Beyond One-Dimensional Portraits: A Synoptic Approach to the Visual Analysis of Biography Data

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Abstract

The study of biography data – and the reasoning with it – can be supported by multiple visualization techniques. Biographical databases contain massive amounts of temporally structured biographical entries, connecting events, places, institutions and actors with a variety of relations between them. We present a synoptic visualization concept for multi-dimensional biographical analyses, to go beyond well-established techniques to portray one-dimensional data aspects. We discuss synergies arising from the combination of multiple synchronic and diachronic views into a more coherent visual analytics environment. Possible synchronic views include geographic, relational and categorial perspectives on biography data (e.g., maps, network and treemap diagrams), while multiple diachronic perspectives are provided by coordinated multiple views, animation, layer superimposition, layer juxtaposition, and space-time cube representations. By closely intertwining these visualization methods we aim to support the creation of more integrated and connected mental models of biographical data. This visual framework is open for other fields of application like prosopographical research, digital history, or many other time-oriented arts and humanities data domains.

Keywords: biography data, prosopography data, information visualization, visual analytics, information integration, mental model

1. Introduction

Digital biographical databases are a rich resource for historical research: They provide a massive amount of information, which used to be scattered in different text collections or local archives, and make it possible to technically connect them to bigger pictures of the life patterns of historic individuals and groups. Yet, analyzing, as well as reasoning and sensemaking with these multi-dimensional data remains challenging, especially for non-experts in digital methods. In this paper we present how an integrated visualization framework (PolyCube project, 2018) addresses these challenges by developing a synoptic visualization approach for the study of biography data.

Information visualizations "use computer- supported, interactive, visual representations of abstract data to amplify cognition" (Card et al., 1999). Visual representations help to explore and analyze data distributions and patterns immediately, and to reason on them interactively. Some biographical databases already offer supportive measures in form of basic visual representations like maps, networks or timelines (cf. APIS project, 2018). These techniques allow to analyze single data-dimensions, such as geographical, relational or temporal aspects of individual biographies. However, such selective or one-dimensional visualizations do not allow to investigate cross-dimensional questions like "*How does the movement of actors affect their social networks, institutional affiliations, or their means and rhythms of cultural production?*".

Going beyond the use of multiple but unconnected views, visualization research already provides various synoptic design strategies, which require a careful adaptation to the biography research realm. Against this background, we consider the integration of one-dimensional data portraits into bigger pictures to be a novel and noteworthy objective for advanced visualization system design.

To do so, we will look at the initial state of textual biography data (e.g., as given by biographical lexica) and how it is currently transformed into structured digital data (Section 2). A discussion of related work in visualization research (Section 3) will be followed by reflections on challenges posed by the utilization of multiple but separated perspectives (Section 4). To effectively tackle these challenges with a novel visualization system design we introduce the PolyCube framework (Section 5) and outline options for its future elaboration (Section 6).

2. Textual biography data

Collecting, documenting and sharing facts and stories about the lives of relevant individuals is a core activity of human cultures, and the essential objective for biography researchers since centuries (Roberts, 2002).

Figure 1: Biographical lexica collect textual data and images about historically relevant individuals. Screenshot from the ÖBL (Österreichisches Biographisches Lexikon, 2018).

As a result, hundreds of thousands of textual descriptions have been accumulated into biographical libraries and dictionaries, which are recently transformed into structured data collections by digital humanities initiatives (Bernád, Gruber & Kaiser, 2017).

2.1 Digital biography projects

While traditional written collections have largely appeared as meaningless textual "strings" to digital research approaches before, methods of natural language processing (NLP) allow to transform these texts into structured, semantically enriched data. Several research groups throughout Europe are currently working on creating enriched linked open datasets (LOD) based on national biographical dictionaries (e.g.. Fokkens et al., 2014; Reinert et al., 2015; APIS project, 2018). Starting from textual entries on historic individuals - see Figure 1 for an exemplary entry on the bishop Friedrich Piffl (1864–1932) from the Austrian Biographical Dictionary 1815-1950 (ÖBL)[1] – NLP methods enable the extraction of structured entities, including (names of) actors, places, institutions, or events, all featuring different attributes and interrelations, which are changing due to actions and developments over time (Reinert et al., 2015; Reznik & Shatalov 2016; Schlögl & Lejtovicz, 2017). The resulting data collections are often modeled as time-oriented knowledge graphs, which are accessible for novel data and text-analytical procedures, including methods of visual analysis and communication (see sec. 3).

