DHQ: Digital Humanities Quarterly
2017
Volume 11 Number 2

Past Visions and Reconciling Views: Visualizing Time, Texture and Themes in Cultural Collections

Katrin Glinka <glinka_at_fh-potsdam_dot_de>, University of Applied Sciences Potsdam
Christopher Pietsch <cpietsch_at_gmail_dot_com>, University of Applied Sciences Potsdam
Marian Dörk <doerk_at_fh-potsdam_dot_de>, University of Applied Sciences Potsdam

Abstract

We present a case study on visualizing a collection of historic drawings along its metadata structure while also allowing for close examination of the artifacts' texture. With regards to the specific character of cultural heritage at the intersection of research, education, and public interest, the presented visualization environment aims at meeting the requirements of both researchers as well as a broader public. We present the results from a collaborative interdisciplinary research project that involved a cultural heritage foundation, art historians, designers, and computer scientists. The case study examines the potential of visualization when applied to, and developed for, cultural heritage collections. It specifically explores how techniques aimed at visualizing the quantitative structure of a collection can be coupled with a more qualitative mode that allows for detailed examination of the artifacts and their contexts by displaying high-resolution views of digitized cultural objects with detailed art historical research findings. Making use of latest web technologies, the resulting visualization environment allows for dynamic filtering and zooming of a collection of visual resources that are arranged along a contextualized timeline. We share insights from our collaborative design process and the feedback and usage data gathered during the deployment of the resulting prototype as a web application. We end with a discussion of transferability of carefully crafted and collaboratively negotiated visualizations of cultural heritage and raise questions concerning the applicability of our approach to related strands of humanities research.

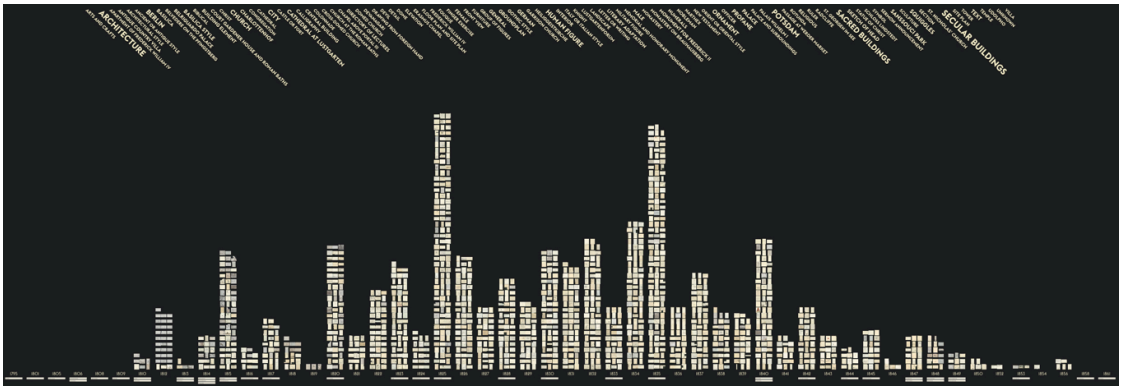

Figure 1. The interface developed for the *Past Visions* case study provides a distanced view on the topical and temporal dimensions of 1492 historic drawings. The view can be filtered and zoomed to see specific subsets and details of individual drawings. http://uclab.fh-potsdam.de/fw4/en/

1. Introduction

In recent years, numerous projects have been initiated and funded that aim to digitize cultural artifacts. Archives, museums, libraries, and other heritage institutions are now facing the challenge to make digitized inventories publicly accessible and provide new modes of engagement with the cultural content. At the same time, there is an increase in

visualization research related to the digital humanities that explores computational and data-driven approaches to literature, art, and other cultural domains. The asset of computational analysis and visualization is often reduced to their benefit in regards to quantitative analysis, which implies a distancing from the singular object or phenomenon. At the same time, the object-centered nature of museums, art history, archeology, and archives is fueling a growing interest in harmonizing digital approaches with qualitative and interpretative methods, i.e., “close viewing” or “close reading,” an approach that we aim to extend with this work.

The case study[1] that we present shows the potential of applying techniques largely drawn from information visualization to an art historical source. With a zoomable visualization environment we seek to explore how a “distant-viewing” approach can be combined with a “close-viewing” mode in a dynamic and contextualized arrangement (see Fig. 1). We aim to examine how visualizing the quantitative structure of a collection can be complemented by allowing for examination of the qualitative texture of the individual object. We describe a design space for visualizing cultural collections that also does justice to the aesthetic value of the collection and objects. Our contributions further include an evaluation of the prototype in regards to usability, user interaction, and audience groups. 2

2. Related Work

Our work builds on prior research on information visualization in the context of digital humanities, the emerging field of digital art history, and visualizations particularly developed for cultural collections. 3

The analysis of textual data has been an important method for the largely language-centric digital humanities [Jänicke et al. 2015] and a major strand of research in information visualization [Kucher and Kerran 2014]. While early text visualizations were created for relatively abstract use contexts, more recent work focuses on specific needs of particular user groups such as humanities scholars [Jänicke et al. 2015] [Koch et al. 2014]. The scope of visualization tools for textual analysis ranges between single-purpose tools [Wattenberg and Viégas 2008] to comprehensive analysis environments [Muralidharan and Hearst 2013]. Moretti’s notion of “distant reading” [Moretti 2005] has become a provocative yet productive term to negotiate quantitative and qualitative methods of literary history, and more generally for interpreting cultural data. The distinction between close and distant readings has informed a wide range of visualization projects aiming to support analysis that ranges from individual words and sentences to documents and entire corpora [Jänicke et al. 2015]. 4

Apart from these predominantly text-based efforts in digital humanities, the broader context of digital cultural heritage has attracted a variety of experimental visualization research and innovative design of collection interfaces. Visualizations of cultural heritage collections promise to offer “rich-prospect interfaces” that represent an entire collection at once, afford interactive control over its arrangement, and provide detailed access to its elements [Ruecker et al. 2011]. This approach is based on the principle that the default interface should “show a meaningful representation […] of every single item in the collection” [Ruecker et al. 2011] that is apparent to the user and helps them to understand, on a visual basis, what is available in a collection. Image plots of thousands of Instagram photos arranged by time and hue fulfil some of these aspirations in that they blend the representation of the metadata with the visual qualities of the images [Hochman and Manovich 2013]. The resulting visualizations offer impressions of large stocks of photos that were not visible in that way before. The Viewshare tool was explicitly designed for rapid creation of visual interfaces that can be used to explore and share patterns in collection data using established techniques such as maps, timelines, and lists [Algee et al. 2012]. In contrast, the “Bohemian Bookshelf” interface contains deliberately idiosyncratic visualizations each offering a unique point of entry to a visually rich and multidimensional collection [Thudt et al. 2012]. The principle of “generosity” can be used to qualify to which degree an interface reveals the material and semantic qualities of a collection and encourages its exploration [Whitelaw 2015]. Our research aims to contribute to this line of work on generous and rich-prospect interfaces for cultural collections in particularly by supporting the shift between abstract, distanced explorations and highly detailed close-up views. 5

Related to these developments in the wider cultural sector, digital art history is gradually emerging as a research area in its own right [Bentkowska-Kafel 2005] [Drucker 2013] [Promey and Stewart 1997] with a distinct set of use cases, tasks, and requirements for digital tools and data structures. While early mentions of the term focused on teaching [Promey 6

and Stewart 1997], there has been a continued interest in making sense of digital technologies and exploring their potential for art history, especially with regard to purposes like preservation and presentation [Bentkowska-Kafel 2005]. Museums and art history, although preoccupied with visual resources, have been predominantly text-based fields of research in that sense that the visual object of study had to be translated into text (e.g. on index cards or in cataloguing systems and databases) to be able to retrieve relevant information from rich collections, either analog or digital. Efforts in computation and digital humanities research thus also include the improvement of ontologies and text-based information retrieval systems [Isemann and Ahmad 2014] or the use of folksonomy or crowdsourcing for textual annotation of cultural heritage [Ridge 2014]. Consequently, some approaches in digital art history research build upon the prior developments in text-based humanities, introducing approaches that allow for “distant viewing” and quantitative analysis of art historical data [Bender 2015]. Computational non-textual analysis of art historical resources, on the other hand, include methods for image analysis that are able to group or cluster artworks on the basis of similarity of artistic style [Shamir and Tarakhovsky 2012] or the development of computer vision algorithms classifying fine-art paintings by style, genre, and artist [Saleh and Elgammal 2015]. Although the application of digital methods in art historical research still represents a small subset of disciplinary practice, digital art history is on the rise [Zweig 2015].

