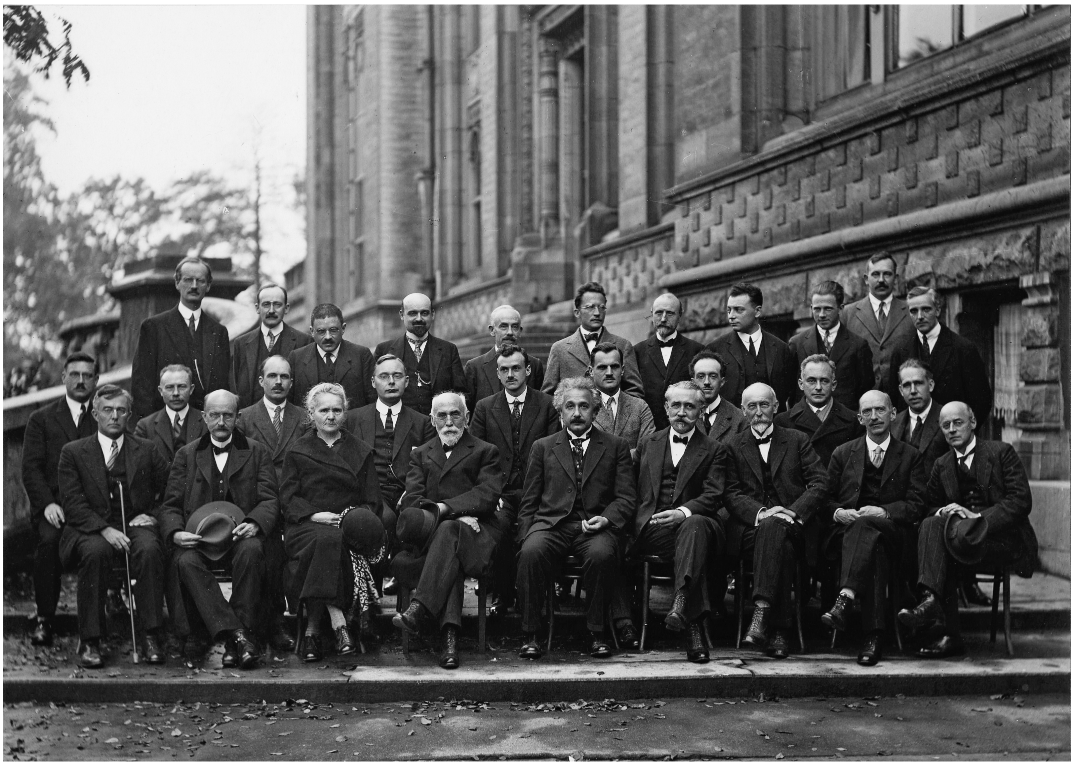


Visualizations of Historical Figures and Events

Hifibot

Seminar Report

Contents

Data of historical figures and events are multi-dimensional, as they contain spatial, relational, categorical, temporal, and muli-medial facets. In this field of research, not a single visualization can display all relevant aspects. Therefore, I divide the visualizations depending on the data facets they highlight: Biographies, relations, movement behavior, historical items, and coherences between events. This seminar report outlines several visualization approaches in the introduced classes. In the end, it highlights relevant visualization aspects for the project group "HifiBot", where we want to answer questions about the life of historical figures using visualizations. It concludes that map and timeline visualizations will be highly beneficial because they are diverse techniques for most of the introduced data classes.

1 Introduction

When talking about historical figures and events, we have to connect many different data dimensions. One person's biography does not only contain the lifespan, the visited places, contributions in textual or multi-media format [11], and relations to other persons, but also events in which they participated.

Events, as a part of a person's biography, also are located in space and time. They can last for one moment or any period [11]. Furthermore, events are neither random nor isolated but are connected as a cascade or tapestry of interwoven events. Finding causes of historical events and the collective behavior of people are aspects of a historian's work. Often they struggle with fragmentary evidence of what happened. Also, the unreliability of the present evidence is problematic [1].

When working with historical data, one has to consider the underlying uncertainty and deal with missing data. Even spatial components, given by events or persons' locations, are not consistent during history - they tend to develop in time. This concerns the geographical aspect and also applies to countries replacing each other [11].

Thus, in a historical context we have spatial, relational, categorical [13], and multi-medial [11] data. All of these diverse data dimensions are furthermore time-oriented [13]. Therefore, time is a particular component in historical data, as it clamps together different aspects and data dimensions in the historical observation.