While the future promises of such technologies for historic research are striking – in terms of openly accessible databases containing millions of actors and relations - there are still a lot of problems to solve. Most of the biographical dictionaries started several decades ago when printing books was still expensive and therefore make extensive use of abbreviations. Most of modern NLP tools on the other hand are trained on digital born texts and perform very bad on these abbreviations. Even when the NLP part (mainly named entity extraction) works well, the automatic linking of entities - finding the real world expression of a string - is still a merely unsolved problem. This is especially true for biographies where we often miss additional information on the entities found in the text. Visual analytics is not only important for analyzing the final data, but can also play a crucial role in detecting errors in this unsteady process.

2.2 The APIS system

The APIS system was developed in the course of the identically named digitization project (APIS, 2018). The APIS project deals with semantically enriching the Austrian Biographical Dictionary (Österreichisches Biographisches Lexikon 1815–1950, ÖBL), which is a supranational work of reference covering courses of life and career of about 20.000 historical figures of the former Austro-Hungarian monarchy and the First and Second Republics of Austria.

[1] Austrian Biographical Dictionary entry accessible online at http://www.biographien.ac.at/.

For the project, a custom relation-based data-model was developed. It covers persons, places, institutions, works and events and allows for interrelating all of these entities. While entities also contain easy to adapt attributes, relations only consist of a time frame and a type. Attributes of entities and the relation type are SKOS (Simple Knowledge Organization System) based vocabularies. The data model also allows for keeping a complete edit log.

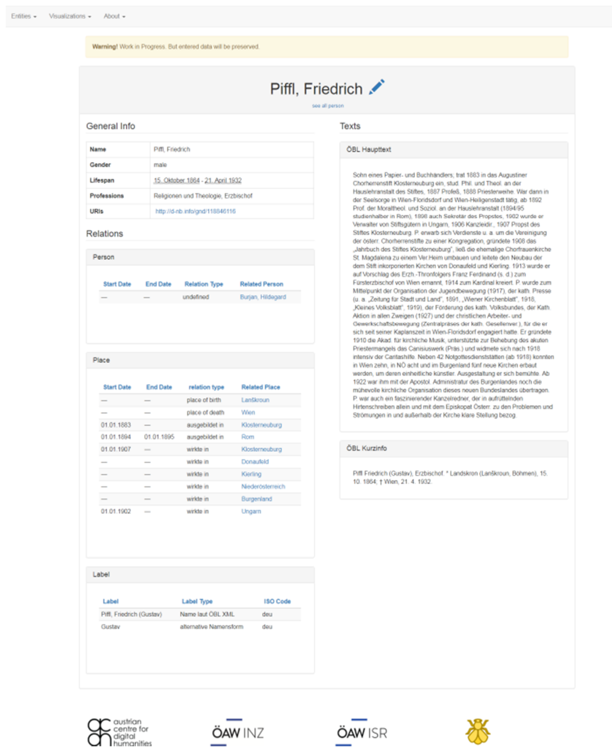

Figure 2: Digital biography projects extract entities (such as places, persons, institutions, events and works) and their interrelations as time-oriented, structured data. Screenshot from APIS project (2018).

For a smooth and easy editing process, a web application was developed (see Fig. 2). Amongst others, it features autocompletes, automatic links to reference resources (such as Geonames and GND), the possibility to highlight or annotate entities directly in the biography, a basic mapping and network visualization component with export functionality (Schlögl & Lejtovicz, 2017).

Similar to other biography digitization projects, the APIS system aggregates large amounts of structured data to support historians and humanities scholars' research activities. Yet to make these large amounts of data more accessible and to efficiently support the corresponding reasoning and sensemaking processes, advanced (visual) analysis methods are required.

3. Visualization of biography data

Recent work in the visualization realm has documented multiple options to support the visual analysis of biographical data from various synchronic (i.e. geographic, relational or structural) and diachronic (i.e., time-oriented) perspectives. The table in figure 3 shows different *synchronic* (i.e., not primarily time-oriented but structure or distribution-oriented) perspectives as rows. Due to their general prominence, maps have already been widely adapted for the visualization of biography data (APIS project, 2018), and methods for the geo-temporal visualization of actor movements are under constant development (Ellegaard et al., 2004; Kapler & Wright, 2005; Kwan et al., 2005; Goncalvez et al., 2015). For the visualization of relations between different actors, network frameworks (Schich et al., 2014; Kaiser, 2017), and mixed method approaches (Armitage, 2016) have been proposed. Attributes of historic individuals (such as professions or fields of activity) have been visualized by treemaps (Hidalgo et al, 2014), whereas other approaches engaged in multi-method investigations and visualizations (Gergaud et al., 2017).