Despite the dominance of “distant” approaches in digital humanities and digital art history, there is a growing recognition that digital methods in these fields should incorporate qualitative and interpretive modes of analysis [Schnapp et al. 2009]. Drucker argues for a fundamental shift in visualization design from viewer-independent representation of data to viewer-codependent interpretation of “capta”, i.e., data that is purposefully collected and constructed [Drucker 2011]. Data in the arts and humanities are not about absolute truths, they are constructed to develop novel interpretations and advance arguments. Visualizations in this sense should be seen as propositions for a certain reading (or viewing) of a phenomenon [Galey and Ruecker 2010]. Current visualization research in the context of literary studies reflects this need for interpretive, experimental, and even playful approaches to data [McCurdy et al. 2016] [Hinrichs et al. 2016]. Similarly, our intention is to conceive intriguing visualizations that make rich art historical collections available for casual analysis and exploration while still supporting detailed inspection. 7

Much of digital art history, and more generally digital cultural heritage, is reliant on textual information about artifacts. Additionally, computationally processed, clustered, and interpreted image data, or sometimes a combination of text and digital image processing, are used to organise and make sense of digital cultural heritage. Metadata, understood as textual information on (digitised) cultural heritage, connects the expert’s knowledge to the visual resources and helps to address entities via title, author, date oder descriptive elements like keywords or classification [Schumacher 2016]. As part of the efforts to also develop visually rich representations of and new modes of interaction with digital cultural heritage, there is a growing interest in the question of how the underlying textual-digital fragmentation of an artifact influences our perception of digital cultural heritage on a more general note. These discourses engage, amongst others, with the question of how to address, represent or preserve the materiality of objects in digital representations. This is especially relevant in the context of museums that, for a long time, have given primacy to the materiality of objects. Nonetheless, within museum studies, and the study of material culture in general, the notion of “object biographies” has come to acknowledge the ways in which objects become invested with meaning through the social interactions they are caught up in [Gosden and Marshall 1999]. This shift away from a strict focus on materiality and towards a notion that understands the accumulation and transformation of an object’s meaning and values as a distinctly sociocultural process can now also be accentuated in the context of digital cultural heritage. Objects, in this sense, can be recognised as being in a state of motion, that might occupy or migrate through different states and media [Parry 2007]. Nonetheless, debates on the meaning, value, and presence of digital objects, quite often still rely on the object-centeredness of museum culture and thus argue from the standpoint of the “superior” physical counterpart of the digital object [Cameron 2007]. In this context, we would like to acknowledge that the materiality of a museum object could also be problematised even in regards to how it is conveyed in a museum display. Although museums can be regarded as “material institutions par excellence” [Dudley 2012], they often limit the extent to which people can engage with the things on display and thus likewise limit the access to the objects’ materiality [Dudley 2012]. Naturally, this restricted access is a due measure of precaution that ensures the preservation of valuable and unique objects. Nonetheless, neither in a physical nor digital display can we touch, feel, smell, taste, or weigh the objects with the help of all our senses. What we have to rely on in both instances is our sense of vision and, if provided, the “knowledge” assigned to 8

the (digital) object by the museum as metadata or other additional information [Dudley 2012]. Concerning the influence of new media on our way of perceiving and engaging with cultural heritage, Jeff Malpas has remarked that we need to retain a sense of the materiality of objects “understood in terms of the way in which human life is essentially formed and articulated, and so also understood, in relation to spatio-temporal formation and articulation” [Malpas 2007, 19]. He emphasises the need to differentiate between what is interpretation and what is the object in its spatio/temporal materiality in order to not “lose a sense of the object” [Malpas 2007, 24]. With our research we are attempting to address some of the challenges arising from the material and interpretative complexity within cultural collections.

9 With the expanding use of digital methods in the humanities, tool creation is certainly a valuable scholarly practice [Davis and Kräutli 2015] [Schnapp et al. 2009] that expands the ways a phenomenon can be seen and examined. Prompted by limited adoption of more advanced tools in the digital humanities, the results of a survey with historians highlight the critical importance of interface design, instructions, and ease of use [Gibbs and Owens 2012]. Besides their immediate function, visualizations also act as arguments and rhetorical expressions [Galey and Ruecker 2010] [Hullman and Diakopoulos 2011] that can serve critical approaches towards cultural collections [Glinka et al. 2015]. Accordingly, to benefit the research agendas in the humanities, it is the scholars themselves who should be much more involved in setting the parameters for the design of tools and formulating questions for their interpretation and critique [Drucker 2013]. Taking these findings into account, we are pursuing an interdisciplinary research process that brings together humanities scholars, designers, and engineers to collaboratively create and make sense of visualizations of cultural collections.

10 The temporal dimension is often of particular importance in cultural collections. When reflecting this by visualizing cultural data along a timeline, it is advisable to also consider its genealogy [Davis et al. 2013], going back to the design decisions made in the 18th century when the first timelines were conceived [Davis and Kräutli 2015]. Even though the timeline is almost omnipresent, there can be good reasons to subvert its linearity, for example, to counter absolute notions of time and advance more complex models of times [Drucker 2011], expose the uncertainty in the dating of artifacts [Davis and Kräutli 2015], or to pique the interest of an exhibition audience about the oeuvre of an artist [Hinrichs et al. 2008]. The temporal dimension can also serve as the basis to trace the evolution of visual features of art such as color usage in paintings [Haber et al. 2011]. Following the aim to provide users with a visual basis for understanding what is available in a collection in rich-prospect interfaces, Ruecker et al. have identified the temporal arrangement of collections as one that helps identify meaningful connections between items [Ruecker et al. 2011]. In our research we continue this line of work of visualizing temporal patterns in cultural collections and further seek to integrate the material and thematic qualities of the artifacts.

11 There is a traditional emphasis on the overview in information visualization [Shneiderman 1996], which is typically understood to be distinct from the preview of individual resources in a collection [Greene et al. 2000]. However, the primacy of overviews is increasingly being challenged, for example, by visually rich “innerviews” as local perspectives that show both the visual material and its dense metadata [Whitelaw 2015]. Akin to blending or alternating between distant and close reading, there is growing interest in bringing bird’s-eye and close-up views on collections together. For shifting from high-level aggregations of an entire collection to the detailed views of individual resources, zoomable interfaces prove particularly powerful [Bederson and Hollan 1994] [Dörk et al. 2012] [Hochman and Manovich 2013] [SFMOMA 2008]. Typically, however, the arrangement of elements in zoomable interfaces is relatively static and highly detailed views of the artifacts are seldom provided. Our intention is to develop dynamic arrangements of rich, visual artifacts that make full use of interactive and graphical capabilities of modern web technologies. Thus, we build upon and refine visualization techniques in the context of the challenges and potentials of cultural heritage and digital art history.

3. Approaching a Collection of Historic Drawings

12 Within the scope of this research project, we are collaborating with the Prussian Palaces and Gardens Foundation Berlin-Brandenburg or SPSG, a cultural heritage foundation that administers several historical buildings, palaces, gardens, collections of paintings, furniture, sculptures, porcelain, drawings, and other historical objects, which have only partially been digitized, so far. Motivated by the lack of research combining quantitative and qualitative analysis of art

historical collections, we proceed with the ambition to select a data set that would allow us to examine a collection along its structure, i.e., based on the artefacts' metadata, as well as their texture, i.e., visual, physical, or aesthetic qualities. Additionally, we seek to incorporate context, i.e., frame the collection in such a way that would allow non-experts (or interested laypersons) to explore the collection. In the following we detail our framework of collaborative, interdisciplinary research and the design and development of cultural heritage visualizations in cooperation with art historians, designers, and engineers.

3.1. Research Questions

Our main aim is to investigate how visualization can reconcile the perpetuated antagonism between qualitative and quantitative methods of distant and close viewing of cultural collections. In accordance with this ambition we pursue two main research questions with our case study: 13

1. How can we visualize a cultural collection in a way that employs a quantitative analysis of a collection's structure while also offering qualitative insights and exploration of the objects' textures?
2. What are promising features of a visualization environment that cater to the needs and interests of interested laypersons as well as art historians and other domain experts?

The overall research project as well as the case study operate on a notion of "cultural sensitivity." We employ this term in two senses. For one, we embrace the differences in disciplinary backgrounds as part of a "culture"[2] within e.g. computer sciences, design, museums, the arts, and the humanities and start from the premise that these cultures should be equally included, respected, and brought to their full potential in any transdisciplinary project. This could be affiliated with the notion that "cultural sensitivity" (in the more common meaning of the term) involves acknowledging "sensitivity to the importance of cultural differences and to the points of view of people in other cultures" [Bhawuk and Brislin 1992, 346]. For the other, we construe this term in a more literal sense as a sensibility towards "culture" (or the cultural artefact) in regards to the collection that we engage with. More precisely, by using this term in its double meaning, we seek to emphasize that the cultural content, meaning, and specific qualities of a collection and its items would be the driving force while developing and designing the visualization in close collaboration and on the basis of mutual respect with the heritage institution and the different involved disciplines. Hence, our approach is not primarily technology driven nor originally aimed at building a "one size fits all" solution for exchangeable datasets. Nonetheless, we deem the findings and results from our case study to be central to our research concerning the transferability of our visualization approach to other image-based collections. 14

3.2 Sourcing Data

When seeking to visualize the quantitative structure of a collection, the data set has to cover a minimum of properties such as year or period of creation, name of artist or school, material, and size. More interpretative metadata might include genre, style, or iconographic classification. While we have seen some promising results from applying computer vision algorithms to fine art [Saleh and Elgammal 2015] [Shamir and Tarakhovsky 2012] and thus, in theory, could compensate missing metadata by algorithmically classifying artworks, most heritage institutions (as our cooperating institution) still rely on manually annotating their collections. Some subsets from the foundation's collection databases do involve descriptive or interpretative texts, research findings, and other related resources, while other areas of the collections are almost untapped. Regarding our aim to also allow for exploration of a collection's texture, we had to make sure that the subset included high-resolution digital images of the collection items. 15

Figure 2. Collage making during co-creation workshop with collaborators.

