A Review of Information Visualization Approaches and Interfaces to Digital Cultural Heritage Collections

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Abstract

After decades of digitization, the web hosts a large scale museum, consisting of millions of digital cultural objects. To balance the drawbacks of parsimonious search-centric interfaces, various approaches have been developed to enable also visual access to these collections, and to browse and explore the cultural richness of existing archives. This paper reviews information visualization approaches to digital cultural heritage collections, reflects on prominent arrangement principles and design choices for digital collection interfaces, and points out options for future research.

1. Introduction

From things making them smart (like tools, achievements, or information artifacts), to things lifting them up (art and entertainment) – cultures collect things. To share and preserve them for future generations, populations draw artful or useful objects (like texts, images, material objects, concepts, music, or films) together. These cultural heritage (CH) collections (libraries, galleries, museums, archives) contain notable works and objects – as well as associated knowledge and data.

With developing media technologies and collaborations, large digital meta collections (e.g. http://www.europeana.eu, http://trove.nla.gov.au/, or http://dp.la/) have emerged, which aggregate cultural heritage objects across institutions, domains, and countries, and make the web the largest museum ever around. Yet the situation is known to be rather bleak, when it comes to actually accessing the collected riches – not only, but especially for non-expert users, who often have no idea what to expect in the digital collection. The rampant problems with the widely dominant search box approach to cultural object collections have been thoroughly exposed and discussed [BOP82, DCW11, THC12, Whi15]. Whitelaw retells the typical search-based visit to online collections as a bizarre purchase order situation, where the widely dominant information retrieval paradigm over-successfully reduces data complexity (which in the CH context is often appreciated as its own reward), thus throwing the baby out with the bath water. Rather than throwing the collection doors open and offering multiple ways of access, visitors have to enter a drab (search box) lobby, which asks them "*yes, what?*" – and urges them to come up with demands towards the unknown [Whi15].

In contrast, more generous interfaces open up the digital archives' walls, tear down the drab lobbies, and offer multiple ways in, where they foster free-roaming, browsing and exploring, and support rich, serendipitous discoveries [DCW11]. We build on the multiply proven assumption, that information visualization (InfoVis) methods and techniques can strongly support such generous approaches. Yet according to our best knowledge, no systematic collection of InfoVis approaches to CH collections has been undertaken until now. To close this gap, we review related work and outline a possible classification of InfoVis approaches and interfaces for digital CH collections, which aims to consolidate the growing research field and to inform future projects.

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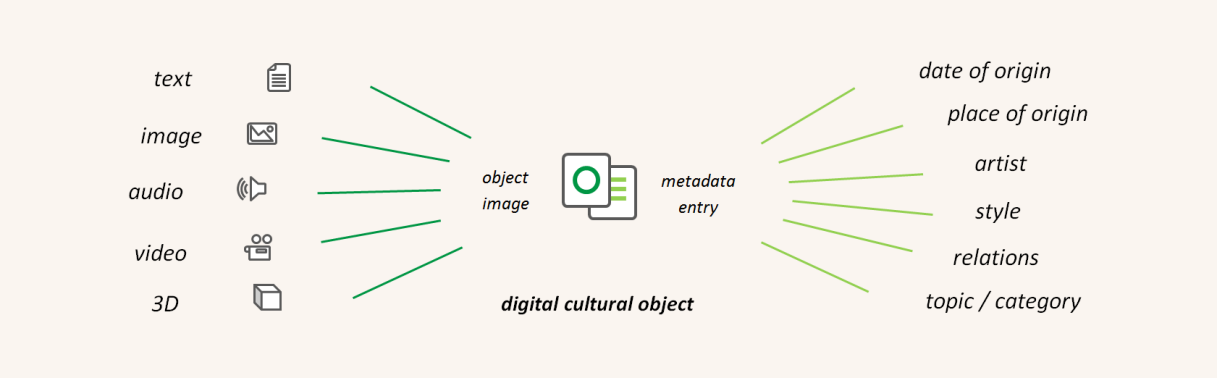

Figure 1: Common cultural object types (left) and common dimensions of object metadata (right).