For *diachronic* perspectives, various approaches have been developed to map time linearly as *timelines* (Hiller, 2011; Brehmer, 2017). Other hybrid methods to visually encode time in addition to synchronic data aspects include *animation*, *layer juxtaposition*, *layer superimposition*, and *space-time cube* representations, which are represented as columns in figure 3.

Despite the growing amount of visualization techniques, which are technically available to analyze selected dimensions of biographical data collections, their orchestrated use has not been advocated and investigated so far. Also the challenge of integrating multiple views on different data dimensions has not been addressed systematically so far. With regard to both of these research gaps, we consider the development of multi-perspective interfaces, which support the integration of different perspectives, to be a next level design objective. Such a multiple-perspective interface would also improve the chances to detect fundamental errors in NLP-based data creation pipelines early on.

4. Combining multiple visualization perspectives

Given the complex and multidimensional nature of biography data, every single visualization technique can reveal only a rather one-sided or one-dimensional data portrait. Specific visualization methods (such as maps, networks or timelines) provide analytical benefits with regard to certain data and tasks, but are limited or useless with regard to others. Advanced visual interfaces aim to overcome these limitations by combining and utilizing multiple visualization techniques synchronously, which cover multiple data dimensions and aspects either by an interface of parallel views (often as *coordinated multiple views*, Scherr, 2008) or as perspectives to be chosen in a serial manner. With regard to the distinction between synchronic and diachronic visualization techniques, we argue that advanced visual-analytical interfaces to biography data are well-advised to integrate multiple views and instances from both categories, also to cover the relevance of the temporal dimension for biographies.

Implemented within multiple coordinated views, *synchronic perspectives* (showing cross-sectional, structural, or distributional data aspects, see fig. 1, first column) can combine their analytical features, but commonly have to be complemented by at least one analytical perspective on temporal aspects of data organization. These *diachronic perspectives* can be added as linear representations (e.g., as timelines in coordinated multiple views, see fig. 3, second column), or as various hybrid techniques to encode time as joint projections together with synchronic representations (see Figure 3, third to sixth column).

Figure 3: A cross tabulation of synchronic (including geographic, relational, and categorial visualizations; rows) and diachronic visualization methods (split screen, animation, superimposition, juxtaposition, and space-time cube perspective; columns) for biography data.

Multiple views are a design principle of general relevance for complex data, "in order to maximise insight, balance the strengths and weaknesses of individual views, and avoid misinterpretation" (Kerracher et al., 2014). This applies for both synchronic and diachronic perspectives: Given the importance of the temporal dimension in biography research, it seems obvious that multiple solutions to represent time can increase the analytical diversity and capacity of a visualization system. Multiple views allow researchers to select and switch between the most appropriate representations for the data and task at hand.

Figure 3 cross-tabulates the various synchronic and diachronic visualization techniques mentioned so far, and depicts a basic design space for biography data visualization, which remains also open for the addition of novel methods (see section 6). It offers well-established options for the visualization of biographic pathways through multiple “space-times” - as orthogonal combinations of synchronic (rows) and diachronic perspectives (columns) on the data. While single methods have already been implemented separately by various interfaces to biographical data collections (cf. Section 2), their well-composed *combination* and *integration* is a next-level design challenge not tackled up to now.

Yet, especially for interfaces with multiple views, a new problem of visual-analytical complexity emerges: When historians aim to answers questions combining multiple data dimensions (such as “*How did the migration of an individual affect her/his social network, institutional* *affiliations, or means and motivations of cultural production*?") they commonly have to combine information from multiple views. This requires to build up a mental model bridging and integrating different data dimensions, which is a task high in cognitive effort (Trafton et al., 2000). Attention is commonly split between multiple views and linked data have to be identified and related, before they can be integrated into one mental model. Yet, different visualization techniques (which we refer to as "*coherence techniques*", Schreder et al., 2016) can support researchers in assembling their local insights into a bigger picture. Well-established techniques for such a support derive from the visual integration of different data dimension into a multidimensional visualization, and among those, *space-time cube representations* show a significant potential to mediate across the different splits and separations of usually unconnected and particularistic perspectives.