Taking all of our requirements into account, we identified a subset of drawings from a collection of prints and drawings, which includes 1492 sheets with drawings executed by King Frederick William IV of Prussia (1795-1861). This subset is part of a larger collection of 7500 sheets with drawings by the King that are in the process of being inventoried and digitized. Many of these sheets reveal the planning eye of the King in the form of architectural visions and dreamy drafts while they bear witness to historical events such as wars and revolutions, literary influences or personal obsessions. Many of the drawings depict actual palaces, churches, gardens, and other sites that are part of the cultural heritage administered by the SPSG. 16

Most of the following data was available for each sheet: inventory number, description of sheet, art historical interpretation, labelling (e.g., hand-written by King or later researchers), watermarks, physical dimensions, year, material, titles of corresponding thematic texts, list of corresponding secondary literature, and hierarchical index-based list of descriptors. The descriptors had been previously developed by a group of art historians during the research process alongside a controlled vocabulary and either belonged to a thematic or a topographical categorization. To make the art historical sources explorable by a non-expert public, we also included the content of an exhibition catalogue, which, in contrast to the object description and interpretation, were written and published for a broader audience and offered contextual information on the King's life, prevailing interests, and general historical background. 17

3.3. Towards Cultural Sensitivity

In order to pursue our research questions, we decided to employ a user-centered design approach that integrates experts from the involved disciplines into a co-creation process. Thus, a key element for our close collaboration with the heritage institution was a workshop framework that practically and conceptually engages participants from various professions in thinking about how different facets of a collection could be translated into a visual representation [Chen et al. 2014]. The first iteration of the workshop, which to a certain degree resembles co-creation practices in design research [Sanders and Stappers 2008], involved 11 participants (seven employees of the heritage foundation including a scientific editor responsible for print and online publications, a collections inventory custodian, a castellan and art historian, a marketing and public relations officer, the head of the center for documentation and information, a classical scholar, and the head of the IT department; one participant was from a company that develops database management systems for museums, three were members of our research group). The first iteration of the workshop had no designated thematic focus, but rather served as a platform to get to know the scope of the partnering institution, the collections, the database structure, and allowed us to identify promising areas for a first case study. 18

The workshop format provides a setting, in which the participants individually create collages from sample material with the aim to tease out promising relationships among objects (see Fig. 2). The workshop was documented (as audio recordings of the discussions, photographs of paper collages and the making process). These records were later transcribed and thematically clustered. By analyzing the material, we were able to identify prevailing topics of interest and challenges that were relevant for the subsequent steps of our project. First of all, most approaches to the collections that were developed during the workshop were of qualitative nature. Participants presented collages and discussed ideas that highlighted content-based facets or interpretational elements. Thus, the collages resembled an approach that is mostly associated with a curatorial practice in museums. When discussing these approaches, a 19

challenge was seen in the fact that the existing metadata and level of digitization of the foundation's collections often did not include such content keywords and in-depth descriptive elements and interpretational texts.

Following this first workshop that identified mutual interests, we analyzed the overall metadata structures of the collections that had already been digitized. As a result, the thematic focus on the drawings by Frederick William IV was influenced by the quality of the digital copies, the thorough and complete art historical metadata, as well as the fact that the metadata included descriptive and interpretational texts. The second workshop was then specifically aimed at identifying promising structures and parameters within this sub-collection of drawings that could serve as a dimension for an exploratory visualization environment. With this specific goal in mind, we invited not only colleagues from our department with a background in interface design and information visualization, but also a scientific editor of the foundation and the art historian that led the research group which produced the metadata. According to our overall goal to proceed on the notion of "cultural sensitivity," the identification and involvement of the right domain experts was a central element of our cooperation [Sedlmair et al. 2012]. With this, we act on the observation that digital research in areas like art and cultural heritage often demonstrates inferior or uncertain cognitive value of the findings when it is not informed by professional art historical knowledge and scholarly methodology [Bentkowska-Kafel 2015]. The collages that were produced during the second workshop were much more specific and related to the actual data and scope of the collection. During an iterative process, we then identified dimensions and parameters that were both appealing from an art historical point of view and offered interesting challenges for visualization research and design.

4. Visualizing Time, Themes and Texture

Our collaborators repeatedly emphasized the temporal and thematic patterns to be particularly important for making sense of the collection. In addition, there was an interest in incorporating the actual reproductions of the drawings in the visualization. This corresponds with the assertion that visualizations, especially in the context of digital humanities, should take into account the unique visual and material qualities of digitized collections to reflect their physical counterparts [Hinrichs et al. 2016]. Obviously, the digital cannot surmount the restricted access to materiality posed upon a museum object. Nonetheless, we can try to at least tap into the full potential of displaying a digitized museum object and still be aware that much of what constitutes the display and the ways of engaging with the object is based on the interpretation and not on its spatio-temporal materiality. Reflecting on these conditions, we have found it to be productive for our research to try and exhaust the given technological potentials in making high-resolution reproductions of fragile (and mostly non-public) objects available to the public. Thus, we hope to at least maximise the visual information about the material qualities that can be extracted from the digital collection at hand, maybe even surpassing the accessibility of the original that would be shielded from the public with "glass cases, picture frames, ropes" [Dudley 2012], or other visually distancing precautionary measures. At the same time, we concede that it is not solely the physical materiality of the objects that affect the conditions under which we can engage with the collection by subjugating the arrangement of the visual resources to their interpretation (of temporal, contextual, or thematic attributes). The aforementioned challenge of conveying the materiality of digitial cultural heritage also influenced our decision-making in regards to the treatment and processing of the digitized drawings. We decided to preserve and highlight the traces of materiality that are conveyed through the high-resolution digital reproductions, such as ripped-out corners, faded-out strokes, and the proportions of the sheets and differences in size. Following our aims and research questions, we have devised a zoomable visualization environment that arranges a collection of drawings based on their temporal attribution, allows for thematic filtering, provides historical and art historical context, and enables the close inspection of the high-resolution images and their visual texture.

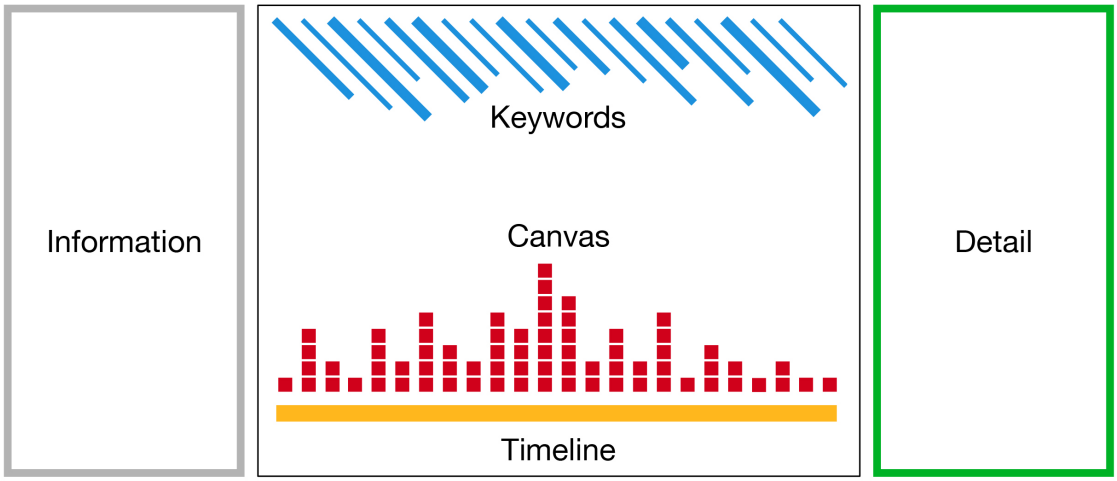

Figure 3. The interface consists of a keyword visualization (top) and a zoomable canvas arranging high-resolution images and historical and biographical events along a timeline (bottom). Information panels can slide out from the sides to provide instruction on how to interact with the interface (left) and read detailed art historical information about a selected object (right)

The interface contains a keyword visualization, a zoomable canvas and timeline, and information panels (see Fig. 3). The visual design of the interface with a dark screen canvas and muted colors takes into account the collection's texture. Many prints, engravings, or drawings are monochromatic and low in contrast. This also being the case for the collection of drawings by Frederick William, a light screen canvas would have blended the drawings with their background. Since the original sheets were furthermore digitized mounted to a dark carrier paper, the contrast between the light sheets of paper and the dark carrier paper, that extends to the screen canvas, makes it possible to discern the cut-outs and texture of the paper more easily. Additionally, the physical context of the original drawings can be associated with the interface, since the design reminds of the dim and concentrated aesthetics of print rooms in museums. In the following we describe the specific design decisions behind the visualization along the three main facets of our visualization: time, themes, and texture. 22

4.1. Time

The primary organization scheme for the collection of drawings is time, which is not only highlighted by the collection experts to be important, but reflects its fundamental significance for the visualization of historical collections [Davis et al. 2013]. According to the date of likely creation, all drawings are arranged on a canvas in columns, each representing one year, spanning the period of 1810-1856. As some sheets do not have an exact year, but rather estimated time ranges, the median of the range is used for the positioning. Within the columns, sheets are sorted vertically based on the complexity of their metadata. Since Frederick William often used one piece of paper for several independent sketches or drawings, some sheets accumulate a number of motives, themes, and places that are identified separately and included in the metadata associated with each sheet. 23