In this context of complex, interwoven data, visualization techniques are used to highlight different aspects of historical data.

In this work, I first introduce the relevant visualization techniques used in the presented examples to display historical figures and events in chapter 2. Afterward, chapter 3 explains how different approaches highlight particular aspects of historical data. Next, I point out how this seminar topic could influence our project group "HifiBot - Did Einstein meet Schrödinger? A Chatbot System for Analyzing Intertwined Lives of Historical Figures" in chapter 4. In chapter 5 the most relevant aspects of this report are highlighted.

2 Overview: Visualization Techniques in the Presented Examples

This chapter gives a short overview over often used visualization techniques in context of historical figures and events.

Timelines Timelines play an essential role in visualizing temporal data. Commonly, time is displayed on an axis and ordered in chronological time steps. To show the temporal aspect of entities, they can be placed onto such a time axis.

When multiple objects are displayed on the time axis in a short period, visual clutter can appear, disturbing the fast insight into the temporal assignment. Enabling a zooming interaction is one way to deal with this effect [11].

Maps Historical data sometimes includes spatial information. Maps are abstractions and simplifications of reality and are known as "the ultimate" graphical representation of spatial patterns. They offer insights into spatial dimensions while displaying them at one moment in time. Maps can be enriched by linking additional information like sound, videos, and pictures to map elements. To tackle the problem of limited information in map visualizations for readability purposes, interactively changing scales is possible [9].

If next to the spatial component, a time element is available, maps can tell stories or explain events. While in some cases, the mapping between space and time can work out, for most map visualizations combining spatial and temporal aspects are challenging [9].

Space-Time Cubes Space-Time Cubes reveal temporal patterns in data because of the inherent display of space and time. In particular, they are suitable to visualize multiple characteristics of movement data [9].

A Space-Time Cube is a three-dimensional visualization in the shape of a cube. Its horizontal plane represents space, mostly by displaying a map. The vertical axis shows the temporal dimension [9].

If used to visualize movement data, three basic concepts can be distinguished: paths, stations, and prisms. Paths represent the movement of objects through space and time. Thus, they build a line in the three-dimensional cube. Stations show locations where objects linger for some time as a nearly vertical path for a while. Prisms describe the space, which is reachable within a prior defined time [9].

The Space-Time Cube offers multiple forms of interaction. A rotation to another perspective changes the view on the visualized data. Also, the map can be moved along the vertical axis so that it follows the trajectory. This shift leads to a better perceptiveness of the location of the path at the current time. Selecting periods or specific objects can be used to reveal temporal aspects within a Space-Time Cube [9].

The three-dimensional Space-Time Cube allows the user to change his perspective and analyze the shown path in more detail. Additionally, the interaction complexity may be overwhelming for non-expert users. The constrained scalability to multiple movement data is another limitation of this visualization technique.

Graphs Graphs consist of nodes and edges. Nodes represent objects, which are connected with edges. Edges, therefore, express the relation between these nodes. There are two types of edges: Bi-directional edges, which indicate that the relationship is the same for the connected nodes, and uni-directional edges symbolizing a relation from one node to the other. Also, the edge can be weighted so that a value is assigned to the relation. When the edge is weighted, a force-directed alignment of the nodes is possible. In force-directed graphs, nodes with a high relation are displayed nearer while closely connected nodes are further away from each other.

3 Visualizations of Historical Figures and Events

Historical data can be spatial, relational, categorical, and multi-medial, while all of these are time-oriented. There exist many visualizations to display historical data in the context of historical figures and events, but none can highlight all relevant aspects alone. Therefore, I divided this section regarding the highlighted aspects in the presented visualizations: biographies (section 3.1), relations (section 3.2), movement behavior (section 3.3), historical items (section 3.4) and coherences between events (section 3.5).

3.1 Biographies

Biography data is composed of multiple data dimensions where every dimension is time-orientated [13]. They are used to gain insights into one persons life or compare a person or group to another.

Events of Historical Figures Events are a part of a person's biography and give insights into the temporal and spatial data aspects. Because of their affiliation with a specific person, they take place in a person's life period. To order events in chronological time, using timelines is a common method.