In the following we introduce a framework revolving around space-time cube representations. While this framework initially demonstrates what one specific diachronic perspective (i.e. the space-time cube) can do for the visual analysis of biography data, we also show how this perspective can play a crucial role for the cognitive integration and mutual translation of multiple other diachronic perspectives (Bach et al., 2016).

5. A synoptic visualization framework utilizing multiple space-time representations

The PolyCube framework has been set up to support synoptic visual data analysis with regard to cultural collection data (Windhager et al., 2016; 2018). With regard to history and biography data, it provides even richer options to support visual investigation and information integration between multiple views. We outline its main perspective by tracing its geo-temporal origins, and move on to demonstrate its analytical potential also for non-geographic aspects of biography data. For this purpose we combine prototype visualizations developed across three different research projects (Federico et al., 2011; Smuc et al., 2015; Mayr & Windhager, 2018), and showcase an exploratory study conducted with biography data (cf. Windhager et al., 2017).

5.1 Geographic space-time

The visual notation of the space-time cube originated in human geography to allow for the visual analysis of human movement patterns and of the diffusion of innovation. This visualization method blends synchronic views like maps (as horizontal plane) and a diachronic timeline (vertical z-axis) in an orthogonal fashion, which allows to model spatiotemporal data points (like events of historic travels) as a three-dimensional shape. Any spatiotemporal behavior thus translates into a unique space-time trajectory and enables historians to interpret biographic movements as visual patterns.

Figure 4 illustrates this option for biography research by taking on the geo-temporal movements of the Austrian archbishop Friedrich Piffl (1864-1932), which were extracted from the textual data shown in figures 1 and 2 (APIS project, 2018). The trajectory shows the main stations (from top to bottom) of his life, including Lanskroun (Czech Republic), Vienna, Rome, and Hungary.

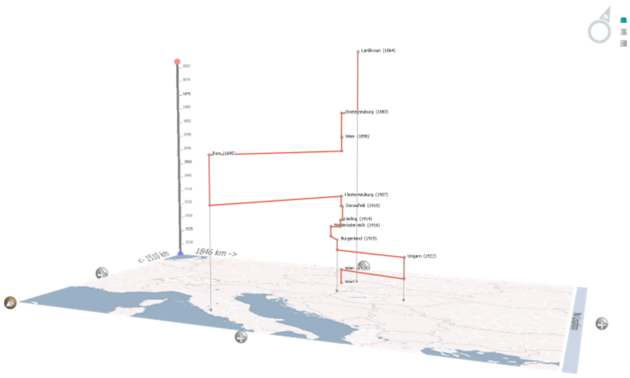

Figure 4: Visualization of the biographical trajectory of Friedrich Piffl (1864–1932) from a geo-temporal perspective, created with GeoTime (Kapler et al., 2005).

For the purpose of comparative and combinatory research, composite visualizations (such as juxtaposed or superimposed space-time paths) enable the visual comparison and combination of biographical life patterns, including the study of similarities and differences of patterns among different actors. Figure 5 illustrates this option by displaying the pathways of the Austrian artists and siblings Josefine and Rudolf Swoboda, whose careers as portrait painters led them into opposite directions and to different royal courts spread across the world map.

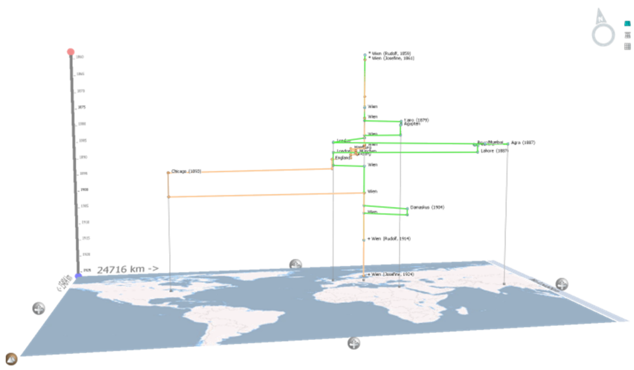

Figure 5: The trajectories of the Austrian artists and siblings Josefine (1861-1924, orange) and Rudolf (1959-1915, green) Swoboda, seen from a geotemporal perspective.

