fluid interactivity and animations between views, we are particularly interested in the potential of carefully designed transitions and consistent representations across scales. The resulting prototype addresses humanistic research questions about the interplay of distant and close reading with visualization research on continuous navigation along several granularity levels, using scrolling as one of the main interaction mechanisms. In addition to presenting the design process and resulting prototype, we present findings from a qualitative evaluation of the tool, which suggest that bridging between distant and close views can enhance exploration, but that transitions between views need to be crafted very carefully to facilitate comprehension.

CCS Concepts

• Human-centered computing → Information visualization;

1. Introduction

Since the emergence of digital methods in the humanities, there has been an ongoing debate about the appropriateness and usefulness of quantitative techniques such as distant reading compared to hermeneutic, qualitative approaches [Dru11, Mor13, MLCM15, HFM15]. While qualitative approaches deal with phenomena on an individual level and therefore demand a close view on objects, quantitative methods à la distant reading are used to discern broader patterns inside a larger corpus through statistical metrics and computational means. Overview visualizations for cultural collections are becoming as common as detail views of their corresponding objects, and the combination of these two modes has already proved valuable for the exploration of cultural heritage data [WFS*19]. Meanwhile, a considerate combination of quantitative and qualitative methods is increasing as well [HFM15, JFCS15].

While there has been prior work on bridging distant and close viewing [GPD17, KJW*14, JFCS15], the corresponding transitions between views of distance, proximity, and multiple abstraction levels have received relatively little theoretical or practical consideration. With this research, we examine how the careful design of interactive transitions and representations could improve the *scalability* of a visualization. Here, scalability does not refer to the algorithmic processing of large data quantities, but rather to the comprehensible scaling of visual representations between different levels of granularity, complexity, and abstraction in an information visualization. The assumption is that such a cognitive scalability of the exploration fundamentally relies on the elasticity of a visualization. For the purpose of this research, *elastic visualization* refers to coherent representations that tightly integrate interactivity and visual encodings with the aim of achieving coherence across multiple perspectives. In other words, transitions need to be designed in parallel with visual encodings, and vice versa. For this we need to better understand how elastic visualizations can be conceived to support scalable exploration across coherently connected views.

In this paper, we pursue these questions and present findings from a collaborative prototyping process as part of an interdisciplinary research project on a cultural heritage visualization. By presenting a design study on the visualization of Theodor Fontane's reference library, a digitized collection of 155 books with more than 64,000 pages and approximately 9,600 reading traces including almost 2,500 marginal notes, we present the concept of scalable exploration and reflect on its potential for scholarly use, but also, more generally, for the design of elastic data visualizations.

For this project, the focus of humanistic inquiry is on the various reading traces: marginalia, markings, provenience marks, supplemented material, and other signs of usage (e.g., fingerprints). Fontane, a popular German realist author, engaged deeply with the books in his library, which becomes apparent in the numerous annotations and markings that mainly he, but also contemporaries, his family, and others left in them (see Fig. 2 for an example). So far, a detailed study of the entire reference library is pending. The digitization of the reference library gives way to this visualization project, which seeks to offer a first overview of the collection and enable access to the single books and annotations. The aim of this research is to facilitate both quantitative and qualitative encounters on multiple levels.

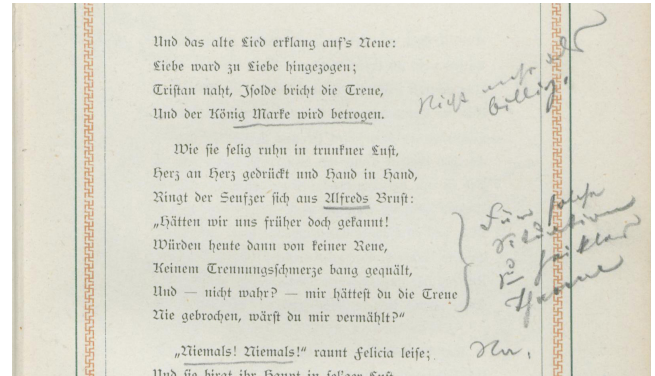


Figure 2: Reading traces by Fontane in the form of marginalia and markings in a book from his reference library.

We make two main contributions: First, we introduce scalable exploration as a design principle for the creation of coherent information visualizations. Second, we present the results from an interdisciplinary design study with literary scholars in which we devised elastic visualizations of a reference library. We recount our iterative and collaborative design process and share the results from a qualitative evaluation. While we see promising indicators for the facilitation of exploration in the use of a scalable interface, the outcome of the evaluation in fact paints an ambivalent picture. We think of this design study as an interpretative approach to visualization research, applying a novel concept to visualization design in a case study and evaluating its merit.

2. Related Work

This work draws from two research areas: the visualization of cultural collections within the digital humanities and, more generally, prior visualization research on animation, transitions, and fluidity in service of open-ended exploratory experiences. Despite efforts to offer interfaces focused on exploration rather than search, the promise of open-ended exploration in cultural heritage interfaces oftentimes does not hold true; on the contrary, the interfaces tend to feature dead-ends in their navigation paths [KBD17]. Nevertheless, over the last few years, interfaces for cultural heritage collections have attracted the interest of researchers and practitioners in particular with the aim to enhance “explorability”, “generosity”, and “serendipity” [DCW11, THC12, Whi15, WFM*16].