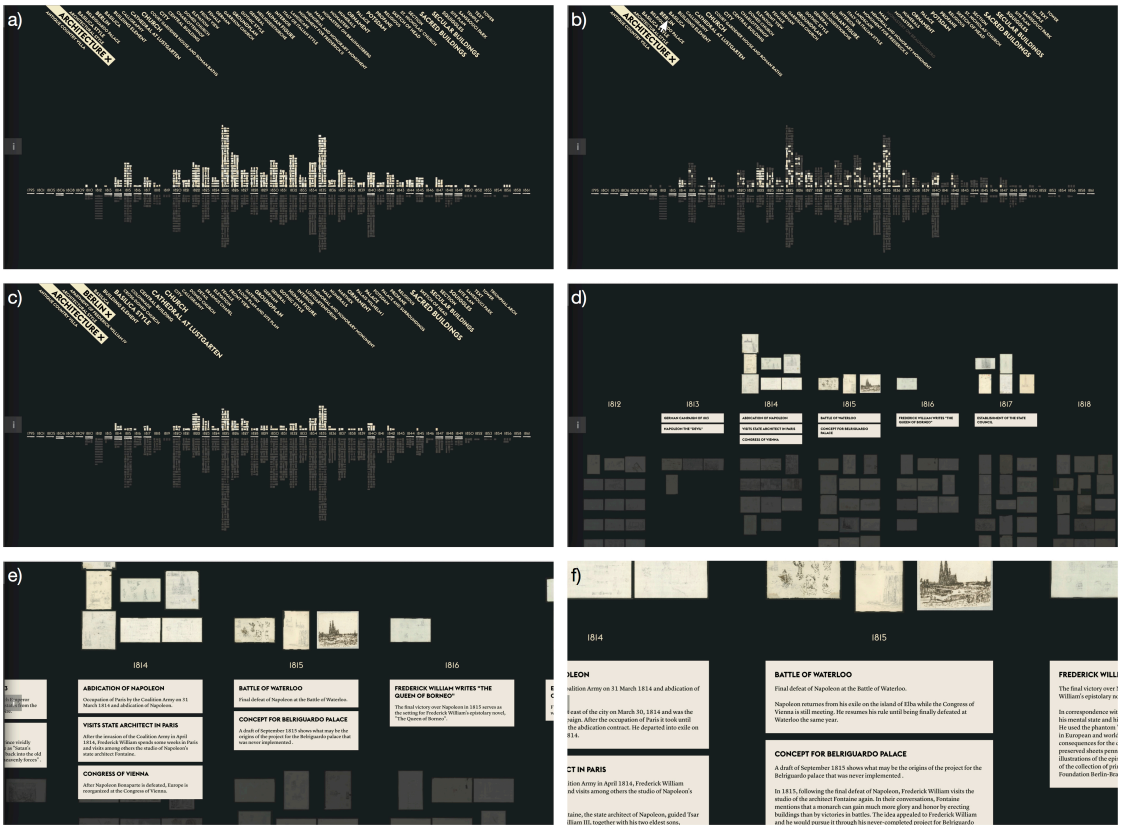

Figure 4. The images on the canvas can be filtered using themes (a-c) and situated in their historical context (d-f). Hovering over a keyword highlights all respective drawings in the canvas (b), clicking it the selection of drawings is further constrained (c). A timeline that separates selected and grayed-out drawings can be zoomed to reveal more details about historical events (d-f).

When the interface is launched, the visualization offers a bird's-eye view on the complete set of drawings with each of the 1492 images being displayed (see Fig. 1). In this initial view the images are shown at a relatively small size of about 20 mm on a 13" laptop display to make room for the entire collection. 24

The temporal arrangement of images is accompanied by a timeline that is positioned at the bottom of the interface, with entries slightly surpassing the scope of the drawings as they provide additional biographical and historical context such as birth and death of the King. The 40 events with historical and biographical context to the drawings were in part derived from the existing exhibition catalogue and collaboratively authored with our partners at the foundation. In order to facilitate the establishment of a connection between the personal and historical developments and the drawings that the King produced at the time, the timeline is positioned right below the columns of drawings. The timeline implements a semantic zoom functionality [Bederson and Hollan 1994], i.e., it gradually reveals more and more detail as the viewer zooms further in into the respective time periods (see Fig. 4, d-f). While the temporal arrangement of the sheets arguably follows a quantitative logic, the integration of the actual digital copies of the drawings and the annotated timeline provide qualitative content and context intended to support a deeper engagement with the collection. 25

4.2. Themes

In the top area of the interface, a keyword visualization displays the most prolific subjects and places as a horizontal list of tags that are derived from the index-based list of descriptors. Depending on the size of the screen, the list contains between 30 and 50 words and phrases. Akin to word clouds, the font sizes represent the relative frequency of sheets per subject. The keywords are sorted alphabetically in order to allow viewers to quickly locate a subject they might be looking for. Interactions with the keyword visualization result in changes in the image canvas. Hovering over a keyword highlights all the sheets that are associated with this subject (see Fig. 4, b). 26

Besides indicating the major subjects and places, the keyword visualization serves as a filtering method for the image 27

canvas. After selecting a keyword, all drawings not associated with this subject move to the bottom of the timeline and are displayed with a lower opacity (see Fig. 4, a-c). The transition is animated in order help the viewer understand the new display state. The images that match the current keyword selection remain above the timeline but will move closer together. The resulting subset of images forms a more specific temporal visualization indicating the ebb and flow of a particular topic within the King's strand of work. As more and more keywords are activated, the selection of drawings gets more constrained, resulting in smaller image columns. As indicated by the cross added to a selected keyword, clicking on a keyword again cancels its selection. Changing the selection of keywords also changes the display of the remaining keywords. As some keywords may not be associated with the drawings in a given selection, they will be hidden, making space for more specific keywords to be revealed, thus increasing the level of specificity of the keywords.

In addition to the themes represented by the keywords, the detail panel provides more in-depth information about each drawing. These details include descriptions of the content shown on each sheet, art historical interpretation, commentaries on their historical significance and relation to other objects, and annotations made by the King or subsequent maintainers of the collection. Besides metadata fields such as the physical dimensions and material of the sheet, the detail panel also provides access to thematic essays written by art historians about specific places or topics depicted in the drawings. 28

4.3. Texture

A key feature of the visualization is the provisioning of high-resolution imagery in an arrangement that supports zooming, panning, and filtering. Similar to image plots of photos or magazine covers [Hochman and Manovich 2013] [Manovich 2015], high-level views on cultural collections can reveal global patterns and trends, however, typically only general shades and shapes can be differentiated. Our intention is to make these arrangements dynamic through filtering and thus allow for rapid access to custom subsets of the collection. The canvas is designed as a continuously zoomable space, allowing for the gradual increase of detail for particular segments of the arrangement of images. Zoom operations can be carried out either through the mouse wheel or by performing scrolling or zoom gestures on touchpads and touch-enabled displays. By zooming into particular groups of images, the thumbnails continuously grow into larger images with a higher resolution. By clicking and dragging, it is possible to pan the canvas in all directions. The viewer can examine sheets in the same year by performing vertical movements and shift in time between different year columns by moving horizontally. By clicking or tapping on an image, it is possible to immediately focus on this particular drawing and display it in high resolution. Once an image is in focus, the neighboring images fade out and the detail information becomes available on the right side panel. In the same visual context of the canvas, it is now possible to further zoom into the image of the drawing to closely inspect the texture of the paper and even the grain of the pencil strokes (see Fig. 5, bottom left). These high-resolution views of the drawings are highly detailed and surpass what would be visible to the naked eye in a museum or archive. 29

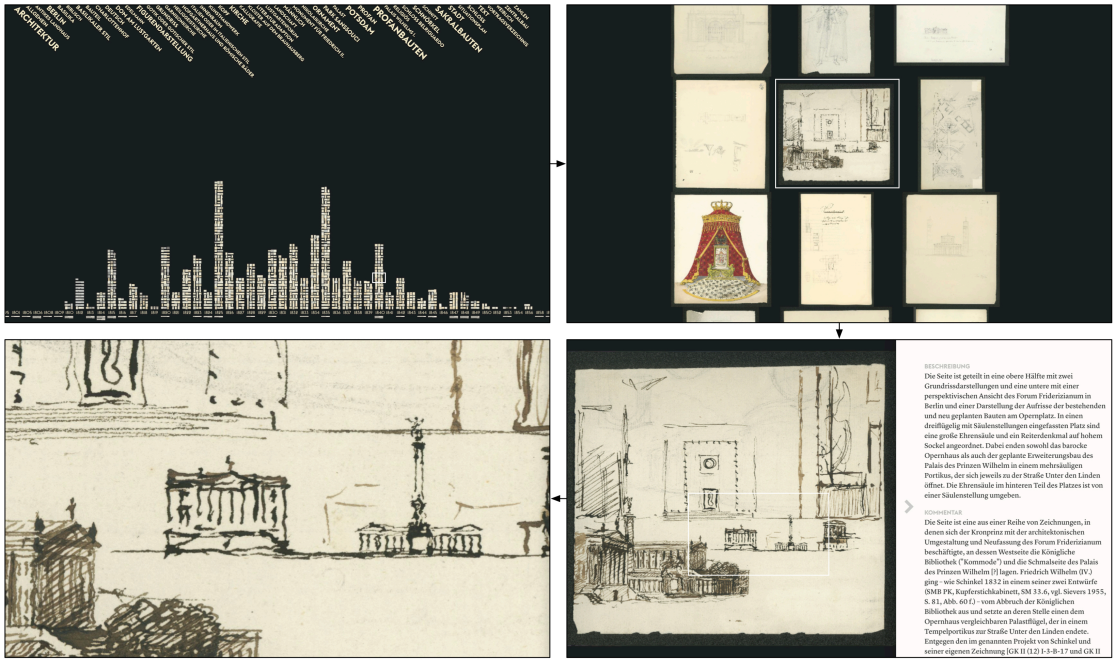

Figure 5. The images' scales in the visualization span several orders of magnitude from a high-level perspective showing the entire collection as small images (top left), zooming into the arrangement revealing more and more detail for each visible image (right), until the very details of one single drawing can be examined (bottom left).