One example of this is Leskien et al.'s tool for prosopographical research. Here the timeline is split into four rows representing different biographical event categories: family events, career events, achievements, and mentions of honor. The events have different colors, depending on their category (Figure 3.1). A map displays the spatial component of the event. The markers' colors in the map correspond to the event colors for better recognition. The size of the markers is determined by the number of events in the selected location. Descriptions of the events are listed on the left side of the window. When an event is hovered, the corresponding marker on the map gets highlighted. By selecting a marker via clicking, a modal window opens. It contains a list of people, whose birth or death took place in the selected location [10].

Insights into Multiple Aspects of a Persons Life Biography data has a high complexity as it can consist of spatial, relational, categorical, and multi-media data all aligned in the temporal context.

Space-Time Cubes can visualize multiple aspects of biographical data and their related time. The horizontal plane can display the biographical data dimension, while the

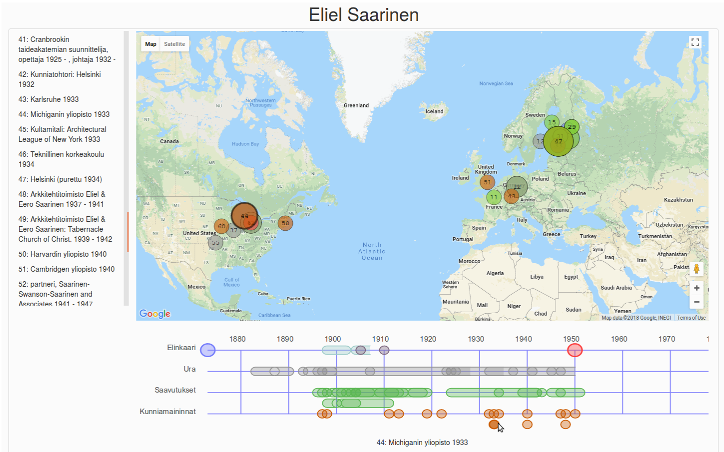
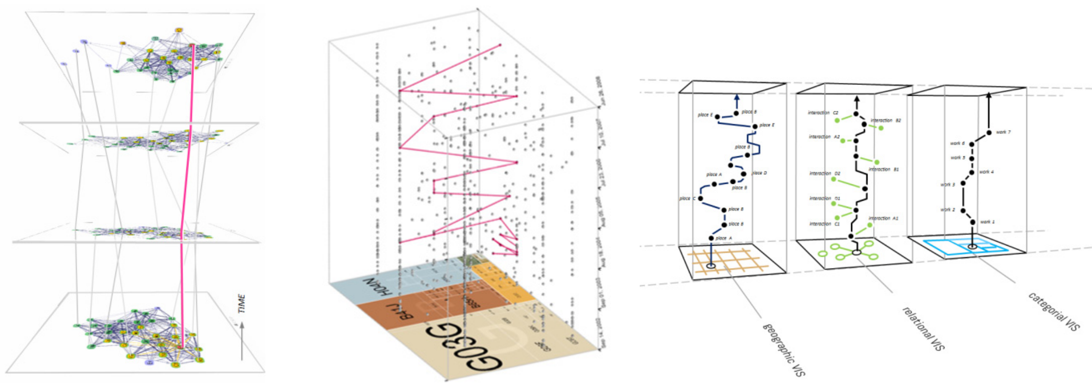


Figure 3.1: Maps & timelines: Links spatial and temporal data of biographies [10, p. 4].

vertical axis represents the temporal dimension. Resulting, every behavior translates into a spatiotemporal trajectory.

Windhager et al. proposed that relations between people can be shown with a graph as the horizontal basis so that the change of a person's social network is visible over time, see Figure 3.2a. For presenting categorical data, a treemap can be used as the horizontal axis. It emphasizes novel behavioral movement patterns as an analytical perspective of people's life (Figure 3.2b). Connecting multiple Space-Time Cubes like geographical, relational, and categorical Space-Time Cubes enables the visual exploration of biographies in space-time, shown in Figure 3.2c. It is possible because of the same time period on the vertical axis. Linking multiple cubes with interactions like brushing or combined navigations further enhances the interconnectedness of the data [13].