According to Shneiderman's information seeking mantra [Shn96], overviews are oftentimes used to provide an entrance point to a collection [Whi15, WFM*16]. Nevertheless, interaction with overviews of individual data entities based on filtering and zooming comes with difficulties; overviews of datasets of up to billions of data points are limited by visual, technological, perceptual and cognitive challenges, making aggregation and grouping inevitable [Shn08]. On the one hand, “distant reading” [Mor13] is an established overview method in the digital humanities used to gain insights in large literary corpora by examining quantitative patterns. On the other hand, accommodating the transition and interplay between distant (abstract) and close (detailed) representations still concerns the digital humanities [KJW*14, Wei17, JFCS15].

The use of animation to transition between multiple states of a view has been a central concern in HCI and visualization research. Animated transitions have become indispensable and are used with several intentions, e.g. for “Keeping in Context,” “Teaching Aid,” “User Experience,” “Data Encoding,” “Supporting a narrative,” etc. [CRP*16]. Early on, the technique of semantic zoom [PF93] and the project pad++ [BH94] built on continuous zoomable information spaces. Approaches such as degree-of-interest, overview+detail or focus+context point to the possibilities of user-centered, flexible information spaces [CN02, CKB09, vP09]. Especially Focus+Context techniques like accordion drawing or fish-eye are often used to allow a more detailed view on a specific area of interest inside a visualization [e.g., [BLC12, CSWP17, MHK*14, RROF18, SHM05]]. One emphasis here is the facilitation of “flow” in the information seeking process, which inspired researchers early on [Csi90, Pac04]. The concept of visual momentum furthermore signified the informational coherence between different views [Woo84]. Implementing these theories into concrete animations, the concept of fluid interaction enables users to navigate through a visualization smoothly [EMJ*11].

Regarding “flow” in visual data-driven stories, research indicates that animated transitions can positively influence reader-engagement. The influence on engagement of discrete scrolling navigation compared to continuous scrolling as a form of movement between views is still open for further research or at least may have less impact [MRL*17]. Even though several studies suggest that animated transitions could facilitate comprehension and perception of display changes [BB03, HR07, KCH19], it proves challenging to make the process of large display changes traceable [CDF14]. Tversky and Morrison link the effectiveness of animations to the principles of “congruence” (form should match underlying content and concept) and “apprehension” (possibility to accurately perceive and comprehend the form), stating that animations oftentimes are too complex and fast to result in accurate comprehension. The use of animations nevertheless offers the potential to encode additional information. This is why studies on the effectiveness of animations when compared to static graphics oftentimes do not use equivalent conditions [TMB02]. Exploring the effects of novel staged animated transitions for aggregation operations, Kim et al. found that staged animated transitions can contribute to the comprehension of a performed aggregation. On the other hand, staged animations sometimes perform worse than static view changes regarding response time. Test participants nonetheless favored staged animations over static or interpolated ones [KCH19].

3. Towards Scalable Exploration

With this research, we want to contribute to the ongoing work in information visualization on animation and interaction, and specifically set a focus on designing for scalable exploration. Although the ideas of open-ended exploration and flow are widely recognized, methods like animated transitions only serve the facilitation of such states to a certain degree. While semantic zoom supports a form of vertical scaling, it is usually limited to zoom and neglects the possibility for differing granularity levels of data on the same horizontal plane. Focus-context techniques on the other hand are oftentimes used to deal with varying complexities on a horizontal

level, but fail to integrate vertical zoom operations. Furthermore, prior research on animated transitions mainly studies their impacts and possibilities inside a laboratory setting of isolated visualizations or fixed transition states, limiting the animation design.

Building on prior exploration and animation research, this design study aims to show how to achieve continuity with multiple arrangements and levels of abstractions, while simultaneously considering information structure and representation changes. We introduce the concept of scalable exploration as an analytical activity relying on multiple, connected representations with various levels of granularity. It offers answers to the question of how open exploration can be supported, while context is maintained throughout the abstraction processes. Visualizations designed for scalable exploration can thus be described as an elastic system, offering multiple options for interaction, while striving for coherence between different states. Elasticity suggests that elements are not cut off and arrangements are not abruptly changed during the process of interaction, but remain intact through forms of stretching and distortion as well as reduction and expansion. The conceptual approach to the visualization development is therefore the main quality that differentiates our design study from other work. One premise here is that designing for elasticity and scalability requires the joint consideration of encoding, interaction, and the in-between-states early on in the design process in order to reach and maintain coherence in a visualization.

To this purpose, we are devising, using, and evaluating animated and viewer-controlled transitions in a prototype, designed to convey operations in the context of granularity changes as well as a form of keeping context between multiple states. We consider and carefully design representational changes on multiple levels while at the same time retaining a certain level of coherence. Questions that might be asked in the creation of a visualization for the purpose of scalable exploration are: How can integrated transitions be designed to bridge views using differing forms of abstraction? How can they be designed to convey meaning and add to the understanding of a visualization? How can different visual representations of the data be designed and linked to each other? How do we deal with discontinuity between different states of a visualization?