2 Design Patterns for Interfaces to Digital Object Collections

If museums, libraries, or archives are the original three-dimensional display spaces for cultural object collections, their spatial arrangements are generated by a minimum of standard layouts: parallel tableaus on museum floors or in showcases, and linear arrangements along walls or shelves, ordered mostly due to the metadata dimensions of date, style, artist, or place of origin. Procedures of digitization extend cultural collections (complementing physical objects with digital ones) – and put their visual arrangement on digital display spaces up for renegotiation. For that purpose, all available metadata dimensions could be utilized – and furthermore encoded into novel collection representations.

Figure 1 illustrates the multitude of possible digital object types (left), and a selection of prominent metadata dimensions (right), with the latter being usually formatted due to a given documentation standard [Bac02]. This two-sided representation also mirrors the common dual nature of digital ob jects, duplicating an object into a realistic image of the object (provided by a spatial layout-preserving *scientific visualization* procedure), and a (semi)structured, multi-dimensional metadata entry. While the realistic image allows to study cultural objects in a close up-perspective, their accessibility in a larger collection is either provided by a search functionality – or by alternate, more generous approaches to interface design, including a wide variety of InfoVis images and methods. With interfaces thus taking over the role of museums or exhibition halls, their design determines an online collections' accessibility and impact, and should not be underestimated as a major factor for the overall success of any arts and culture mediation initiative.[1] We focus on the question how to visualize collection overviews and assemble relevant design patterns in the following sections, which will provide the categories for a more systematic recollection of InfoVis interfaces further down.

2.1 Close-ups, Previews and Collection Overviews

Cultural object collections commonly contain much more objects than could be displayed in a parallel close-up perspective on a screen. This challenge is commonly taken on by the design of macroscopic collection overviews – and their connection to vertical drill down and horizontal browsing options on demand [DCW11, GMPS00].

As a review of interfaces shows, collection overviews are usually following one of three design options: Whole object collections could be represented as i) multitudes of miniature previews (thumbnails), or

[1] Well knowing that the remote exploration of cultural collections on screens still "doesn't compare to being there" [RHQ14], digital interfaces mostly strive to augment and enrich traditional *in situ*-interaction with collections. This includes the design of approaches i) to provide macroscopic perspectives on high-volume collections in which patterns and relations become visible, ii) to extend visitors' working memory to grasp large, complex datasets often for the first time, iii) to add to richer, contextualized observations through linked data dimensions, or iv) to reduce collectors' and curators' biases and to facilitate more inclusive representations, suited for a broader user group [Sul13, GMD15].

as ii) multitudes of abstracted visual marks only (e.g. dots representing objects), whose arrangement principles are laid out in section 2.2. As a third option (iii), overviews can abstract from displaying separated objects, but encode selected object attributes into the visual variables of various diagrams (cf. 2.2.5), which opens up the field for the use of a wide spectrum of InfoVis methods, that can support further collection exploration too.

From a user and interaction perspective, overviews feature as natural starting or entry points to a collection. They provide initial orientation, and commonly enable further operations of zooming, filtering, and browsing to study details and close-ups on demand. While these transitions between micro and macro perspectives pose a central challenge for interaction design, we turn to prominent arrangements for macroscopic overviews first. As mentioned above, this is where various dimensions of object metadata (like place of origin, date of origin, artist, topics, or styles) come into play.

Figure 2 shows prominent arrangement principles for collection overviews: While the center left column features traditional ways of (multi)linear aggregations, the center right column lists methods for the visual encoding of *spatial* (i.e. cross-sectional, non-temporal) metadata aspects. Here "spatial" not only refers to geographic aspects of metadata, but also to their distributions in algebraic or vector spaces.

2.2 Encoding of Spatial Data Dimensions

Following a distinction by Kerracher et al. [KKC14], we distinguish methods of encoding *spatial* data dimensions from encoding methods for *temporal* (i.e. longitudinal) data aspects, which we consider to play a crucial role for the omnipresent time-orientation of CH collection data. Distributed across both sides of this distinction, we refer to the most prominent traditional spatial arrangement principle of object collections as (multi)linear arrangements (2.2.1), which are also frequently chosen for digital collection interfaces.