(a) Relational x-axis (b) Categorical x-axis (c) Linking diverse biographical data

Figure 3.2: Space-Time Cubes: Multiple dimensions of biographical data [13, p. 3, 4]

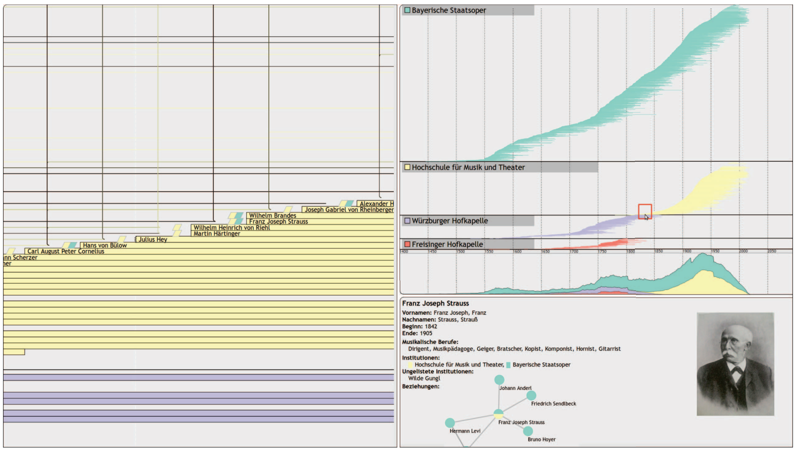


Figure 3.3: Prosopographical analysis of biographies with timelines [8, p. 7].

Comparing Multiple Biographies Prosopographical research is a specialized analysis of biographies to identify similarities or differences in large biographical data.

Some of the previously introduced techniques can be enlarged for multiple biographies, like the introduced Space-Time Cubes, which offer the possibility of comparing similarities and differences of patterns for groups [13]. Even though Leskien et al.'s map, Figure 3.1, can display aspects of multiple persons, like comparing the death and birthplaces of Finish clergy [10], the scalability may become problematic.

For comparing the work of groups of persons, their life spans can be visualized onto a timeline, as proposed by Khulusi et al. As an overview, the life spans of all musicians are represented by thin horizontal lines as an area graph on the right upper side (Figure 3.3). Furthermore, they are stacked and sorted to enable time-dependent pattern analysis. Also, a stacked graph is supported, where quantitative changes and developments are observable. On the left side, a semantic zoom shows the life spans of musicians as horizontal bars in greater detail. An icon represents a person's affiliation to a specific class on the left side of the bar. Uncertain datings are indicated by triangles, which point to the direction of the temporal uncertainty. For example, time designations like "before" create a triangle pointing to the left side, datings like "after" induce a triangle to the right side. Vertical lines map each bar to the timeline for precise datings. The selected musician's biographical information, like his profession and musical institutions, are shown on demand. It consists of a portrait, if provided, a graph of the selected musicians' subnet, and some descriptions. Interactions link these different views. The user can search for musicians or filter the data after different criteria. Hovering over the time span in the overview leads to a semantic zoom in the left view. Clicking on an area in the overview freezes the selected viewpoint. A clicking interaction on the life span bar grays out all relations not belonging to the selected musician. At the same time, the corresponding information appears in the details view [8].

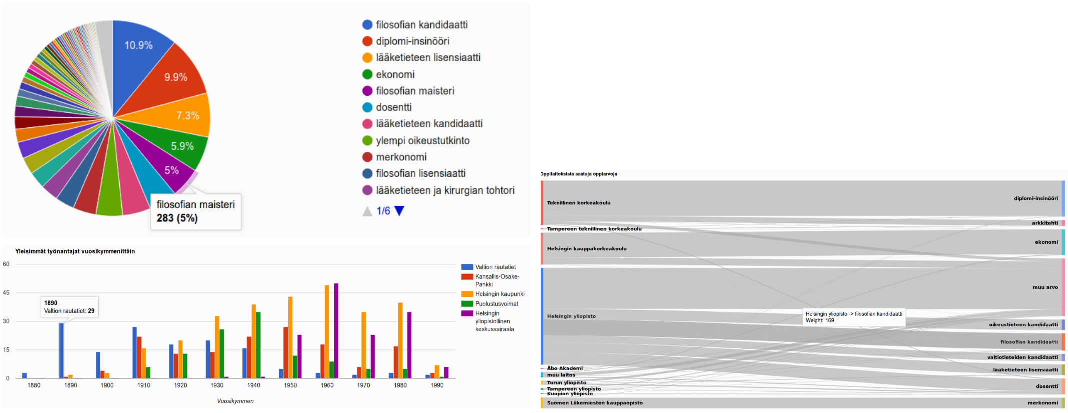


Figure 3.4: Statistics in context of prosopographical analysis [10, p. 2, 3, 4].