4. Visualizing Reading Traces in an Author’s Library

In the digital humanities, the interplay—and perhaps also tension—between distant and close reading resembles the juxtaposition of overview and detail in information visualization. During an interdisciplinary visualization research project on the visual analysis of reading traces in an author’s library, we were faced with questions of representation and animation accordingly. The joint research with our literary collaborators offers an opportunity to pursue questions of scalable exploration, linking modes of distance and proximity with continuous transitions. They are interested in gaining new insights into the complete corpus through distant perspectives, while also observing the necessity to analyze phenomena on an individual level. In the following, we introduce the corpus and describe the design considerations and decisions that emerged from a reciprocal cooperation between visualization research and literary studies.

4.1. Project Collaboration and Background

Reference libraries hold the books an author has read, possessed, or used in the production of their works. In literary studies, there is growing interest in the digitization and study of reference libraries as they provide additional context to make sense of an author's oeuvre [VHVM04]. Today, 155 books from Fontane's reference library are (re)stored in the Theodor Fontane Archive in Potsdam. For the project, they were digitized individually, forming a dataset of approximately 64,000 pages. The books vary deeply in topic, length, and style, but also in the way Fontane made use of them: Some show heavy signs of reading and annotating, while others have remained rather untouched. For the project, the annotations, markings, comments and additional material were transcribed and added to the dataset during the digitization. The variety of reading traces can open up new perspectives on the author, his works and working habits, as well as his personal thoughts and is thus of great interest to researchers [Bus19].

The digital presentation of reference libraries has, until now, often been limited to the provision of digital catalogs that make library metadata and digital copies available in a specific viewer and/or as a PDF download. While these forms of presentation do provide access to the material for research, they hardly convey the autographical patterns in the book collections, which are distinctly characterized by the reading traces that have been left in them. While current research practices are based on time-consuming extensive individual book research and oftentimes require applications to get access to the books, we aim to devise modes of access that provide synoptic perspectives on the whole material at once as well as detailed views on particular books and pages. This resembles what Wieland calls a diachronic-vertical way of reading the reference library in addition and distinction from the usual horizontal reading [Wie15]. The goal of the project was not to provide a research tool for close-reading practices, e.g., by developing an integrated PDF viewer for annotation, but to create a tool that enables a completely new perspective on the material for exploration, serving as an entrance point to the formulation of tentative research questions.

In order to link our visualization questions with domain-specific research requirements, we followed a grounded design process [IZCC08]: the project was conducted in an interdisciplinary team with academic expertise in literary studies, interface design, and visualization research. In a rapid-prototyping process we iteratively generated small prototypes and conceptual sketches to familiarize ourselves with the collection, to identify first interesting patterns and to stimulate discussions with our partners. A joint presentation at conferences helped identify relevant user-tasks for researchers of author's libraries. Research questions from our partners extend over a wide range of questions, such as *"which books are annotated extensively?"*, *"what are common types of marginalia?"*, *"are there certain authors whom Fontane is more likely to judge than others?"* or *"did Fontane work differently with his own books than with those of other authors?"* Besides finding answers to questions, even more important was the desire for a completely new perspective on the data, potentially opening up completely new research questions or possibilities that may not emerge through extensive individual linear book research.

A particular characteristic of the collaboration was the simultaneity of data acquisition and the visualization design process, which led to a mutual influence of research and design practices, e.g. prioritization of some functionalities over others. In initial visualizations, it became once more apparent that data are inherently subjective: It was partly visible which researcher had annotated which books, leading to an accumulation of specific categories. Here, the visualization helped to make such initial interpretations visible, while patterns and findings from the growing dataset on the other hand influenced the design of the prototype. While it was sometimes challenging that the dataset was developing slowly, it reinforced one of the main takeaways from this research format, which was that visualizations serve not only to transfer knowledge, but—as described by similar interdisciplinary design studies [HFM15]—also contribute to (humanist) research processes themselves.

4.2. Design

The visualization of the reference library, developed with the JavaScript library D3.js [BOH11], features two modes, each providing access to multiple granularity levels to help explore the data from different perspectives (see Fig. 1). While the first mode ("distribution mode") arranges and directly visualizes the frequency and types of reading traces along the linear reading order of the books, the second mode ("similarity mode") displays books and authors based on similarity measures according to frequencies and types of reading traces left in the books. The purpose of the "distribution mode" is to reveal broader patterns in the reading traces over the whole corpus at various levels of granularity. On the other hand, the aim of the "similarity mode" is to highlight unexpected statistical similarities and features. In coordination with the team at the Theodor Fontane Archive, we focused on the comparability of authors, but with the idea to create design concepts that could in principle be transferred to other types of categorizations and accumulations (e.g., genre).

In both modes, the visualization design focuses on continuous navigation that can be zoomed and filtered on several levels, along which particular reading traces as well as broader patterns can be discerned. Scrolling up or down leads to continuous transitions between three levels in the distribution mode—authors, books, and pages—and two levels in the similarity mode—authors and books (see Fig. 1). Akin to semantic zoom [PF93], scrolling upwards leads to higher levels of abstraction and downwards to more detail. Following the principle of apprehension [TMB02], the goal of scrolling as the main interaction method is to promote user-dependent transition speed that allows for perception and comprehension of meaning during the process of transitions, while retaining continuity and context between the various granularity levels. To arrive at smooth transitions, a user's scroll position in the website is directly translated to a state in the visualization, which leads to scroll position dependent gradual changes in the visualization. However, as an alternative to scrolling between the different levels, there is also a navigation bar on the left that contains buttons for switching between the modes and a vertical slider indicating the current position and offering an animated switch between the levels per click selection or by dragging the slider.