2.2.1 Lists, Slideshows, Grids and Mosaics

Mirroring the sequential arrangements in physical exhibitions along walls or shelves, vertical *lists* or

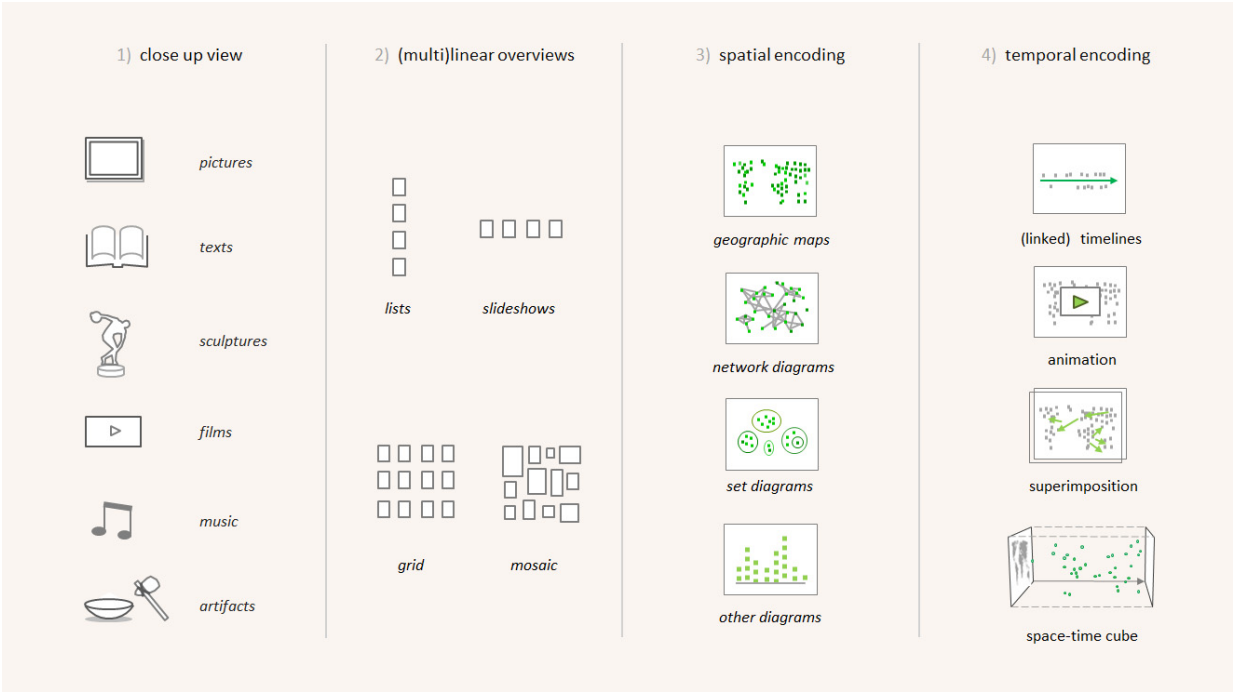

Figure 2: Principles for the visualization of cultural collections, from close-ups (left), to (multi-)linear aggregations (center left) to spatial (center right) and temporal (right) visual encoding methods.

horizontal *slideshows* arrange object collections in an unilinear sequence of previews on computer screens [IF:HTA]. As multilinear arrangements, *grids* and *mosaics* arrange previews in multiple rows, to raise the item-screen-ratio (Fig. 2, center left). In contrast to physical hangings, the guiding aspect for (multi)linear arrangements can often be freely chosen amongst existing metadata dimensions, so that either date of origin, alphabetical sequence, or even user metrics (like item popularity) determine the visible sequence of objects on screens [IF:GCI]. Furthermore, grids and mosaics can be dynamized, so that tiles represent object categories or subcollections and change their content over time, to enable also passive contemplation without clicking and scrolling [Whi15, para 39]. Going beyond (multi)linear arrangements, several InfoVis methods support the visual encoding and exploration of spatial (non-temporal) data aspects for whole collections.