Analyzing and visualizing exemplary entries from the APIS data collection also made the problem of incomplete and implicit information obvious: Biographical articles contain a lot of implicit information that is hard to extract and visualize: Exemplarily, an entry stating "*1922 X moved to Rome and became a professor at the University of Vienna in 1928*" makes clear that X moved to Rome in 1922, but says only implicitly that he moved to Vienna in

1928. Similar is the problem of incomplete data: Piffl was known to have managed monastery estates in Hungary. However, his biography does not mention the exact locations of these monasteries. By proxy, the visualization in Figure shows a point where Piffl most certainly never was (i.e., the middle of Hungary). We consider data aspects and issues like these to be drivers for the future development and necessary implementation of methods of uncertainty visualization in the historical research and visualization realm (sec. 6.4).

5.2 Relational space-time

Going beyond the geo-temporal data domain, space-time cube representations can also offer insights into the dynamics and developments of different other non-geographic data dimensions. The resulting trajectories then represent the movements of individuals through further space-times of analytical value, like social-relational space-times, generated by interaction patterns of collaboration or conflict.

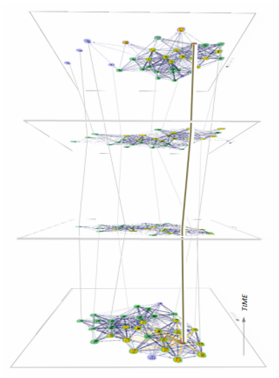

Figure 6: Visualization of an individual movement through social-relational space-time, as demonstrated by Federico et al. (2011).

Figure 6 conceptually illustrates this option by the highlighted movement of an actor through an evolving social-relational structure, as defined by a group of other actors (Federico et al., 2011). Depending on the richness of relational and temporal data, such visualizations can enable historians to study the interactions of individuals of interest and to track their careers as movements, which often lead them from the socio-cultural peripheries of larger network graphs or clusters to their structural cores. These visualization thus can show macro patterns and also detailed interactions of individuals, including their relative positions and the development of their network centrality measures (Weingart, 2013; Bernád et al., 2017).

5.3 Categorial space-time

As a third variation of space-time cube representation we outline the option to visualize the pathways of individuals through any other space defined by categories, which historians use for classifying activities. With regard to all possible activity spaces, in which historical individuals have been active (such as social-structural fields of re-production, professions, cultural domains, or knowledge areas), visualizations like treemaps can provide a valuable synchronic perspective (cf. Hidalgo et al., 2014). Thus, by implementing treemaps into categorial-temporal cubes (see Fig. 7), a diachronic perspective unfolds, which discloses novel patterns of movement or persistence through categorial spaces (Smuc et al., 2015).

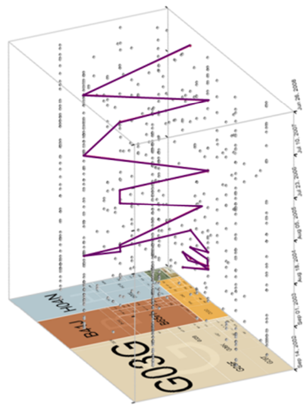

Figure 7: Individual movement through categorial space-time, as demonstrated with regard to the knowledge space of a patent classification by Smuc et al. (2015).

5.4 Linking multiple space-time cubes

In analogy to multiple coordinated views (Scherr, 2008), we promote the connection of multiple space-time cubes to synoptic ensembles. This enables the visual exploration of biographies in multiple relevant space-times in parallel (Figure 8). The specific line up of space-time-cubes - which could include various further methods - naturally depends on available data (and data dimensions), and the intended analytical tasks. We consider such a synoptic setup to provide an effective visualization environment, which could be explored by the means of different interaction techniques (such as brushing and linking), but which could also serve as a versatile scaffold for the selection of more detailed analytical perspectives, including well-established methods of flat visualization design, as will be discussed in the next section.

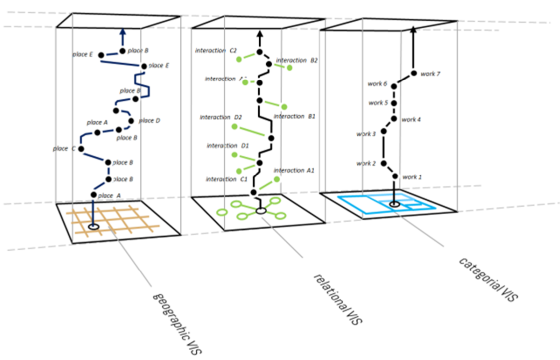

Figure 8: The PolyCube visualization environment for biography data using multiple coordinated cubes, based on space-time cube representations utilizing maps, network diagrams and treemaps (from left to right).

