Shapes of Time: Visualizing Set Changes Over Time in Cultural Heritage Collections

S. Salisu[1], E. Mayr[1], V. A. Filipov[2], R. A. Leite[2], S. Miksch[2], and F. Windhager[1]

[1]danubeVISlab, Department for Knowledge and Communication Management, Danube University Krems, Austria
[2]Centre for Visual Analytics Science and Technology (CVAST), Vienna University of Technology, Austria

Abstract

In cultural heritage collections, categorization is a central technique used to distinguish cultural movements, styles, or genres. For that end, objects are tagged with set-typed metadata and other information, such as time of origin. Visualizations can communicate how such sets organize a collection - and how they change over time. But existing interfaces fall short of a) representing an overview of temporal set-developments in an integrated fashion and b) of representing the set elements (i.e., the cultural objects) themselves to be contemplated on demand. Against this background, we introduce two integrated visualization techniques - a superimposition and a space-time cube view - depicting the development of sets and their elements over time. We share first results from a qualitative evaluation with casual users and outline open challenges for future research.

CCS Concepts

• ***Human-centered computing*** → *Information visualization;* • ***Computing methodologies*** → *Temporal reasoning;* • ***Applied computing*** → *Arts and humanities;*

1. Introduction

The time of history – as the art historian Kubler noted [Kub62] – stretches like a sea, occupied by innumerable cultural objects, which yet belong to cultural forms of "a finite number of types" (p. 32). Arts and humanities scholars have to reassemble these forms and types, and analyze their evolution and development in larger continuous sequences, to better understand the cultural "shapes of time". With this poster we turn our attention to the development of corresponding visualization techniques for set-typed and temporal data in the context of cultural heritage (CH) domains. After recollecting design requirements and related work (Sec. 2), we introduce two visualization techniques for set-typed CH data to support exploration of set changes over time (Sec. 3) and provide an outlook on first evaluation results and future work (Sec.4).

2. Design requirements and related Work

Visualization of CH collection data is an area of increasing importance in information visualization [WFS*18]. Visualization-based interfaces to galleries, libraries, archives and museums provide collection overviews, support exploratory browsing, and facilitate the contemplation of details on demand [DCW11]. While a wide spectrum of visualization techniques has already been utilized – such as maps, graphs, trees, charts, or timelines – only a few examples of set-based visualizations have been documented up to now [WFS*18], which did not take the temporal dynamics of sets into account. Yet, set-typed, time-varying metadata is omnipresent in the CH domain, due to archival knowledge management strategies given by CH taxonomies, categories, genres, topics, or styles.

In other domains beyond CH, we find a great variety of visualization techniques to represent set-typed data [AMA*16, CPC09, VBW15], for which the representation of *change* counts as a crucial challenge [AMA*16]. In a simplified manner, sets can be described by the number of elements they contain, and their temporal variation can be visualized by line charts, stacked area charts, or variations thereof, such as *ThemeRiver* [HHN00] or *Tag River* [FAHL11]. These methods also provide basic options for temporal visualization of CH sets (see e.g., [DPC17]). However, these visualizations build on significant abstractions and do not represent the elements within the set-like categories - which hinders further exploration of single objects. This also holds true for more advanced visualization systems, such as *TimeSets* [NXWW16], *KelpFusion* [MHRS*13], *VISTopic* [YYQ17], or for systems with coordinated multiple views [FMH08, BAA*11, vLBA*12], which remain limited with regard to important functions, tasks, and design requirements in the CH domain.

3. Design: Shapes of Time

In a CH context, casual users do not really pursue concrete tasks, but they want to look and stroll around and have been shown to benefit mostly from being provided an overview and orientation (T1) [MFM*16, DCW11]. With regard to further documented knowledge about casual users [MFM*16] and our case study data