Diagrams are often used to obtain insights into the statistical properties of biographical data. For this purpose, Leskinen et al. used pie charts, a Sankey diagram, histograms, and three multi-column charts as inFigure 3.4. They enable researches to gain insights into what happened to school alumni after their graduation or coherences between different universities and education [10]. Another example is a histogram displayed over a timeline in Novak et al.'s tool for the analysis of historical figures relations in “HistoGraph”, to visualize the statistical properties of the selected data, see Figure 3.6b [12].

3.2 Relations

A relation is a connection between entities based on a specific property. In the context of historical figures and events, mostly relations between persons as social connections are represented. There also exist visualizations for relations between people, events, places, and time.

Social Relations between Historical Figures For displaying social relations of persons, mostly bi-directional force-directed graphs are designed. Interactions and the graph's layout, which is dependent on the computation of the edge's weight, differ according to their context and goal.

One example is the “sociogram”, build by Dr. Bunning to visualize relationships between persons for prosopographical research based on correspondences, shown in Figure 3.5. Relationships between persons were categorized and can be filtered with the inputs on the left side. Afterward, the chosen relation types are highlighted with different colors [4].

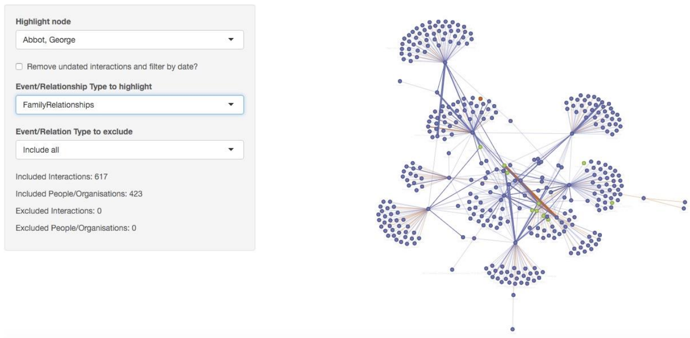
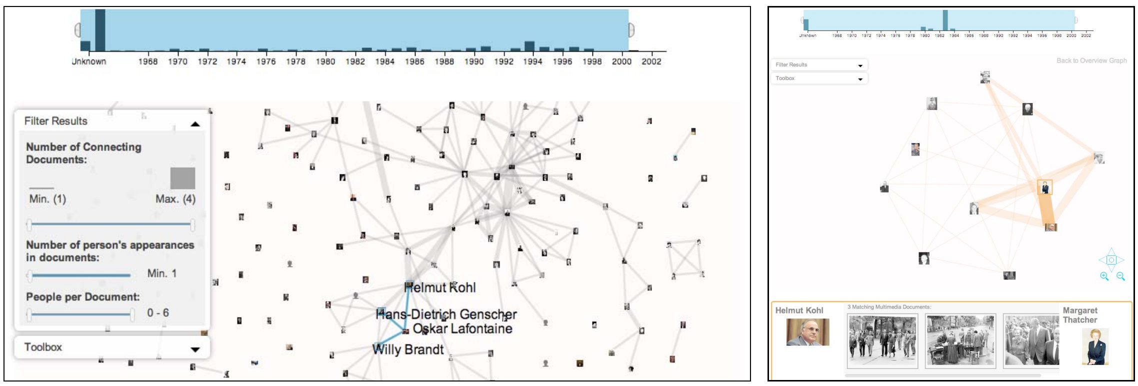


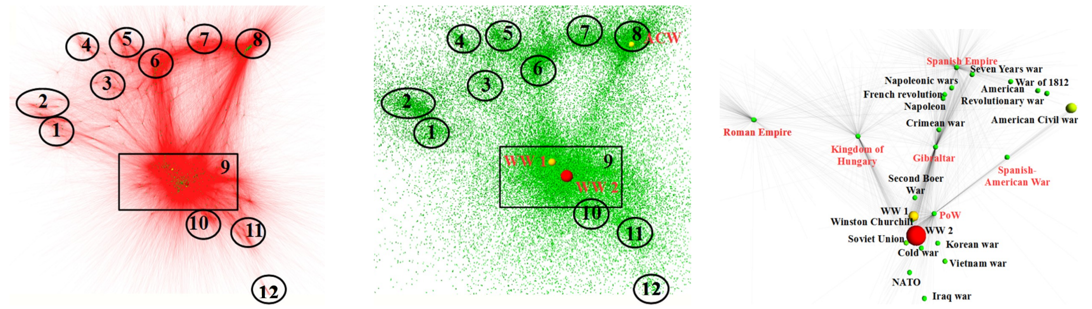
Figure 3.5: Sociogram: Visualizes relations and various relation types [4, p. 3]