2.2.2 Geographic Maps

As place of origin counts among the most frequently documented data dimensions of cultural objects and artifacts, *geographic maps* often serve as a visualization method to show the spatial distribution of artifacts' origins [BGSvdB14, IF:DGB, TO:GBDE, TO:PAL, TO:VS].

2.2.3 Network Diagrams

As for relational data (e.g. influences, references, inter-artifact relations) network diagrams allow users to explore the proximities and distances of artifacts or cultural actors in relational or topological spaces [HSC08, IF:DDBV, IF:ECB, IF:IA, IF:HG, IF:EDG, TO:PAL].

2.2.4 Set Diagrams

Given different thematic or stylistic classifications of cultural artifacts, set diagrams or treemaps offer insights into categorically and often also hierarchically structured object metadata constellations [XEJJ14, UPM12, IF:PAN].

2.2.4 Other Diagrams

When overviews abstract from single objects and focus on data distributions in different metadata dimensions, a wide variety of further InfoVis diagrams can provide overview on selected collection aspects, including area charts [IF:SCE], ring charts [IF:DDBV], scatter plots [Man09, ABO12, IF:CG], and many more.

These different diagrams again could be integrated into multiple coordinated views by CH collection dashboards [UTA10]. As an interesting crossover approach, diagrams could also be synthesized from object previews, allowing for seamless micro-macro transitions [IF:PVWF].

2.3 Encoding of Temporal Data Dimensions

While maps, networks, set and other diagrams provide specific insights into spatial data aspects and distributions, they initially offer static images for aggregated data only. Yet with *temporal aspects* (like date of origin) playing a crucial role in the domain of CH data, most interfaces have to encode temporal information too**.**

2.3.1 (Linked) Timelines

One prominent option is to represent time linearly, which is done with linear timelines as singular views, or with *linked timelines*, usually implemented as coordinated temporal view in addition to spatial representations [Kra16, IF:DGB, IF:HTA, IF:MOTW, IF:NL, IF:PAN, TO:VS].

2.3.2 Animation

Further options for encoding temporal data aspects build on the abovementioned spatial visualizations and add temporal information in a hybrid, spatiotemporal way. Among these, *animation* is frequently used, mapping time to time [IF:DGB, IF:PAN].

2.3.3 Superimposition

Superimposition approaches merge multiple temporal layers or snapshots into one visualization, with temporal data aspects often being distinguished by different colors [BGSvdB14], or visualization of movement trajectories [TO:NL].

2.3.4 Space-Time Cube

Space-time cube representations build on 2D planes of encoded spatial data dimensions (like maps or networks), and map time to an additional spatial dimension, i.e. the orthogonal z-axis. Cultural object collections thus arrange as characteristically shaped 3D

point clouds, according to various spatio-temporal layouts [Kra05, WMS*16].

2.4 Multi-Method Interfaces

As the assembly of approaches and interfaces in *table 1* shows, multiple spatial encoding methods have already been implemented in the CH data domain – often also as multi-method interfaces to enable the combination of different exploratory views on the data. The same holds true for different temporal encoding methods: It is well known that different temporal encoding methods show different strengths and weaknesses. Due to this reason, advanced InfoVis interfaces increasingly combine multiple temporal and spatial encoding techniques, to compensate their drawbacks and add up their complementary benefits [KKC14]. This equals the provision of multiple access points and overviews [THC12], which form complementary composites, revealing different "parallax" views of a collection [Dru13]. Due to the relevance of this design principle, the following collection primarily takes approaches and interfaces into account which have been implementing a multi-method approach.

3 Assembling Information Visualization Approaches to Digital CH Collections

Table 1 provides an overview of prominent InfoVis approaches to digital CH collections. Interfaces are classified and specified according to four main categories. While the first two categories make the chosen spatial and temporal encoding methods visible (cf. 2.2 und 2.3), the third column specifies the focus of interest, which predominantly is either a certain type of cultural objects, or a focus on cultural actors (FCA), or a focus on cultural topics or styles. The fourth column points out whether the approach is of conceptual and prototypical nature, or whether it provides an open, web-based interface [IF:XYZ] or a

Table 1: Information visualization approaches and interfaces to digital cultural object collections, ordered according to their chosen method of spatial encoding, temporal encoding, entity focus, and type of project.