5.5 Mediating multiple synchronic and diachronic views

Bach et al. (2016) have shown, that space-time cube representations also support the (cognitive) translation and mediation of the working principles of multiple diachronic and synchronic views - also by the means of seamless canvas transitions and the smooth adaptation of the perspective on the visualization (figure 9). Given the outlined (linked) visualization of the outer right column of figure 3, the other temporal visualizations (i.e. layer juxtaposition, layer superimposition, or animation - as well as all possible "space-flattened or time-flattened" standard perspectives - could be seamlessly generated out of the different space-time cubes. We contend that such seamless translations will have a positive effect on the preservation of mental models of complex time-oriented data, and as such for the navigation and visual reasoning - especially in the early stage of an exploration process.

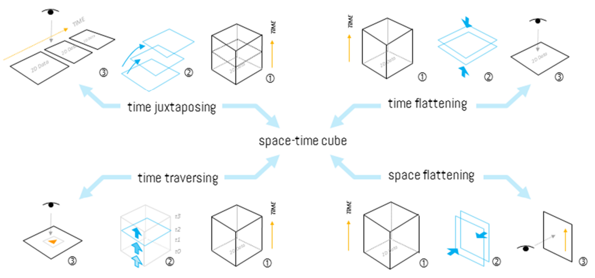

Figure 9: Space-time cube representations can help to preserve and translate mental maps and visualization perspectives (adapted from Bach et al., 2016).

6. Discussion

With regard to the visualization framework outlined so far, we discuss interesting options for further development.

6.1 Prosopographical data visualization

Going beyond single trajectories, the outlined framework is open for more complex analyses to be undertaken with bigger prosopographical datasets. *Prosopography* is the domain for studying biographies as seen from a collective perspective (Keats-Rohan, 2007). Historians deal with a wide variety of social collectives – such as organizations, religions, art schools, political entities, conflicts, or movements of innovation. For their analyses, the proposed framework can also be adapted to map the temporal development of groups as *sets*.

Figure 10 enumerates different visual patterns, which - in combination - can map all the complex developments of historical groups or collective entities. As a method for aggregated representation, prosopographical or collective set visualizations can complement the display of line-like, individual trajectories in geographic or relational space-times.

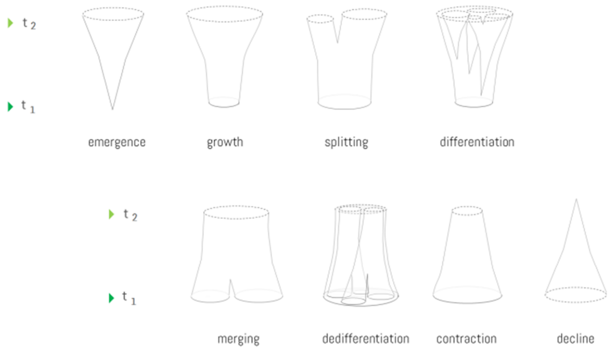

Figure 10: Visualization of the temporal development patterns of groups or organizations, as seen from a set-typed prosopographical research perspective.

6.2 Process and project visualization

While actor trajectories have been featured and visualized as consistent lines so far, these life paths can obviously also be parsed and segmented according to biographically meaningful units of a finer temporal granularity. This allows to visualize and annotate single processes or projects, whose pursuit is strongly structuring and guiding individual behavior - also if nothing else (e.g. no movement or interaction) is visible from another visualization perspective. Practical means to visualize projects or processes derive from the separation of (colored) segments, tick marks, or annotations, which could be applied in a nested temporal structure, signifying long-term work or life phases, mid-range projects or procedures, and basic actions or events (Figure 11).

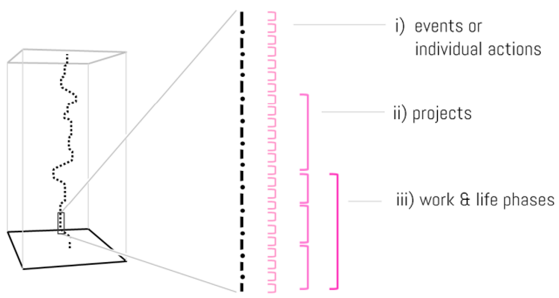

Figure 11: Options of process and project visualization, building on temporal activity patterns.