Another example is Novak et al.'s "HistoGraph", which extracts social relations between persons from historical photographs. In the graph-visualization, the nodes represent the identified persons, while the relation to other persons is visible as an edge between the nodes. The edge weight corresponds to the number of times the connected persons appear in the same image, which, due to the force-layout, leads to a nearer positioning of nodes and a greater edges width when they appear in more pictures together. Additional information like labels of date, location, and events are linked to the edges. The graphs overview, Figure 3.6a, can be used to identify clusters and sub-networks of social relations. By using the search bar, users can locate specific persons in the graph. Hovering over one node highlights the name of the person and connections to other persons in the graph. The selection of one node leads to zoom on a subnetwork of the selected person. Selecting an edge by clicking displays all corresponding photographs and a list of additional documents. Filtering is possible by time, the number of existing documents, the people's quantity, and their appearance in the linked photo. Afterward, the system generates a smaller sub-graph from these parameters, like in Figure 3.6b [12].



(a) Overview: Clusters of social relations (b) Zoom: Precise analysis

Figure 3.6: Social graph: Displays relations between historical figures [12, p. 246, 247]

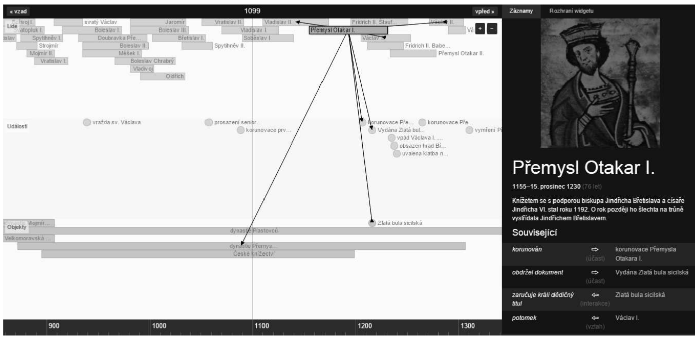


(a) Overview: Displays edges (b) Overview: Shows nodes (c) Zoom: Detailed view

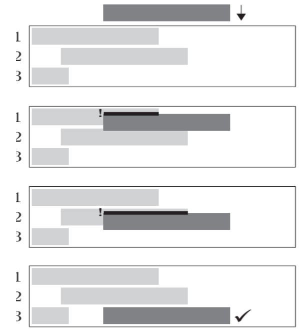
Figure 3.7: Graph visualizes relations between events and persons [5, p. 4, 6]

Relations between Historical People and Events Dzwinel et al. also use a graph to highlight relations between historical people and events. They choose a uni-directional force-directed graph to represent these relations based on links in Wikipedia articles. The acquired overview visualizes the relation of Wikipedias persons and events. It can either display the edges (see Figure 3.7a) or nodes (Figure 3.7b) Since there are many entities, only clusters of the nodes are identifiable. To see the nodes and their edges in greater detail, the user can perform a zoom into the network's structure, as shown in Figure 3.7c. After the zoom, the nodes of related historical events and people are separable from each other [5].

A different approach to visualize relations between historical events and persons is Richard "Scalable Timeline Visualization". He uses a timeline visualization to display the entities and their relations (Figure 3.8a). The timeline is vertically divided into several stripes to organize the displayed entities according to specific properties. A subjective modification of these properties is possible through filtering. The horizontal axis visualizes the time dimension with a time axis, where zooming determines the temporal granularity. Elements are displayed either as rectangles for periods or circles when they have only occurred at one point in time. A fuzzily drawn border represents an uncertain dating. Relations between these elements are shown with arrows after selection. At the same time, a detailed description appears on the right panel. Also, the time interval is highlighted on the time axis. To avoid visual clutter, automated zooming on the time axis is performed, which changes the length of displayed events. Also, the zooming adds or removes events in regards to their calculated relevance. Figure 3.8b shows the algorithm's process of aligning the elements to avoid clutter [11].