		spatial encoding					temporal encoding				focus on cultural objects or actors							type of project		
reference	DCHC visualization projects	lists, slideshows, grids, & mosaics	geographic map	network diagrams	set diagrams (category)	other diagram	(linked) timeline	animation	superimposition + cc	3D	other encoding	texts	images	artifacts	music / audio	film / video	artists / persons	topics / styles / areas	concept / prototype	interface	tool
[IF:GCI]	Google Cultural Institute	x					x						x				x	x		x	
[Whi15]	Generous Interfaces (Case Studies)	x						x					x					x	x	x	
[ABO12]	ViewShare	x	x			x					x		x							x	
[IF:HG]	histograph	x		x								x	x			x	x			x	
[IF:CS]	CultureSampo		x	x	x	x						x	x	x	x	x			x	x	
[IF:DGB]	GeoBrowser / Europeana 4D		x				x	x	x			x	x	x	x	x	x			x	
[TO:PAL]	Palladio		x	x								x	x	x	x	x	x				x
[BGS+14]	GLAM Map		x						x			x							x		
[WMS+16]	PolyCube		x	x	x					x		x	x	x	x	x	x	x	x		
[IF:HTA]	Heilbrunn Timeline of Art History		x				x						x	x						x	
[IF:NL]	Neatline | Omeka		x				x	x	x			x	x	x			x			x	x
[IF:ROL]	Republic of Letters		x	x			x					x					x			x	
[IF:IA]	The Invention of Abstraction [FCA]			x					x								x			x	
[DBBV]	DBB visualisiert			x		x	x		x			x	x	x	x	x				x	
[HSC08]	EMDialog			x		x					x	x					x		x		
[IF:ECL]	eclap-Browser - Social Graph			x									x		x	x				x	
[IF:EDG]	Edgemaps [FCA]			x			x										x		x	x	
[XEJ*14]	Xu et al. 2014				x														x		
[IF:PAN]	Pantheon [FCA]		x		x	x	x										x			x	
[IF:CG]	Culturegraphy			x		x										x				x	
[IF:KB]	Kindred Britain [FCA]		x	x		x	x		x								x			x	
[IF:SCE]	SelfieCity Exploratory	x				x							x							x	
[IF:PVFW]	Past Visions by Frederick William IV					x	x						x							x	
[Man09]	Imageplot Suite [TO:IPS]					x							x								x
[IF:MOTW]	Museum of the World						x			x		x	x	x						x	

tool [TO:XYZ], with which external DH collection data could be visually explored [cf. Pos16].

3.1 Interpretation

While looking at single approaches helps to specify their implemented combination of methods, parsing of columns helps to explore the prominence of encoding methods or object types. With regard to the overall distribution, well-established InfoVis techniques can be identified, as well as structural holes, which might deserve closer attention by future interface design and research. Exemplarily, the distribution of temporal encoding methods shows a dominant use of (linked) timelines, which again are known to evoke split attention effects [AS05]. To reduce cognitive, load more spatio-temporally integrated encoding techniques like space time-cube representations could be tested.

3.2 Limitations

Aiming for the consolidation of the research field and for orientation of future approaches, we are still aware of two obvious limitations. As the interaction with 'cultural object collections' is investigated in multiple academic domains, the current review is far from exhaustive. Yet by highlighting and comparing recent works and developments, we hope to lay ground for a more systematic and critical discussion – as well as for their future enrichment and refinement.

Furthermore, we consider the chosen categories of classification to be relevant from an InfoVis methods perspective, but are aware of possible other foci of attention. As such we exemplarily consider interaction and navigation techniques to provide productive categories or further analysis, as well as a wide variety of 'humanistic' user experience and design principles [Dru13, DCW12, Whi15], which could help to shape the focus on relevant DH interface functions and features with even more precision.

4. Conclusions and Outlook

We presented a review of InfoVis approaches and interfaces to digital CH collections, and arranged existing work by the means of a categorical framework, which we submit for critical examination and collective refinement.