DOI: 10.2312/eurp.20191142

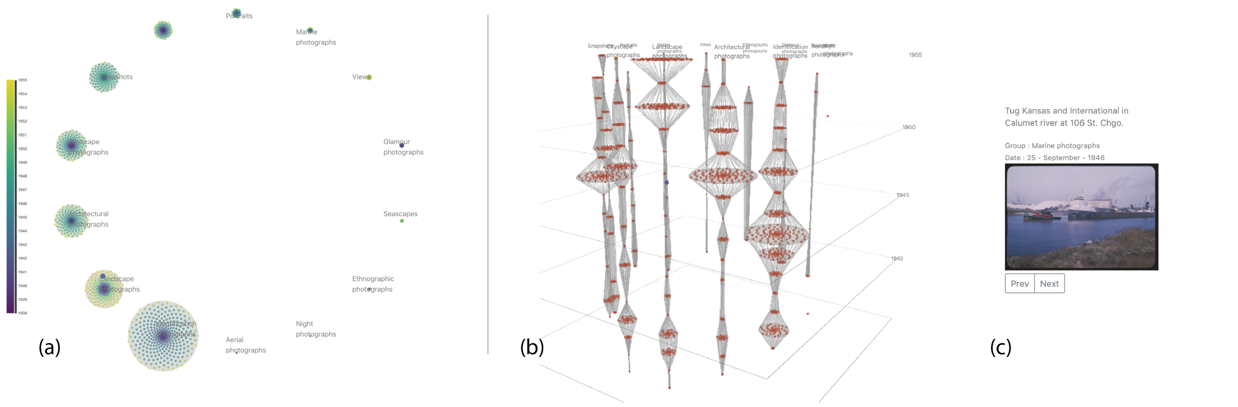

Figure 1: *Visualizing set changes over time in the Cushman photography collection: (a) Superimposition view, (b) space-time cube view with set changes connected by a "hull", and (c) preview of an individual cultural object.*

(a photography collection from Charles W. Cushman, which has been documented online [cus17]) we could derive three additional tasks, which also translated into further design requirements: Aside from overviews, CH visitors require means to *trace temporal developments* (T2), *access individual objects* (T3) and to engage in *exploratory browsing* (T4). To answer these requirements, we developed multiple visualization designs, two of which we implemented and evaluated in comparison: While a *superimposition view* utilizes a color scale to encode temporal information, a *space-time-cube* encodes time along an additional spatial dimension.[†]

3.1. Arrangement of Multiple Sets

For both designs, sets are represented as circles and set elements are arranged as points inside, which thus can be selected, previewed and accessed for detailed information at any time (T3 and T4). In general, elements within sets are arranged according to an Archimedian spiral - with earliest objects placed in the middle of each circle, and later objects following towards the periphery. The radius of each circle thus encodes the number of objects in any given set. As for an overview arrangement of parallel sets (T1), we provide multiple layout options for the users' choice in both views, including a circular layout (default), a linear layout, and a matrix-based layout. For user guidance, labels next to each individual set annotate the corresponding genres (such as person, landscape, or architectural photographs), which have been assigned to each picture by the photographer himself. A preview on the right hand side (Fig. 1c) grants access to individual objects (T3), which can further be enlarged to a full screen view with a lateral browsing option (T4).

3.2. Sets in the Superimposition View

To further support the analysis and the tracing of time-oriented data aspects (T2), the color-coded Superimposition view utilizes the Viridis color scale to encode the time of origin of each object within each circle (see fig. 1a).

3.3. Sets in the Space-Time Cube View

Secondly, we offer a space-time cube (STC) representation for the time-oriented exploration of set-typed data (see Fig. 1b). Even though 3D representations are known to introduce additional interaction costs to compensate for problems of visual occlusion, the STC also offers a combination of unique visual-analytical strengths [WSSM18, VFC10, pp. 15], which renders the STC a compelling and complementing alternative view in addition to the superimposition view. When adapted for set-typed data, the horizontal data plane of a STC arranges multiple sets in parallel – as seen in the superimposition view – and stacks temporal segments vertically, from the earliest segments at the bottom to the latest at the top, based on a user-controlled interval of temporal granularity. These stacks along the vertical axis are further connected by a geometric mesh or hull. The specific angle and shape of this hull denotes basic development patterns of set dynamics, such as emergence, growth, diminution and decline [WSSM18], and thus supports users analysis of development of sets over time.

4. Evaluation and Future Work

First evaluation results of a qualitative evaluation with four casual users showed specific strengths and limitations for both designs: The STC view was more effective when performing *traceability* (T2) tasks, while some users preferred the superimposition view for *individual access* (T3) tasks, although, both views where equally effective for the *provision of overview* (T1) and for the support of *exploratory browsing* (T4).

Aside from a transfer of the outlined designs to linked CH visualizations with a geo-temporal and a relational-temporal focus, future work will specifically investigate representation options for data quality and uncertainty, which poses specific challenges in the CH domain [WFSM18].

[†] For an interactive version of the visualization techniques see https://bigdata-vis.github.io/polycube/shapeoftime.html

Acknowledgments

This work was supported by a grant from the Austrian Science Fund (FWF) Project No. P28363-24.