(a) Arrows indicate relations in the timeline visualization



(b) Algorithm avoids visual clutter

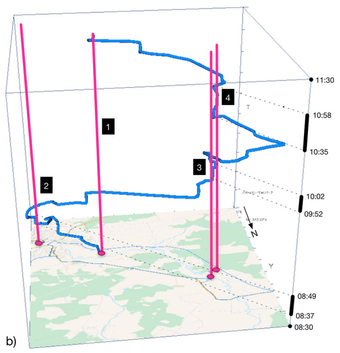
Figure 3.8: Sorting timeline visualization: Relations of events and persons [11, p. 4, 5]

3.3 Movement Behavior

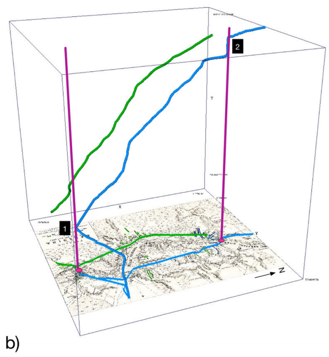
Movement is a change of the spatial dimension over time. It occurs as part of an event or event chain, which can be aligned to specific persons or groups.

Trajectories Trajectories display the continuous movement behavior of an entity over space and time. Mostly, they are visualized by three-dimensional Space-Time Cubes.

Figure 3.9a displays the movement behavior during a trip with a Space-Time Cube, where its path and stations are highlighted. Furthermore, the path can be enriched with qualitative and quantitative information by coloring or varying the width. It also can be enhanced by linking multimedia objects, whose details are displayed on demand. Space-Time Cubes are also able to display multiple trajectories. Kraak et al. show this by comparing the Russian and French troops movements in 1812 within a single Space-time Cube (Figure 3.9b) [9].



(a) Path and Stations of a trip



(b) Comparing paths of two armies

Figure 3.9: Space-Time Cubes: Continuous movement as trajectories [9, p. 58, 59]

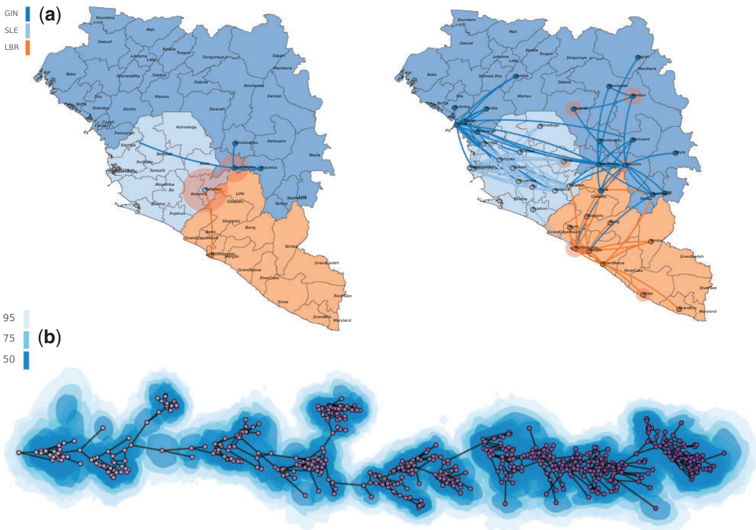


Figure 3.10: Process trait mapped onto animated map to display movement [3, p. 2].

Discontinuous Movement Data In the context of movement data, often space and time are only available at discrete points in a person's history. For this discontinuous data, trajectories may not be the best visualization possibility.

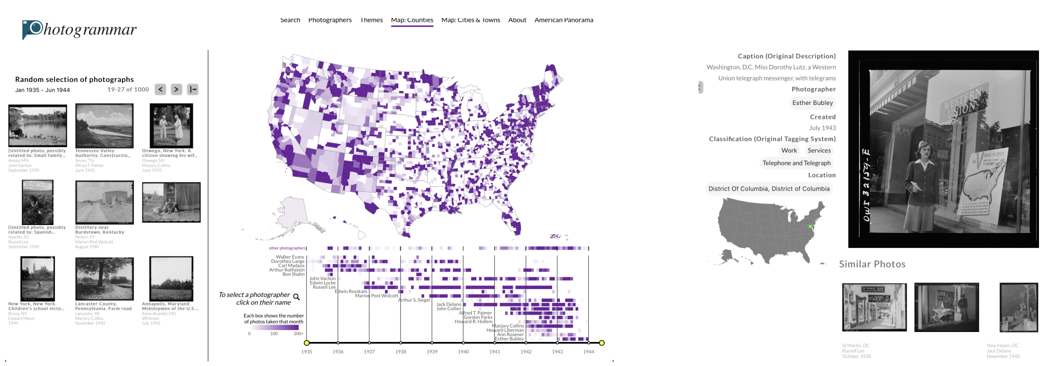
A person's location at an event can, for example, be visualized using maps, as previously introduced in section 3.1 (see Figure 3.1) [10].