5. Technology

To make the visualization of 1492 images immediately responsive and interactive we take several optimization measures[3]:

- *Multiple resolutions:* Images are provided at three different resolutions depending on the current zoom level. The smallest versions (100 pixels per longer side) are rendered immediately when the visualization is opened. This version provides sufficient resolution for an overview and some level of zooming without loading additional images. The next level of detail (1000 pixels per longer side) is rendered when the interface is zoomed to such a detail that only a few images are visible in the current clip-out of the canvas (see Fig. 5). Once one image is viewed individually, the highest resolution is retrieved (5000 pixels), which allows the viewer to see details of the drawing such as pencil strokes.
- *Image multiplexing:* The images of each zoom layer are bundled and transferred as combined HTTP packages, in which the binary image data is base64 encoded JPEG. This reduces the number of server requests and enables faster transfer [Grigorik 2013]. ImageMagick's lanczos2 algorithm provides the best compression while keeping borders and contours of the drawings sharp. The HTTP payload is subsequently reduced through gzip compression, in order to compensate for the bloating due to the base64 encoding. To allow for dynamic interaction right from the start, we employ a progressive loading approach (see Fig. 6).
- *Web graphics:* The browser-based graphic rendering is implemented using the graphics library pixi.js[4], which utilizes a WebGL context in a canvas element. In addition, we used the visualization library d3.js[5] for scales, transitions and the zooming behavior. All images are rendered in their full resolution onto a layer, which is then downscaled to the corresponding zoom level. Once a scaled layer reaches its native resolution, the subsequent new layer containing the images with higher resolution will be displayed. This layer itself will start with a downscaled version and will be scaled up when zooming.
- *Performance tweaks:* To prevent stuttering during panning and zooming operations [Liu and Heer 2014], we made sure that computation-heavy tasks trigger after, not during interactions. For example, during zooming, more detailed images are put in a queue, which is pushed into the WebGL canvas after the zoom

interaction is finished. The canvas only renders images that are within 50% reach beyond the current viewport. When the viewport is panned, high-resolution images beyond this area will be removed from the render cache (not the browser cache) to reduce the rendering load. To achieve fast and seamless animations for the text-based elements, the rendering of the keywords and timeline is done using CSS3 animations of translate and scale operations, which are carried out on the GPU.

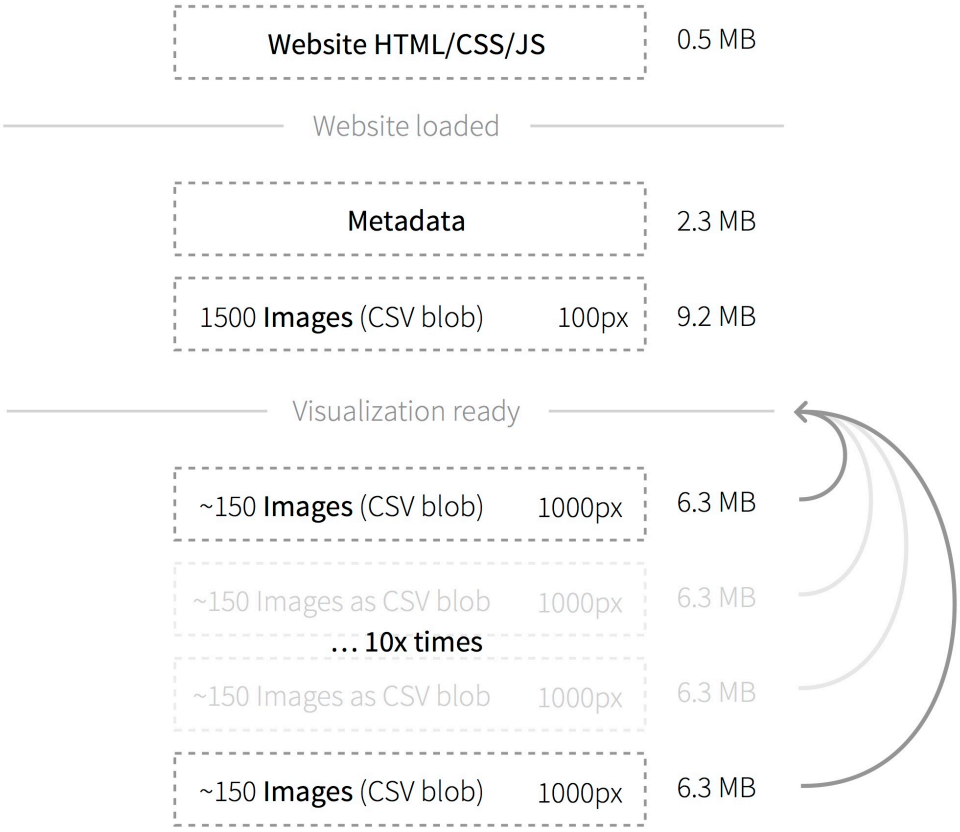

Figure 6. Progressive loading: The user is able to view and interact with the visualization after the first layer of detail is loaded. The second layer of detail is being transferred in the background, which is split into multiple CSV files, holding up to 150 high-resolution images per file.

6. Evaluation

According to our research questions, we studied the visualization in different settings and with a range of audiences. Besides regularly discussing the prototype with our collaborators, we also presented it to other domain experts at network meetings, public talks, or research colloquiums and collected their responses and questions. At an earlier stage of development, the visualization was shown during an exhibition in Berlin under the title “Past Visions of the Future City–Exploration of drawings penned by Frederick William IV of Prussia,” putting an emphasis on the subset of drawings that depict architectural and urban planning visions for Berlin and Potsdam. Visitors mainly identified as being from the visualization and design community, but also as groups of museum professionals. Still, there was a good balance with spontaneous visitors from the neighborhood and surrounding areas with no expertise in neither one of the fields. Most exhibition visitors had no, or only little, knowledge of Prussian history or the King’s life. Accordingly, one particular insight from conversations with visitors was their desire to also learn more about Frederick William’s personal life or the political developments of his time that had an influence on the drawings and sketches.Thus, we decided to supplement the timeline with general historical facts, biographical events, and other relatable information that would help to

comprehend the collection with little prior knowledge about the subject matter. By presenting these earlier stages of the prototype in controlled environments and with the potential to engage in conversations with domain experts or the general public, we were able to continuously react to feedback by our peers during the development process and learn more about how different types of users react to the visualization and interface. Finally, we deployed the visualization as a web application, logged user interactions, and linked a questionnaire in the interface.

6.1. Into the web

The visualization was then deployed online, framed by an introductory microsite that laid out some general information about the scope and background of the project. We integrated a questionnaire and anonymously logged the user interaction on the basis of a list of pre-defined parameters, including session time, time spent with the different visualization components, and zoom level along these activities. The deployment was monitored and logged over a 6-week period (10 February until 22 March 2016), during which a total of 994 unique users interacted with the visualization. In addition to the data gathered from tracking the interactions, we collected responses from 49 users that filled out the questionnaire. Thereof, 31 identified as being residents of Potsdam or Berlin, eight identified as living in other cities in Germany, Austria, and Switzerland, three were UK residents, two each were from Australia and the USA, one from the Netherlands. 14 users had a professional education in both the humanities (art, history, cultural sciences, or architecture, which we refer to as “arts or culture experts”) as well as in design, computer sciences, or data visualization (referred to as “design or vis experts”). 20 users had a background only in arts or culture, 10 had a background only in design or vis. All but three users had at least a university degree, 16 had a doctorate degree. The log was linked to the questionnaire and allowed us to analyze the interaction in correlation to the evaluation of the respective user. We clustered the participants into experts in both fields (group 1), arts or culture experts (group 2), design or vis experts (group 3), and laypersons (group 4). 32

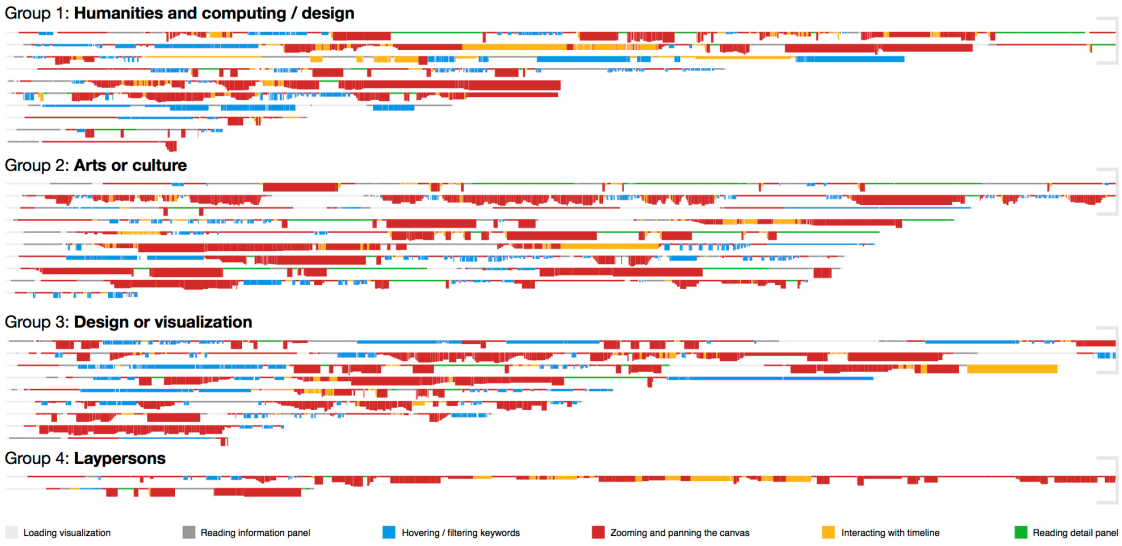

Figure 7. The interaction sequence visualization shows the first 6 minutes of usage for participants who also filled out the questionnaire. Each sequence is divided into blocks, which are colored by the interaction classification corresponding with the different interface elements, and scaled vertically to represent zoom level and the specificity of the current keyword filter.

We analyzed the log files using an interaction sequence visualization (see Fig. 7) with which we can see the order of functions used and level of engagement with the visualization. Each relevant interaction parameter is translated into a visual variable indicating the components of the interface using color, temporal length as width, and the level of “closeness” reached during the interaction as height. Closeness is defined by the zoom level in the canvas and timeline as well as by the number of keywords that were clicked and combined as a filter (thus resulting in more refined results and only a few images displayed above the timeline). The overall impression of the sequence visualization indicates that people using the visualization in fact shifted between distanced (small) and very detailed (tall) perspectives. A closer look on the sequence visualization shows two distinct ways of bridging the different levels of detail, one more gradual 33

(triggered via zooming) and the other very abrupt (triggered by clicks on individual images). Furthermore, the iterations between canvas and timeline interactions are clearly visible by the alternating red and orange blocks.