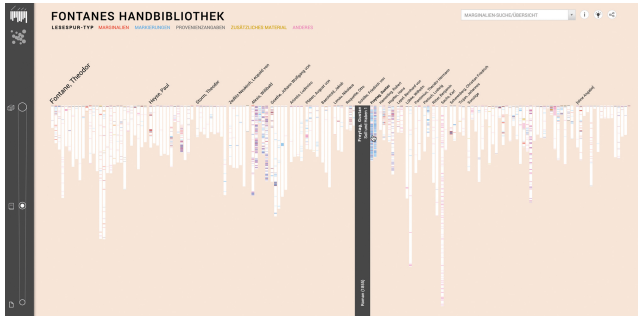


Figure 3: Landing page/book level inside the distribution mode with overview of all 155 books displayed in form of vertical bars, ordered by author. Navigation bar on the left side in grey, with buttons on the top to switch between the modes and a draggable and clickable scroll indicator/slider.

A filter bar above the visualization in both modes serves as a legend for the color coding and offers the possibility to focus on certain reading trace types. To reduce perceptual difficulties caused by too many nominal color categories [Mun14], subcategories (e.g., comments) of a main category (e.g., marginalia) are only unfolded through a click on one category, which also applies the responding filter to the visualization. Unfolding of subcategories fans out the color of the selected category into additional nuances of the same color to allow further differentiation between the respective subcategories, while blending out other categories (see Fig. 4 & 6). In general, while white represents the absence of any type of reading traces in a page, the five main categories of reading traces are differentiated by color that can be seen in both visualization modes. Here, considerations of each category's importance informed the choice of color, which is why marginalia are indicated in red tones and provenance data assume gray tones:

1. marginalia (red): ratings, comments, text corrections, text variants, translations
2. markings (blue): underlinings, highlightings, text cancellations, other marks
3. provenance data (gray): ownership/provenance notes, institutional stamps
4. additional material (yellow): glued-in newspaper articles, etc.
5. other reading traces (pink): dog-ears, stains, fingerprints, etc.

With the intention to reach coherence between the levels, it was important to match the main encodings across all views. In both modes, the color encoding is consistent across all levels. Another constant is the logic behind the placement of elements. While in the “distribution mode” vertical placement is based on the linear appearance of reading traces in the books, the horizontal positioning of books is based on a grouping by author, ordered by number of books by an author. In contrast, the positioning of elements in the “similarity mode” is based on similarity measures inside an abstract plane, which disregards the linear order of the reading traces and dissolves the differentiation between individual pages. While the design of a meaningful transition between both modes was a desired goal, we did not arrive at a useful outcome. In addition to the break of elastic visualizations, in order to emphasize the differ-

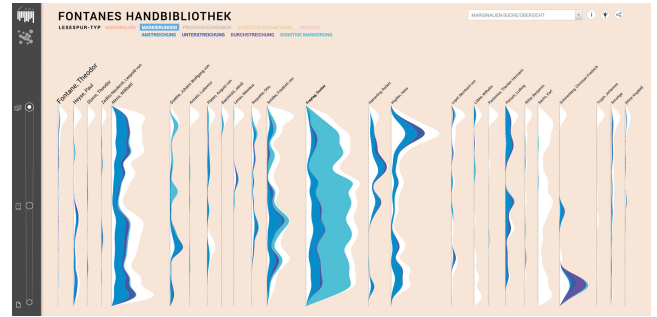


Figure 4: Author level inside the distribution mode, unfolding the colors of the applied filter “markings” into multiple shades of blue.

ent logic behind both modes, the background color changes from a brighter beige to a dark blue. Moving between the different levels and modes of the visualization, the filter selections are maintained in order to allow for fluent motions between the two visualization modes and the granularity levels. In addition, all selections, filters, and the zoom level are encoded in the URL, allowing exact link referencing, bookmarking, and sharing of particular views.

4.2.1. Distribution of Reading Traces

The starting point for exploring the visualization is the **book level** of the distribution mode, which provides an overview of all books in the reference library, sorted by authors (see Fig. 3). Each book is represented by a vertical bar, in which one page is represented by a rectangular segment, displayed in reading order of the individual books from top (first page/cover) to bottom (last page/cover). By assembling each page in the form of individual segments, the book length can be estimated by comparing the length of the bars. While pages without reading traces are displayed in white (visible due to the beige background), pages that contain reading traces are colored according to the category of their occurrences, creating a kind of bar code that is unique for each book. By displaying all books in “small multiples” [TGB90] next to each other, the juxtaposition is used to enable overall comparison and to expose patterns [GAW*11]. Hovering over the bars displays respective general information about the book (title, genre, date of publication). Clicking on a book at the book level unfolds additional information (e.g., cover image, title, date of publication, etc.), shows the count of pages on which reading traces occur, and gives an overview of the transcribed marginalia.