6.3 Sentiment visualization

Along with the visualization of biographical project and work cycles, we consider the visualization of sentiment data (whether of individual actors or within actor networks) to be of high interest for future approaches. With increasing options to also extract sentiment data from textual sources, rich and qualitative biographical accounts will allow the visualization of emotional stages phases, or chapters of life, related to critical events, like success or defeat, as well as stages of illness, recovery, thriving, and many more (cf. Kucher et al., 2017).

6.4 Uncertainty visualization

In the more general context of history and humanities data collections, we see a specific need to handle questions of *data quality* and *uncertainty* in a reflected manner. Critical questions of data provenance and quality necessarily arise from the investigation of historically fragmented and often disputed data sources. In this context, the deliberate representation of uncertainty measures can help to bring transparency, awareness and trust into the collective interpretation process (Sacha et al., 2016).

6.5 Mapping controversies

Differences and debates about data, sources and representations are all the more likely when experts and scholars are working in distributed or even competing settings of multilateral data curation and interpretation. Aside from the options to collaboratively and consensually enrich visual representations of historical figures, we consider it relevant to also make different scholarly standpoints and interpretations available and visible. This would allow to utilize the outlined framework not only to communicate agreed-upon results, but also to motivate and support the collective critical editing, revising and annotating of biographical knowledge graphs. As such, competing interpretations could be studied, compared and taught on a visual basis, and historiographical controversies could be made productive (Marres, 2015).

6.5 Visual storytelling

Given the increasingly advanced options for the largely user-driven exploration of biography data by the means of multi-perspective visualizations, we consider it specifically interesting to merge these representation techniques with narrative or author-driven representation techniques (Segel & Heer, 2010) to tell life stories, e.g. of national cultural heroes. Storytelling then could enrich the analytical systems with sequential guidance for the purpose of scholarly communication, the pedagogy and teaching realm, but also for data-driven journalism and public knowledge communication (Mayr & Windhager, 2018).

6.6 Integrating close & distant reading

As for its application, the outlined framework can be productively used as an interface connected to structured data collections, or as an interface visualizing textual data via automated natural language processing pipelines. In this context it seems essential, to offer access to textual source data in parallel to visual representations. This allows to study and "close-read" a source text in comparison to a visualization, possibly including further supportive text visualization techniques, such as colored mark-up of textual entities, connection to various layers of annotation, or coordinated highlighting (Jänicke et al., 2017). Eccles et al. (2008) show how a system of coordinated multiple views can link back to textual data representations. As such, space-time cube representations can provide overview and orientation, while still keeping the original textual data accessible. Another option to combine textual data with a graphic representation is to actually tell a story sequentially and incrementally on a textual basis, while zooming and panning to selections of a space-time path, as it is already offered for two-dimensional representations by tools like StoryMapJS[2] or ESRI storyteller.[3]

6.7 Automated vs. qualitative visualization

To further foster and enable control and curation of largely automated natural language processing endeavors – but also for the means of a qualitative complementation of these highly complex procedures – we consider options for manual input and data curation to be an essential future feature. This will aid to the existing options for data development and enrichment, but also enable shorter modelling cycles by starting to generate structured biography data from scratch. For this purpose, we consider either options for manual data creation (e.g., by a simple event-based spreadsheet notation), or direct spatiotemporal drawing functionalities to be of high practical value, which will allow to generate biography visualization – and quantitative or structured data – from existing expert knowledge, which has not been codified or formalized in any other context so far.

7. Conclusion

With this paper we discuss the creation of structured data from biographical texts, and advanced options of their visual analysis. The outlined visualization framework firstly provides visual-analytical access to complex biography data, as well as visual reasoning support on an overview and detail level. Secondly, it offers multiple perspectives to generate richer and non-reductionist portraits of the available data. Finally, it aims to considerately support scholar's information integration by utilizing space-time cube representations. In addition to challenges arising from the ongoing effort of implementation and evaluation, we suggest to focus on a number of objectives for future research (see sec. 6) to enable a more complex and synoptic understanding of the life and work of historical individuals.

8. Acknowledgements

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