6.2. Findings

With the questionnaire, participants were asked to evaluate a number of statements on a Likert-scale (see Fig. 8). Regarding the usability of the visualization, the assertion “While using the visualization, I was able to easily find my way around the interface” (question 7) reached a median agreement of 5 on a scale from 0 (strongly disagree) to 6 (strongly agree). Accordingly, the statement, “the interface is difficult to operate” only scored a median agreement of 2. While more detailed user experience testing has to be conducted to identify more specific problems and obstacles, these first usability results already show us a tendency towards decent operability. The participants reported that they were able to get an overview of the contents and objects of the visualization (median agreement of 5), while it also invited them to explore the scope of the themes and engage with unfamiliar topics (question 3 and 5). Thus, the questionnaire confirmed our analysis of the interaction sequences, which had already shown a good balance between “close” and “distant” viewing. The questionnaire also showed that the visualization is not perceived as being solely a research tool but suitable for people looking for a cultural recreational activity (questions 10 and 11). Due to the fact that only five of the respondents were not experts in arts, culture, design or visualization, it would nonetheless need further evaluation in order to be able to better assess if the visualization also works well for interested laypersons.

34

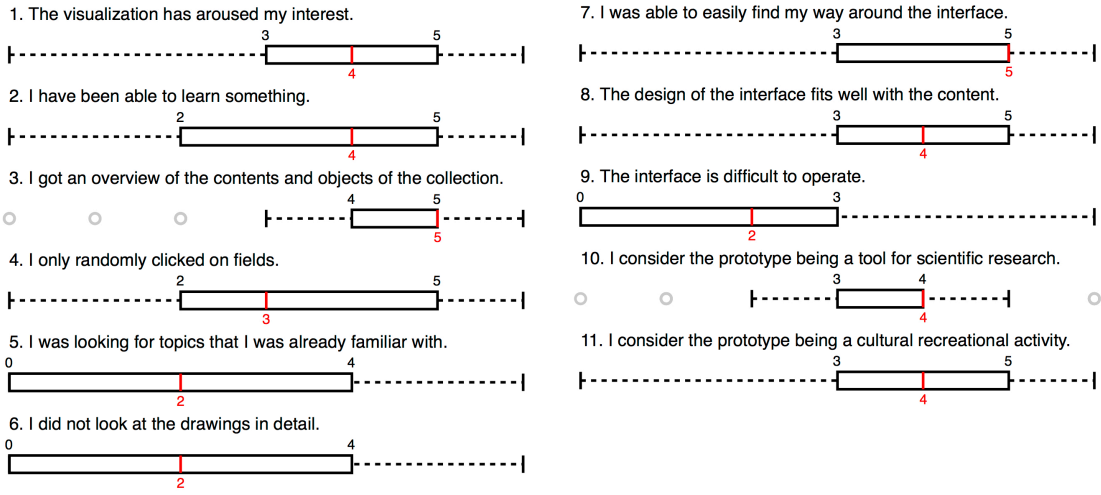

Figure 8. Box-and-whisker plot of questionnaire results along a Likert-scale from 0 (strongly disagree) to 6 (strongly agree).

We also included two open questions and invited the participants to share some general insights and suggestions for improvements. The answers given in this qualitative section of the questionnaire can be grouped into four categories of recurring feedback: interaction, content, design, and general observations. All of which covered a range from positive to negative observations.

35

- *Interaction.* The ability to zoom in into the canvas, filter images by selecting tags, and have the images displayed in high resolution was pointed out as positive features of the visualization and were remarked as being noteworthy by seven participants. Nonetheless, although the basic interactions are illustrated in the information sidebar of the interface, five participants reported experiencing trouble while using the visualization. As an example, one person misinterpreted the text labels as a selector for the images instead of a filter and thus was irritated when no image “opened in full size” [P3, 40-45 years, group 1] after clicking on a tag. This was also the case for two other participants, stating that the images were too small - although the visualization is indeed zoomable up to a high-resolution image. The visual indicators on the info sidebar and the a text panel in the single-image view (clickable arrows pointing to the side that hide the panels for a full-screen view of the canvas and images) seemed to be too subtle for some participants, since three people stated that they e.g. “had wished to be able to see a full-screen version of the images” [P28, 40-45

years, doctorate degree, group 2] without having the info sidebar or the text panel block the view. In one instance, the panning was perceived as cumbersome. One person remarked that the zoom interaction depends on a scroll wheel or touchpad and thus might exclude users that use other hardware. This concurs to the call for being able to interact with the interface using a keyboard and to improve accessibility as expressed by one person.

- *Content.* The scope and richness of the drawings, the artistic talent of the King, as well as his interest in architecture, were pointed out as being memorable and impressive by seven people. The King's repeated journeys to Italy were among the discoveries pointed out by several participants.

  > Well, up to now I have not engaged much with Frederick William IV. In this respect I definitely learned something new. This is a nice method for learning in a discovery-mode. [P40, 45-50 years, group 3].

  The timeline was perceived as novel and descriptive (4x) and deemed to be well suited for the thematic scope (1x). One person pointed out that the descriptions and art historical comments were very valuable for research purposes but might be deterring for laypersons. Another person found the visualization in itself interesting but not the content of it. One person alludes to a key question of visualization in the humanities, how to reveal what is missing or uncertain:

  > The metadata is great, but the visualization seems to focus on what is in there and easily accessible, not what is needed to really be interesting [P35, 35-40 years, group 3].

- *Design*. The combination of a timeline with entities of different themes was pointed out and highlighted by one person as a "pleasant stimulation" [P2, 40-45, group 1]. Being able to focus on a time of creation in relation to the themes within the drawings, thus rapidly gaining an overview on what the king was preoccupied with the most during what time, was also a feature that was singled out (2x). One person found the visualization particularly immersive:

  > I soaked up so much information in a relative short amount of time and can now describe the setting of this time period. I love the zooming and stumbling across this great collection [P34, 30-35 years, doctorate degree, group 2].

  The intersection of quantity and content with the drawings piled up as bar chats was singled out as an interesting design feature (3x).
- *General.* Along more general observations, one person stated that the visualization created the urge to revisit it with more time on hand to be able to delve into the images. The quality of the images was positively remarked (2x), while another person pointed out that the loading time of the high-resolution images was disruptive. A remark on possible improvements made by two people was to include full-text search. Other desired features were additional content linked to the timeline and the images (2x), such as historical photos or a geovisualization of the places and buildings depicted in the drawings.

6.3. Expert observations

We were interested to evaluate if the visualization could also be used as a tool for art historical research. Thus, we asked one of the art historians from the heritage foundation to assess if he or his colleagues are able to derive insights by using the visualization. His feedback summarized the advantages of the temporal arrangement and thematic filter functionality, which creates curve progressions that are highly interesting for art historical research. One significant example for this observation is provided by the sheets covering Charlottenhof Palace. The shape created by the bars along the timeline clearly shows the intensity with which the crown prince worked on his later executed designs after receiving the estate by his father in 1825. Other biographical or political events, such as his marriage or the dawn of revolutions, equally left their traces in his drawings. Thus, his intensive planning on the restructuring of his study and his apartment can be related to his marriage and settling with his wife in the Berlin city palace. Apart from being able to identify dominating themes, the visualization could be instrumental in the effort of obtaining more precise dating. One of

the examples is the depiction of the German piked helmet on some of the King's drawings. The helmet was not used by the Prussian Army earlier than 1843, allowing for a specification of time assigned to some sheets that accumulate several drawings that were interpreted and dated independently. From an expert point of view, the visualization may provide an effective and powerful tool to refine and verify previous art historical findings, datings, and examinations.

7. Discussion

The importance of close collaboration with domain experts in fields like digital art history [Promey and Stewart 1997] was self-evident throughout the process of our research and the development of the visualization. Only by including expert knowledge from the humanities as well as from interface design, computer science, and data visualization we were able to reach a level of mutual understanding for the relevant topics and challenges that were crucial to our work. Pursuing the notion of "cultural sensitivity," the content of the collection was the driving force during the design process. Although the resulting visualization was not intended as a one-fits all solution in the sense of a visualization tool that could be used unmodified for a broad range of data sets, we recognized some promising aspects in the zoomable and filterable canvas that can be transferred to other use cases beyond this specific collection. In the following, we discuss some of our insights and critically evaluate our use case with regard to the areas that would call for additional research and refinement.

37

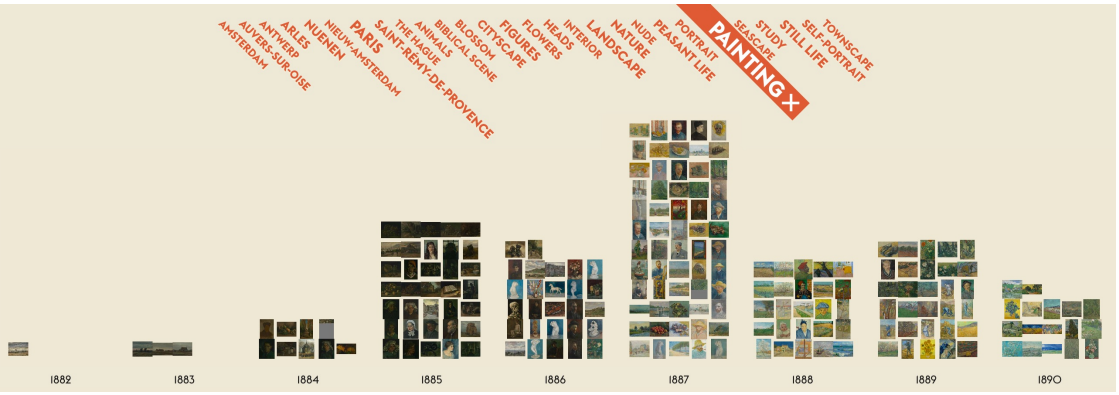

Figure 9. The temporal arrangement of paintings by Van Gogh reflects a general tendency from dark to lighter colors.