Navigating up leads to the **author level**, where all books of all authors are grouped together by presenting the average distribution of reading traces in the form of an area chart. The decision to use the abstraction of area charts instead of more concrete forms of accumulating discrete points, such as bee plots, was informed by previous prototypes, which suffered from space and performance issues. The resulting curve shows the average distribution of reading traces within all works of one author from top (book start) to bottom (book end). Here, a staged transition between the levels is used to communicate the basic data operations of normalization and accumulation, by first normalizing all book bars to one length. Thereafter the book-bars for each author merge and an area chart

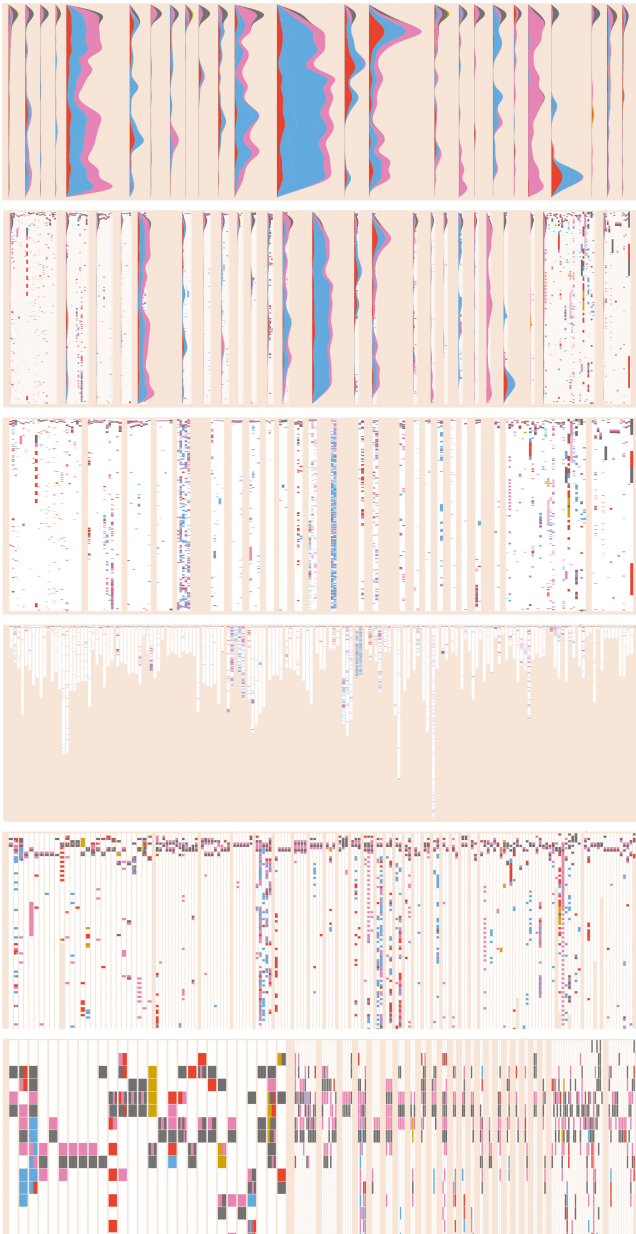


Figure 5: Staged transitions between the author (top), book (center), and page (bottom) levels of the distribution mode.

appears, conceptually linking the previous normalized positions of the reading traces to the vertical axis and the number of traces to the horizontal axis in the subsequent chart, which enables the viewer to make a connection between the displayed states (see Fig. 5).

Navigating down from the starting point (book level) leads to the **page level**, enabling a zoomed-in view of individual pages and reading traces with focus on books of one selected author (see Fig. 1 bottom left). Hovering over a page segment displays a scan of the respective page. In addition to the change between granularities and filtering, clicking on a book unfolds further details and com-



Figure 6: Page level in the distribution mode with a book and filter selected and hover over an element. Through the selection of the book, additional details have been unfolded, displaying the number of reading traces on the page, the transcriptions for the marginalia of a page and the (assumed) author of marginalia.

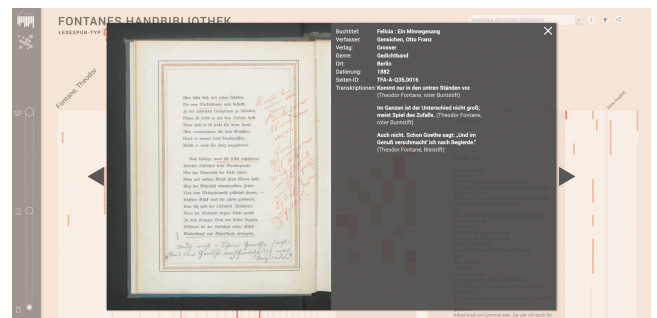


Figure 7: Detail view of one page, showing the scan, meta data, and transcriptions of marginalia.

presses the other books, using a focus+context approach [CKB09] similar to accordion drawing [SHM05]. After reaching the page level, further scrolling down makes the visualization fall back to the browser's usual scrolling behavior, enabling vertical movement through the zoomed-in reading traces. Clicking on a book at the page level offers the selection of individual reading traces and shows the transcribed marginalia directly next to the corresponding page segments (see Fig. 6), which includes an icon that can be hovered for a (presumed) identification of the marginalia's author. Another selection opens a detail view of the page showing the respective scan image (see Fig. 7).

Finally, a search field, which serves simultaneously as an overview list of all marginalia notes (sorted by number of occurrences), offers the possibility to search for specific words or phrases such as “good” or “brilliant” and highlight their occurrences directly in the visualization.