We expect the field of CH collection visualization to further develop and diversify – not least due to the fact that the world wide web renders itself ever more indispensable as a medium for knowledge communication. Despite restricted budgets of local collectors and institutions, efforts for digitization and dissemination will continue, as will the development of web-based interfaces.

From an InfoVis perspective, we consider the field of CH data, users and tasks, to be a specifically productive one, revolving around grand design challenges. While CH data is often characterized by massively heterogeneous and time-oriented data complexity, its audiences approach it with heterogeneous, underspecified tasks [MFM*16]. Besides the consideration of well-known principles of graphical excellence, such casual users require also more aesthetics-oriented, entertaining approaches. In contrast to principles of parsimonious design and complexity minimization, the preservation of aesthetic complexity and diversity matter in the CH domain, and non-conclusive explorations provide their own reward. Therefore, the value of methods supporting horizontal browsing, multiple access points and serendipitous insight creation is ranging high. This makes CH data a challenging research field, expanding and enriching the scope of consolidated playing fields for InfoVis research far beyond expert-oriented professional applications.

Furthermore, we expect new options for interface design to emerge from the expansion and pervasion of *linked data* in the CH realm [KAR15, IF:CS], as well as the utilization of *user data,* which will open up new ways to weigh, highlight, recommend, and tailor interfaces for general audiences and specific user groups alike.

From a systematic point of view – which might be most relevant because of its *didactic* implications – we hope for a continued discussion and consolidation process to accompany the outlined developments. We consider such macroscopic reflections not only to be relevant for integrating the state of the art on academic grounds (informing new directions and approaches), but also for introducing visitors to the workings of their new online museums and archives. In contrast to traditional encounters with culture collections, their experiences and learnings will also depend on their ability to comprehend and master the powerful (re-) arrangement, encoding and interaction techniques, which new interfaces are already providing us with.

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CH InfoVis Web-Interfaces

[IF: CG] *Culturegraphy*

URL: http://www.culturegraphy.com/

[IF:CS] CultureSampo

URL: http://www.kulttuurisampo.fi/?lang=en

[IF:DDBV] *Deutsche Digitale Bibliothek Visualisiert*
URL: http://infovis.fh-potsdam.de/ddb/

[IF:DGB] *DARIAH-DE Geo-Browser* / *Europeana4D*
URL: https://geobrowser.de.dariah.eu/

[IF:ECB] *eclap-Browser / Social Graph*
URL: http://www.eclap.eu/portal/

[IF:EDG] *Edgemaps* [FCA]

URL: http://mariandoerk.de/edgemaps/demo/

[IF:GCI] *Google Cultural Institute*
URL:https://www.google.com/culturalinstitute

[IF:HG] *histograph*

URL: http://histograph.cvce.eu/

[IF:HTA] *Heilbrunn Timeline of Art History* | *The MET*
URL:
http://www.metmuseum.org/toah/chronology/

[IF:KB] *Kindred Britain* [FCA]

URL: http://kindred.stanford.edu/

[IF:IA] *Inventing Abstraction 1910-1925* [FCA]
URL: www.moma.org/inventingabstraction

[IF:MOTW] *Museum of the World*

URL: https://britishmuseum.withgoogle.com/

[IF:PAN] *Pantheon* [FCA]

URL: http://pantheon.media.mit.edu/

[IF:PVFW] *Past Visions by Frederick William IV*.
URL: https://uclab.fh-potsdam.de/fw4/

[IF:ROL] Republic of Letters [FCA]

URL: http://ink.designhumanities.org/dalembert/

[IF:SCE] *SelfieExploratory* | *SelfieCity*

URL: http://selfiecity.net/selfiexploratory/

CH InfoVis Tools

[TO:GBDE] *Geo-Browser Datasheet Editor*
URL: https://geobrowser.de.dariah.eu/edit/

[TO:IPS] *ImagePlot Suite*
URL: http://lab.softwarestudies.com/p/software-for-digital-humanities.html

[TO:NL] *Neatline* | *Omeka*

URL: http://neatline.org/

[TO:PAL] *Palladio*
URL: http://hdlab.stanford.edu/palladio/#/

[TO:VS] *ViewShare*
URL: http://viewshare.org/