38

The collection subset used for the case study consists of about 1500 data records of a collection of drawings that will eventually include more than 7000 sheets. Knowing that the collection will be gradually digitized, we had to take into account the scalability of our approach. Although we have already run some preliminary tests with 7000 images, we would have to assess the performance of the visualization when scaled to such a size more thoroughly. These questions of scalability pave the way for transferring our approach to other image datasets of varying sizes and metadata structures. While the use case was specifically designed and developed for the drawings of Frederick William IV, the relatively monochrome drawings with low contrast are weaker in a 'distant' viewing mode, compared to images with higher contrast and a broader palette of colors. Thus, in order to assess the general viability of transferring our framework, we ran two trials with other data sets. For one, we explored about a thousand paintings, drawings, and other artworks by Vincent Van Gogh[6] (see Fig. 9). For the other, we loaded 3915 items from the New York Public Library collection of Detroit Publishing Company postcards[7]. Initial results indicate that images with a higher contrast and broader palette of colors lend themselves well to exploration in a zoomable and filterable image plot. For example, in the case of Van Gogh, not only quantitative insights about the thematic distribution of works are visualized, but also their visual texture can be examined, e.g., the dominance of darker colors in his early paintings compared to brighter or more colorful shades in the later years becomes clearly visible (see Fig. 9). Similarly, the potential of alternative layouts came up during the iterative development. On the one hand, these layouts could be particularly relevant to the specifics of a collection, for example, the geographical distribution was suggested by participants of our study. On the other hand, we are interested to see how the collection would behave in similarity-based layouts (such as t-SNE) or grid layouts [Klingemann 2015] based on the metadata. Since the metadata is based on in-depth art historical research

along a controlled vocabulary, similarity-based layouts may support the exploration of drawings by affinity. In that sense, such layouts could translate the qualitative insights from the art historical classification into a spatial arrangement.

39 Cultural heritage data is often characterized by incompleteness and uncertainty. While we were able to employ a subset from a collection that had a relatively high level of completeness in regards to required metadata fields, depth of assessment, and a standardized taxonomy, it lies in the nature of qualitatively sourced data to implicate uncertainty, especially with regard to time [Davis and Kräutli 2015]. This also being the case for the subset of drawings by Frederick William IV, discussing the issue with our project partners again highlighted that this is not a problem that is possible to be solved, but that needs to be addressed in the design of what might be called “humanistic interfaces” [Drucker 2011]. During the next iteration of the prototype, we hope to be able to futher discuss and explore how timeline visualizations could visually reflect temporal uncertainty. Even though we already decided to integrate additional contextual information in the timeline — thus including data that had to be specifically sourced and authored manually — some responses by participants in the questionnaire showed that there is a desire for even more contextual data and content from sources that go beyond the defined collection data set. Although the problem was addressed as a general one in regards to cultural heritage interfaces, considering the expansion of used sources and maybe even implementing a layer for community co-creation and annotation (by using folksonomy or crowdsourcing [Ridge 2014]) could be valuable during the next phase of the project. Nonetheless, the question of missing data also has to be seen with regard to the reality and actual state of digitization in most collecting institutions. The sheer amount of collection items, the costs of the digitization process, and the need of expertise when assessing an item and its metadata often make it hard for collecting institutions to meet such requirements just yet.

8. Conclusion

40 With this research we have explored the potential of zoomable visualizations of cultural heritage collections. A collaborative design process with a heritage institution resulted in a visualization technique, which is aimed at supporting a “distant-viewing” approach coupled with a “close-viewing” mode for the exploration of a historical collection. We showed how visualizing the quantitative structure of a collection can be complemented by allowing for examination of the qualitative texture of the individual object. This work contributes insights to discourses on digital heritage as well as on information visualization. In the early years, research in the field of digital cultural heritage and the digital humanities was often dominated by computational or technological solutions originally developed in other fields and for other purposes. Following a shift towards digital heritage research that puts the needs, challenges, and requirements of cultural heritage in the focus and then seeks to find technological and computational solutions for a mainly content-driven approach, we introduced our research in a sense of “cultural sensitivity.” At the same time, humanities research that employs computational methods is often perceived as dominated by a solely quantitative, positivist, or distant approach. Quantitative research in the humanities, in turn, is often questioned on the notion of the alleged necessity of qualitative examination in order to be able to truly grasp the sources’ significance. This “quantitative-qualitative divide” in the humanities, though, is not inherently a digitally inducted discord. Empirical or quantitative methodologies existed in the humanities long before the establishment of computers and web technologies in these fields [Drucker et al. 2015]. Even in pre-digital humanities research, the tendency to either value quantitative research over qualitative research or vice versa already existed [MacNealy 1999]. Rather than carrying on an antagonistic discourse of “close vs. distant,” “qualitative vs. quantitative” under the slogan of “digital vs. analog,” there is an increasing recognition of the potential in experimenting and engaging with digital technologies that can help to actually unify these seemingly opposed strands, predominantly in language-centric research [Jänicke et al. 2015] [Koch et al. 2014] [Muralidharan and Hearst 2013]. With our research we expand on this notion and apply it to a collection of visual resources. Our contributions thus are relevant for the ever growing research activities in digital art history, as well as a foundation for further work on visualization in the context of digital cultural heritage.

Acknowledgements

41 We wish to thank the reviewers of the Digital Humanities Quarterly for their thoughtful feedback and suggestions. We would like to acknowledge the German Federal Ministry of Education and Research (BMBF) for their generous funding of our research project VIKUS - Visualizing Cultural Collections (Visualisierung kultureller Sammlungen). We thank our

project partners SPSG and Programmfabrik GmbH for the productive cooperation. We wish to thank Matthias Graf for his work on a previous version of the visualization, Jörg Meiner for his scientific consulting and for valuable ideas, Carsten Dilba for his continuous feedback, and – last but not least – we are thankful for the support from our colleagues Sebastian Meier, Till Nagel, Stephanie Neumann und Jan-Erik Stange.

Notes

[1] The visualization prototype presented in this paper has been previously mentioned in a project description published under the title “Linking structure, texture and context in a visualization of historical drawings by Frederick William IV (1795-1861)”, K. Glinka, C. Pietsch, C. Dilba, M. Dörk, *International Journal of Digital Art History* 2 (2016).

[2] Although much has changed in educational systems since C. P. Snow’s 1959 lecture on "The Two Cultures" [Snow 1959], some of his analysis of the differences in culture in “the sciences” and “the humanities” still hold true today.

[3] We are currently working on generalizing our prototype. In this process, we will also publish the code and a detailed documentation in an online repository for re-use and replication of our framework.

[4] http://www.pixijs.com/

[5] http://www.d3js.org/

[6] http://www.vangoghmuseum.nl/

[7] http://digitalcollections.nypl.org/collections/detroit-publishing-company-postcards/

Works Cited

Algee et al. 2012 Lauren Algee, Jefferson Bailey, and Trevor Owens. 2012. “Viewshare and the Kress Collection: Creating, sharing, and rapidly prototypingvisual interfaces to cultural heritage collection data.” *D-Lib Magazine*, 18(11):3.

Bederson and Hollan 1994 YB.B. Bederson and J.D. Hollan. 1994. “Pad++: a zooming graphical interface for exploring alternate interface physics.” In *UIST 1994: Symposium on User Interface Software and Technology*. ACM, 17–26.

Bender 2015 K Bender. 2015. “Distant Viewing in Art History. A Case Study of Artistic Productivity.” *Int. Journal for Digital Art History* 1 (2015).

Bentkowska-Kafel 2005 Anna Bentkowska-Kafel, Trish Cashen, and Hazel Gardiner (Eds.). 2005. *Digital art history: a subject in transition*. Computers and the history of art series 1, Vol. 1. Intellect.

Bentkowska-Kafel 2015 Anna Bentkowska-Kafel. 2015. “Debating Digital Art History.” *Int. Journal for Digital Art History* 1 (2015).

Bhawuk and Brislin 1992 Dharm Bhawuk and Richard Brislin. 1992. “The Measurement of intercultural sensitivity using the concepts of individualism and collectivism.” *International Journal of Intercultural Relations*. 16(4), 413-436.

Cameron 2007 Fiona Cameron. 2007. “Beyond the Cult of the Replicant–Museums and Historical Digital Objects: Traditional Concerns, New Discourses.” *Theorizing Digital Cultural Heritage A Critical Discourse*. The MIT Press, 49–75.

Chen et al. 2014 Ko-Le Chen, Marian Dörk, and Martyn Dade-Robertson. 2014. “Exploring the Promises and Potentials of Visual Archive Interfaces.” *iConference 2014 Proceedings: Breaking Down Walls. Culture - Context - Computing* (2014).

Davis and Kräutli 2015 Stephen Boyd Davis and Florian Kräutli. 2015. “The Idea and Image of Historical Time: Interactions between Design and Digital Humanities.” *Visible Language* 49, 3 (2015), 101.

Davis et al. 2013 Stephen Boyd Davis, Emma Bevan, and Aleksei Kudikov. 2013. “Just in time: defining historical chronographics.” In *Electronic Visualisation in Arts and Culture*. Springer, 243–257.

Drucker 2011 Johanna Drucker. 2011. “Humanities approaches to graphical display.” *Digital Humanities Quarterly* 5, 1 (2011).

Drucker 2013 Johanna Drucker. 2013. “Is There a “Digital” Art History?” *Visual Resources* 29, 1-2 (2013), 5–13.

Drucker et al. 2015 Johanna Drucker, Anne Helmreich, Matthew Lincoln, and Francesca Rose. 2015. “Digital art history: the American scene.” *Perspective [Online]* 2 (2015). http://perspective.revues.org/6021

Dudley 2012 Sandra Dudley. 2012. “Materiality Matters: Experiencing the Displayed Object.” In *Working Papers in Museum Studies* 8. University of Michigan (2012).