4.2.2. Similarity Comparison

Through the buttons in the top left corner, the visualization can be switched into the “similarity mode”, which arranges books and authors based on similarity measures by way of multidimensional scaling (MDS). Here, as an indication of conceptual disruption in contrast to the first mode, the background and text colors (exclud-

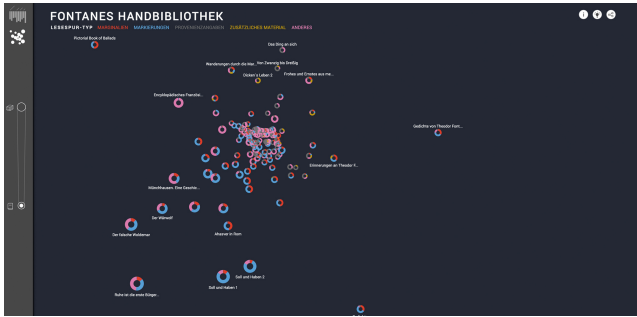


Figure 8: Book level of the similarity mode, ordering the books based on similarity of total number of reading trace occurrences. Books with comparatively average numbers of total occurrences are clustered towards the center through the MDS-algorithm.

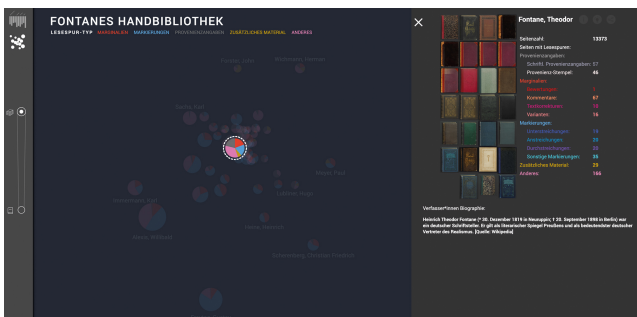


Figure 9: Selecting an author inside the author level of the similarity mode displays their biography, all covers of their books, and the number of reading traces inside them.

ing the category colors) are inverted, changing the appearance into a kind of dark mode. This mode also offers the possibility to gradually navigate between two granularity levels through scrolling, dragging the slider, or selecting the respective elements in the navigation bar. Here it is possible to move between the book level (see Fig. 8), which arranges all books based on similarity of occurrences of reading traces, and the author level (see Fig. 9), which arranges the authors in the collection by similarity between average numbers of occurrences of reading traces in their books. The transition between the granularity levels visualizes the merging of the books into an author average and vice versa (see Fig. 10). Navigating from author to book level, donut charts for each book move out of the pie charts of their author on a linear path towards their similarity-based position. At the same time, the pie charts of the authors shrink towards invisibility. During the transition, network edges connect books with their author, indicating the centroid of the network. This encoding aims to strengthen the impression of connectivity between books of the same author during transitions.

For the MDS matrix we used the average count of reading trace occurrences in each subcategory (including pages without traces) for the authors and the total count of occurrence in each book and calculated the matrix together to be able to link both views through transitions. Books or authors with similar reading traces



Figure 10: Gradual transition between the author level (top) and the book level (bottom) inside the similarity mode.

(total number of types) are positioned close together, which leads to books containing unusual reading trace occurrences being positioned towards the outer edge and books with rather average reading traces tending to accumulate in the center. Pie charts on the author level and donut charts on the book level mark the position of a book/author inside the similarity plane. The small pie/donut charts also act as glyphs that encode the shares of a category of all reading traces through the size of the colored slices and the total number of reading traces via the size of the pie/donut chart. Here, the goal is not to provide charts that enable exact reading or comparison of shares, but to give a general overview of shares and to display overall trends to enable an interpretation about the results of the multidimensional scaling.

At the author level, the average occurrence of reading traces in all of their books is arranged in a similarity-based view, so that authors with similar quantities and types of reading traces are positioned close to each other. A click on an author opens a detail view on the right side, which gives a tabular overview of the reading traces, the covers of all books of the selected author, and a short biography (see Fig. 9). At the book level, a click on a book highlights all books of the same author (see Fig. 1 bottom-right), marks the average value of all their books (position of the author in the matrix) through a network graph, and opens a side view with additional detailed information for the selected book including all marginal notes. Here, a click on one transcribed item opens the corresponding page where the respective marginalia appear. In both, author and book levels, further scrolling leads to activation of a common semantic zoom, giving the possibility to scatter the denser clusters in the centers through zooming.

5. Evaluation

In addition to comments and insights we received from our literary collaborators, we were interested to get ‘fresh’ feedback on the potential of elastic visualization for scalable exploration. For this purpose, we have undertaken a qualitative user study. We conducted an open-ended “think aloud” study coupled with a short written questionnaire before and a few specific tasks and questions at the end of a session. Eight participants (who were not involved in the project) took part in the study; half had backgrounds in literary studies, which represented the main group of interest, while the others came from varying disciplines. The questionnaire assessed previous knowledge about Fontane, literary research, or data visualization. Five of the eight participants had none to very little experience with data visualization.

Each study session took approximately 30 minutes. The specifics of the prototype such as visual encodings and interaction techniques were not explained. After giving a short introduction about the topic and the purpose of the study, participants were asked to interact on their own terms with the prototype, while stating audibly what they do, think, interpret, question, and so forth. Afterwards, we asked the participants to perform three basic tasks: 1) compare two authors and two books, 2) open the scan of a specific marginalia type, and 3) scroll up and down between the different granularity levels. Finally, we asked them for their personal assessment of the potential of the prototype for literary studies, on the potential for visualization research, and for more specific comments on the prototype. Besides the identification of usability issues of the prototype, the broader focus of the evaluation was to validate our approach on coherent, flexibly scalable views, i.e., elastic visualizations. Accordingly, the following section focuses on the effects and descriptions of scaling and transitioning between the varying zoom and abstraction levels.