References

[AMA*16] ALSALLAKH B., MICALLEF L., AIGNER W., HAUSER H., MIKSCH S., RODGERS P.: The State-of-the-Art of Set Visualization. *Computer Graphics Forum 35*, 1 (Feb. 2016), 234–260. doi:10.1111/cgf.12722. 1

[BAA*11] BREMM S., ANDRIENKO G., ANDRIENKO N., SCHRECK T., LANDESBERGER T. V.: Interactive analysis of object group changes over time. In *EuroVA 2011* (2011). doi:10.2312/PE/EuroVAST/EuroVA11/041-044. 1

[CPC09] COLLINS C., PENN G., CARPENDALE S.: Bubble sets: Revealing set relations with isocontours over existing visualizations. *IEEE Transactions on Visualization and Computer Graphics 15*, 6 (2009), 1009–1016. doi:10.1109/TVCG.2009.122. 1

[cus17] Indiana University Archives. Charles W. Cushman Photograph Collection [Online] Available: https://webapp1.dlib.indiana.edu/cushman/index.jsp. URL: https://webapp1.dlib.indiana.edu/cushman/index.jsp. 2

[DCW11] DÖRK M., CARPENDALE S., WILLIAMSON C.: The information flaneur: A fresh look at information seeking. In *Proc. SIGCHI Conference on Human Factors in Computing Systems* (2011), ACM, pp. 1215–1224. doi:10.1145/1978942.1979124. 1

[DPC17] DÖRK M., PIETSCH C., CREDICO G.: One view is not enough. High-level visualizations of a large cultural collection. *Information Design Journal 23:1* (2017), 39–47. 1

[FAHL11] FORBES A. G., ALPER B., HÃŰLLERER T., LEGRADY G.: Interactive Folksonomic Analytics with the Tag River Visualization. In *IEEE Workshop on Interactive Visual Text Analytics for Decision Making* (Providence, RI, 2011). 1

[FMH08] FREILER W., MATKOVIC K., HAUSER H.: Interactive visual analysis of set-typed data. *IEEE Transactions on Visualization and Computer Graphics 14*, 6 (2008). 1

[HHN00] HAVRE S., HETZLER B., NOWELL L.: ThemeRiver: Visualizing Theme Changes over Time. In *Proceedings of the IEEE Symposium on Information Vizualization 2000* (Washington, DC, USA, 2000), IEEE Computer Society, pp. 115–. 1

[Kub62] KUBLER G.: *The Shape of Time: Remarks on the History of Things*. Yale University Press, 1962. 1

[MFM*16] MAYR E., FEDERICO P., MIKSCH S., SCHREDER G., SMUC M., WINDHAGER F.: Visualization of cultural heritage data for casual users. In *IEEE VIS Workshop on Visualization for the Digital Humanities* (2016). 1

[MHRS*13] MEULEMANS W., HENRY RICHE N., SPECKMANN B., ALPER B., DWYER T.: KelpFusion: A hybrid set visualization technique. *IEEE Transactions on Visualization and Computer Graphics 19*, 11 (Nov. 2013), 1846–1858. doi:10.1109/TVCG.2013.76. 1

[NXWW16] NGUYEN P. H., XU K., WALKER R., WONG B. W.: TimeSets: Timeline visualization with set relations. *Information Visualization 15*, 3 (2016), 253–269. doi:10.1177/1473871615605347. 1

[VBW15] VEHLOW C., BECK F., WEISKOPF D.: The State of the Art in Visualizing Group Structures in Graphs. In *Eurographics Conference on Visualization (EuroVis) - STARs* (2015), Borgo R., Ganovelli F., Viola I., (Eds.), The Eurographics Association. doi:10.2312/eurovisstar.20151110. 1

[VFC10] VROTSOU K., FORSELL C., COOPER M.: 2d and 3d representations for feature recognition in time geographical diary data. *Information Visualization 9*, 4 (2010), 263–276. 2

[vLBA*12] VON LANDESBERGER T., BREMM S., ANDRIENKO N., ANDRIENKO G., TEKUŠOVÁ M.: Visual analytics methods for categoric spatio-temporal data. In *2012 IEEE Conference on Visual Analytics Science and Technology (VAST)* (Oct 2012), pp. 183–192. doi:10.1109/VAST.2012.6400553. 1

[WFS*18] WINDHAGER F., FEDERICO P., SCHREDER G., GLINKA K., DÖRK M., MIKSCH S., MAYR E.: Visualization of Cultural Heritage Collection Data: State of the Art and Future Challenges. *IEEE Transactions on Visualization and Computer Graphics* (2018). doi:10.1109/TVCG.2018.2830759. 1

[WFSM18] WINDHAGER F., FILIPOV V. A., SALISU S., MAYR E.: Visualizing Uncertainty in Cultural Heritage Collections. In *EuroVis Workshop on Reproducibility, Verification, and Validation in Visualization (EuroRV3)* (2018), The Eurographics Association. doi:10.2312/eurorv3.20181142. 2

[WSSM18] WINDHAGER F., SALISU S., SCHREDER G., MAYR E.: Orchestrating Overviews. A Synoptic Approach to the Visualization of Cultural Collections. *Remaking Collections. Special Issue of the Open Library of the Humanities* (2018). doi:10.16995/olh.276. 2

[YYQ17] YANG Y., YAO Q., QU H.: Vistopic: A visual analytics system for making sense of large document collections using hierarchical topic modeling. *Visual Informatics 1*, 1 (2017), 40 – 47. doi:10.1016/j.visinf.2017.01.005. 1