Dörk et al. 2012 Marian Dörk, Sheelagh Carpendale, and Carey Williamson. 2012. “Fluid Views: a zoomable search environment.” In *AVI 2012: Advanced Visual Interfaces*. ACM, 233–240.

Galey and Ruecker 2010 Alan Galey and Stan Ruecker. 2010. “How a prototype argues.” *Literary and Linguistic Computing* 25, 4 (2010), 405–424.

Gibbs and Owens 2012 Fred Gibbs and Trevor Owens. 2012. “Building better digital humanities tools: Toward broader audiences and user-centered designs.” *Digital Humanities Quarterly* 6, 2 (2012).

Glinka et al. 2015 Katrin Glinka, Sebastian Meier, and Marian Dörk. 2015. “Visualising the Un-seen: Towards Critical Approaches and Strategies of Inclusion in Digital Cultural Heritage Interfaces.” In *Kultur und Informatik*. vwh, 105–118.

Gosden and Marshall 1999 Chris Gosden and Yvonne Marshall. 1999. “The Cultural Biography of Objects.” *World Archaeology*, Vol. 31, No. 2 (1999), 169-178.

Greene et al. 2000 Stephan Greene, Gary Marchionini, Catherine Plaisant, and Ben Shneiderman. 2000. “Previews and overviews in digital libraries: designing surrogates to support visual information seeking.” *Journal of the American Society for Information Science* 51, 4 (2000), 380–393.

Grigorik 2013 Ilya Grigorik. 2013. “Making the Web Faster with HTTP 2.0.” *Queue* 11, 10 (2013), 40:40–40:53. 1542-7730

Haber et al. 2011 Jonathan Haber, Sean Lynch, and Sheelagh Carpendale. 2011. “ColourVis: exploring colour usage in paintings over time.” In *Proceedings of the International Symposium on Computational Aesthetics in Graphics, Visualization, and Imaging*. ACM, 105–112.

Hinrichs et al. 2008 Uta Hinrichs, Holly Schmidt, and Sheelagh Carpendale. 2008. “EMDialog: Bringing Information Visualization into the Museum.” *TVCG: Transactions on Visualization and Computer Graphics* 14, 6 (Nov/Dec 2008), 1181–1188.

Hinrichs et al. 2016 Uta Hinrichs, Stefania Forlini, and Bridget Moynihan. 2016. “Speculative Practices: Utilizing InfoVis to Explore Untapped Literary Collections.” *Visualization and Computer Graphics, IEEE Transactions on* 22, 1 (2016), 429–438.

Hochman and Manovich 2013 Nadav Hochman and Lev Manovich. 2013. “Zooming into an Instagram City: Reading the local through social media.” *First Monday* 18, 7 (July 2013).

Hullman and Diakopoulos 2011 Jessica Hullman and Nick Diakopoulos. 2011. “Visualization Rhetoric: Framing Effects in Narrative Visualization.” *TVCG: Transactions on Visualization and Computer Graphics* 17, 12 (Dec 2011), 2231–2240.

Isemann and Ahmad 2014 Daniel Isemann and Khurshid Ahmad. 2014. “Ontological Access to Images of Fine Art.” *Journal on Computing and Cultural Heritage* 7, 1, Article 3 (April 2014), 25 pages. 1556-4673 http://doi.acm.org/10.1145/2538030

Jänicke et al. 2015 Jänicke, Stefan; Franzini, Greta; Cheema, Muhammad Faisal; Scheuermann, Gerik 2015. “On Close and Distant Reading in Digital Humanities: A Survey and Future Challenges.” *Eurographics Conference on Visualization (EuroVis) - STARs* (2015), 83–103.

Klingemann 2015 Mario Klingemann. 2015. “Raster Fairy transform any kind of 2D point cloud into a regular raster.” https://github.com/Quasimondo/RasterFairy – Retrieved 2016-03-25. (2015).

Koch et al. 2014 S. Koch, M. John, M. Worner, A. Muller, and T. Ertl. 2014. “VarifocalReader – In-Depth Visual Analysis of Large Text Documents.” *TVCG: Transactions on Visualization and Computer Graphics* 20, 12 (Dec 2014), 1723–1732.

Kräutli 2016 Florian Kräutli. 2016. *Visualising Cultural Data: Exploring Digital Collections Through Timeline Visualisations.* PhD thesis, Royal College of Art.

Kucher and Kerran 2014 Kostiantyn Kucher and Andreas Kerren. 2014. “Text visualization browser: A visual survey of text visualization techniques.” *Poster Abstracts of IEEE VIS* 2014 (2014).

Liu and Heer 2014 Z. Liu and J. Heer. 2014. “The Effects of Interactive Latency on Exploratory Visual Analysis.” *TVCG: Transactions on Visualization and Computer Graphics* 20, 12 (Dec 2014), 2122–2131.

MacNealy 1999 Mary Sue MacNealy. 1999. *Empirical Research in the Humanities*. Vol. Strategies for Empirical Research in Writing. Allyn and Bacon, Chapter 1.

Malpas 2007 Jeff Malpas (2007) “Cultural Heritage in the Age of New Media.” In: Yehuda Kalay, Thomas Kvan, Janice Affleck (eds.) *New Heritage: New Media and Cultural Heritage.* Routledge, 2007.

Manovich 2015 Lev Manovich. 2015. “Data Science and Digital Art History.” *Int. Journal for Digital Art History* 1 (2015), 13–35.

McCurdy et al. 2016 N. McCurdy, J. Lein, K. Coles, and M. Meyer. 2016. “Poemage: Visualizing the Sonic Topology of a Poem.” *TVCG: Transactions on Visualization and Computer Graphics* 22, 1 (Jan 2016), 439–448.

Moretti 2005 Franco Moretti. 2005. *Graphs, Maps, Trees: Abstract models for a literary history*. Verso.

Muralidharan and Hearst 2013 Aditi Muralidharan and Marti A. Hearst. 2013. “Supporting exploratory text analysis in literature study.” *Literary and Linguistic Computing* 28, 2 (2013), 283–295.

Parry 2007 Ross Parry. 2007. *Recoding the Museum. Digital Heritage and the Technologies of Change.* Routledge.

Promey and Stewart 1997 Sally M Promey and Miriam Stewart. 1997. “Digital art history: A new field for collaboration.” *American Art* 11, 2 (1997), 36–41.

Ridge 2014 Mia Ridge. 2014. *Crowdsourcing our Cultural Heritage*. Ashgate Publishing Company.

Ruecker et al. 2011 Stanislaus Ruecker, Milena Radzikowska, and Stéfan Sinclair. 2011. *Visual interface design for digital cultural heritage: A guide to rich-prospect browsing.* Ashgate Publishing.

SFMOMA 2008 SFMOMA. 2008. *Explore Modern Art — ArtScope.* https://www.sfmoma.org/experience/artscope/ – Retrieved 2016-08-26. (2008).

Saleh and Elgammal 2015 Babak Saleh and Ahmed Elgammal. 2015. “Large-scale Classification of Fine-Art Paintings: Learning The Right Metric on The Right Feature.” *arXiv preprint arXiv:1505.00855* (2015).

Sanders and Stappers 2008 Elizabeth Sanders and Pieter J. Stappers. 2008. “Co-creation and the new landscapes of design.” *Co-design* 4, 1 (2008), 5–18.

Schich 2010 Maximilian Schich. 2010. “Revealing Matrices.” In *Beautiful Visualization: Looking at Data through the Eyes of Experts*. O’Reilly, Chapter 14, 227–254.

Schnapp et al. 2009 Jeffrey Schnapp, Todd Presner, Peter Lunenfeld, and others. 2009. *The digital humanities manifesto 2.0.* http://http://manifesto.humanities.ucla.edu/2009/05/29/the-digital-humanities-manifesto-20/ – Retrieved 2016-08-25. (2009).

Schumacher 2016 Susanne Schumacher (2016) “Using words to network images: indexing and interaction strategies in a digital archive,” *Visual Studies*, 31:2, 121-130.

Sedlmair et al. 2012 Michael Sedlmair, Miriah Meyer, and Tamara Munzner. 2012. “Design Study Methodology: Reflections from the Trenches and the Stacks.” *TVCG: Transactions on Visualization and Computer Graphics* 18, 12 (2012), 2431–2440.

Shamir and Tarakhovsky 2012 Lior Shamir and Jane A. Tarakhovsky. 2012. Computer “Analysis of Art.” *Journal on Computing and Cultural Heritage* 5, 2, Article 7 (Aug. 2012), 11 pages. 1556-4673 http://doi.acm.org/10.1145/2307723.2307726

Shneiderman 1996 Ben Shneiderman. 1996. “The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations.” In *Proceedings of the IEEE Symposium on Visual Languages*. 336–343.

Snow 1959 C. P. Snow. 1959. *The Two Cultures and the Scientific Revolution. The Rede Lecture*. Cambridge University Press.

Thudt et al. 2012 Alice Thudt, Uta Hinrichs, and Sheelagh Carpendale. 2012. “The Bohemian Bookshelf: Supporting serendipitous book discoveries through information visualization.” In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1461–1470.

Watkins et al. 2015 Rebecca D. Watkins, Abigail Sellen, Siân E. Lindley. 2015. “Digital collections and digital collecting practices.” In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems,* pages 3423–3432.

Wattenberg and Viégas 2008 Martin Wattenberg and Fernanda B. Viégas. 2008. “The Word Tree, an Interactive Visual Concordance.” *TVCG: Transactions on Visualization and Computer Graphics* 14, 6 (2008), 1221–1228.

Whitelaw 2015 Mitchell Whitelaw. 2015. “Generous Interfaces for Digital Cultural Collections.” *Digital Humanities Quarterly*

9, 1 (2015).

Zweig 2015 Benjamin Zweig. 2015. “Forgotten Genealogies: Brief Reflections on the History of Digital Art History.” *Int. Journal for Digital Art History* 1 (2015), 101–110.