5.1. Usability aspects

The study participants were able to successfully interact with the prototype in most cases, moving between trial and error to understand its functionality and concrete actions to answer questions. From the start page of the distribution mode, they started to make sense of the arrangement first and then either tried filters or began to navigate between the different levels of the visualization. While most participants were able to comprehend and decode the arrangement of the first mode, a majority could not make sense of the positioning in the more abstract similarity mode:

“Here you can now see an overview of similarity, [...]. What I don’t understand is the arrangement. If I imagine this as a geographic map of Germany, for example, I wouldn’t know why Wichmann is forming Berlin and Freytag Munich, so to speak.”

Participants were able to navigate between the modes and recognize a different order criterion, but they were not able to decode the meaning of the arrangement. Accordingly, they described what they saw and compared the different granularity levels and filter possibilities to the first mode, but did not use it for further inquiries. While we discouraged the reading of the “help” page, in order to provoke user-specific interpretations of encoding and interactions, many of the participants expressed the wish for a short tutorial at

the beginning of the exploration process—in particular for the understanding of the similarity mode.

5.2. Levels of representation

The participants were all able to navigate between the multiple levels of representation in the prototype and to recognize them as different aspects of the dataset. The usage of different levels of information was mentioned to be especially helpful about the visualization by half of participants. The granularity levels were perceived to be both complex in the sense that they offered different answers to different questions, but also that they added a certain complexity to the visualization itself, which could sometimes lead to confusion, but nevertheless interest:

“[...] what I found interesting about it. So, for instance the different levels, that it is actually super complex. And that you try to make it as understandable as possible.”

The interplay of multiple granularity levels and the navigation between the various layers was oftentimes used when it came to more specific questions about the data, using them to validate first impressions or as a starting point for exploration:

“So first of all I see in the initial view that he obviously possessed more of Goethe than of Schiller. However, [...] he made significantly more comments on Schiller’s works than on Goethe. [...] The closer I zoom in, the clearer it can be seen. So in this wave-like overview it is much better, so now you can see very well in comparison that he obviously worked his way through Schiller, especially by adding many markings.”

Furthermore, we noticed that the use and comparison of the different levels led to peaks of interest and further exploration of already more refined questions regarding the content:

“So I clicked marks and now cancellations as an option [...]. And now I see he did not cross out that much, but I’m interested in what he crossed out in his own books.”

The literary scholars stood out as they more often than others mentioned the value of overviews over the whole collection as the main advantage of a visualization of this type. Although it is difficult to validate the usefulness of the prototype for the uncovering of completely new research questions, especially the participants with background in the literary studies nevertheless ascribed the prototype domain-specific utility:

“Well, I think it is exciting that you can visualize this mess that you usually have in all these books for the first time. Well, usually I have got a thousand books with small traces and I cannot do anything with them at first. Here I can see at a glance which authors are particularly affected and which books.”

5.3. Interactive control of transitions

During the interaction with the prototype as well as the questions at the end, half of the participants highlighted the movement between the different levels as helpful and noteworthy about the visualization. The interactive transitions were said to make the complexity of the collection more graspable:

"I find the scrolling very interesting in the way that it has such a smooth transition in the display. And I think I find it exciting, [...] how the transition is and how through this you [...] explain different levels that are somehow connected with each other."

Most of the participants referred to the mechanics they saw in the display changes as a form of "zoom," which they oftentimes used and described effectively, but sometimes had problems to translate the abstraction process into words:

"Now I'm going up from the middle. [scrolls up back and forth] So it feels like I'm zooming in here. [...] Well, then I'll scroll down now, yes, it's a similar feeling somehow, like zooming in again, but this time in a way that it's really something that changes in size."

While scrolling is a possibility for navigation and was of special interest to us as a form of gradual, self-operable, and linear transition, it was not the only option to navigate between the various granularity levels. Here, we noticed that scrolling compared to switching levels by clicking is more prone to user-specific difficulties, e.g., caused by different scrolling speeds or unexpected behavior:

"I'm confused by the scrolling [...] and that a single scroll seemingly brings me somewhere else entirely and that I can't scroll up and down as on a website."

Furthermore, the scrolling seems to be more vulnerable to misinterpretations. While clicking on the navigation always results in full execution of a transition, some participants did not always scroll to the end, leading to confusion about mixed encoding of information. However, we could often see participants trying to make sense of the encoding in one granularity level by actively using scrolling, watching closely what happens between the views:

"The books are contracting. Are they contracting? Ah—and then slowly appear [...] beautiful wave diagrams, where the individual authors are marked and no longer the individual books." [Distribution mode]

"The graphic becomes denser or something like that one could say, so there are fewer points. So the number of circles of works are combined." [Similarity Mode]

6. Discussion

We think of this design study as an interpretative approach to visualization research, during which we make sense of the qualitative evaluation results as one possible facet of results [MD20]. Aspects of observer-dependence make it difficult to investigate effects on explorative characteristics or the usefulness of a visualization for the development of research questions. Additionally, we do not claim that our evaluation is able to give definite answers about the general usefulness of our approach, since the effectiveness of such complex design interfaces is dependent on many small factors. An A/B-testing of a prototype with and without transitions could give more conclusive results. Nevertheless, we think that the elastic interplay between abstract or compressed views with concrete detailed views has proven to be promising to accommodate the complexity of rich cultural heritage datasets. Furthermore, scalable exploration was a useful aspiration to characterize the design space of

interactive transitions and representations that convey various levels of information.

However, the primary use of scrolling to control transitions has triggered ambivalent reactions among participants. While six of the participants almost exclusively used scrolling for their sense-making of the visuals (oftentimes perceivable in their interaction by seeing them scroll back and forth), others were confused by incomplete in-between states or the interaction through scrolling itself. This could also be explained by the irritations described as "scrolljacking" [Bos14], where usual scrolling behavior of a website is interrupted or exchanged with the risk of leading to frustration caused by unexpected behavior. One of the main insights that we took from the evaluation is that it is important that transitional and final views are easily distinguishable to avoid misinterpretation. For most transitions, the encoding cannot stay true to the data at all steps of a transition, as expressed in the design principle of congruence by Heer and Robertson [HR07], but it should be aspired to avoid invalid data attributions during the transitional states. To communicate the distinction between the states, the prototype includes a navigation bar with icons for each final state corresponding to a specific scale (authors, books, pages). Nevertheless, two participants specifically mentioned problems in finding their position and expressed that the scrolling state could be communicated more effectively. Considering difficulties that resulted from interaction in incomplete in-between states, scroll thresholds for main views that automatically snap in might be an approach to solve this problem.

We intentionally did not provide a previous introduction into the functionalities of the tool during the evaluation, because we were specifically interested in the reactions to the transitions and scrolling, which uncovered general usability issues as participants had to explore the functionalities of the prototype on their own. Some difficulties that participants encountered we ascribe to the limited time to get to know the tool without an introduction. While five of the eight participants asked for more help or explanation in the beginning, two were specifically interested in more contextual information or interpretations. The integration of such a narrative or interpretative layer was explicitly excluded from the project, so as to leave the interpretation of the data to the viewers or researchers. Nevertheless, one request of our partners was to enable direct linking to specific views for future referencing in research or narrative practices, e.g., about specific phenomena or findings for blog posts or research articles. We see the prototype itself as an explorative research tool that can and will be connected to more narrative and explanatory content in the future.

With the second mode of our prototype, the "similarity mode", we aimed to explore and offer an alternative, more abstract way of representing the data, knowing that the abstraction of dimensionality reductions may be difficult to grasp without much explanation. Furthermore, our intention of designing useful transitions between the two modes was not sustainable, because the encoding of each mode follows very different logics, leading to a discontinuity in our general approach, visualized through the color change. This break in consistency manifested itself in the responses towards the arrangement in the similarity mode. Our evaluation showed that most participants could not make sense of such a representation, just knowing that elements are positioned based on similarity.

Nevertheless, after reading through our help page, which includes annotated examples and explanations, participants stated that such a visual was interesting in theory, but that they would need more assistance. For similar projects, we would suggest to consider how unfamiliar visualization techniques could be communicated more effectively.

Although conceptualized with the notion of elastic data visualizations in support of scalable exploration, in the resulting prototype we arguably break out of this paradigm in some places. E.g., while in the first mode scrolling is generally used for changes in granularity, at the page level it switches back to conventional view-port changes. Furthermore, the discrete switch between the distribution and similarity modes breaks with the ambition to make display changes gradual and comprehensible. In fact, it can be difficult if not impossible to arrive at useful transitions and elastic systems that incorporate multiple spatial logics. Nevertheless, we noticed that especially these parts with abrupt breaks of concept led to difficulties in comprehension—which arguably points toward benefits of coherent and connected views.

More generally, an arguably unavoidable limitation of this research is that it was pursued in the context of a specific case study. While Fontane's reference library only contains 155 books, other collections may include tens of thousands of objects. For more extensive collections, we see even more necessity for a range of granularity levels and continuous navigation between them. We would be curious to examine how our ideas of scalable exploration and elastic visualization translate to other kinds of cultural collections and maybe other domains.

7. Conclusion

Based on the premise that scalable exploration describes the shift between close and distant reading in digital literary studies, we described our iterative and interdisciplinary research on elastic visualizations designed to bridge different granularity levels. In order to examine the viability of this approach, we presented a design study in collaboration with a team of literary scholars about the reading traces in an author's library. During this collaboration the domain-specific research questions matched and ran in parallel to the visualization research questions and design goals.

In this paper, we described the concept of a visualization designed to support distant as well as close viewing of reading traces with a conceptual focus on interactive, user-controlled transitions between multiple levels of detail. Our exchanges with our collaborations and the results from a qualitative evaluation indicate that fluid shifts between multiple levels can support exploration and can have positive effects on the level of engagement with the underlying information. Even though we still see potential for user-controlled interactive transitions, at least regarding the use of scrolling there are difficulties to overcome potential confusion or mis-interpretation. Nevertheless, especially in the field of digital humanities, where the modes of close and distant reading are long-debated methodological challenges, we see great potential and necessity for supporting the interplay between multiple abstraction or granularity levels.

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