Similar processes, which have a temporal and spatial component and therefore show movement behavior, can be displayed with map visualizations. An example is Bielejec et al.'s visualization of the Ebola virus spread process in Africa. They used a distribution tree with continuous trait annotations (Figure 3.10 a)). The authors propose that any one-dimensional phenotypic trait, which evolves on a tree, can be plotted as a function of time. Because of the spatial component of the data, the tree could be projected on a geographic map (Figure 3.10 b)). The user can control the temporal spread with a time slider. It enables the animation of the evolutionary process in time and space, showing the spreading process and its movement. The animation can be paused, fast-forwarded, or re-winded [3].

3.4 Analysis of Historical Items

Historical items as objects are created at a unique time by a specific person at an assigned or multiple locations. Visualizing such items has a high complexity, as multiple data dimensions are present, similar to biographical data.

An example of visualizing historical items is Arnold et al.'s "Photographer", which allows an exploration of an image collection in space and time, see Figure 3.11a. At the bottom

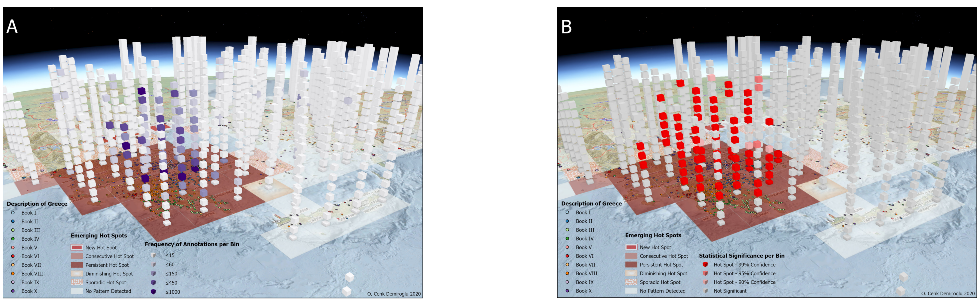


(a) Lists selected items and their spatial and temporal context (b) Detailed view of images

Figure 3.11: Analysis of photographs: Visualizing multiple data dimensions [2, p. 3, 4]

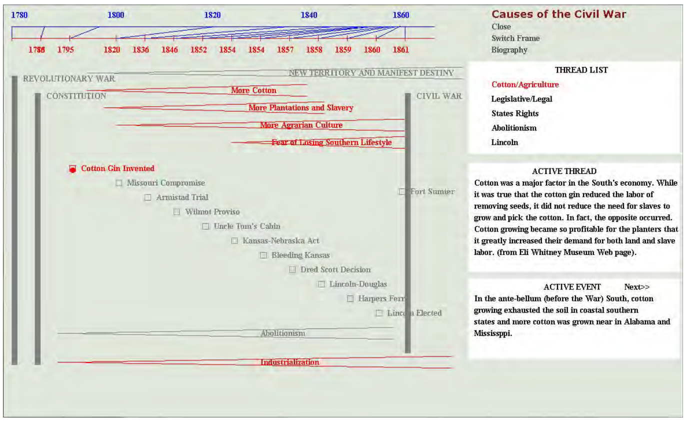
of the main view, a visualization displays the distinct photographers in their temporal dimension. The horizontal axis shows a chronological timeline, while the photographers are aligned on the vertical axis. On the upper map, locations are highlighted with colors corresponding to the number of taken photos. At the left panel, photos of the current selection are displayed. On selecting an image, its details like metadata and textual descriptions appear in a new window if available (Figure 3.11b). The different parts of the view are linked by clicking interactions. Furthermore, the user can filter the selection according to his goals [2].

Another example of visualizing historical items is Foka et al.'s "HistoGraph". It visualizes Pausanias's "Periegesis Hellados", a series of 10 travel novels, which describes Greek towns, buildings, monuments, and objects at different historical moments oriented around events. They used a Space-Time Cube as a visualization technique. In contrast to a classical Space-Time Cube, the time axis is not chronologically scaled but represents time intervals of the specific book's appearance as rows and columns. With colors, either the annotations per grid-book or the statistical significance of emerging hot spots in the book, time and place are highlighted (Figure 3.12). Descriptions of the related events are linked to each book's bin. If selected, details are shown on demand [6].

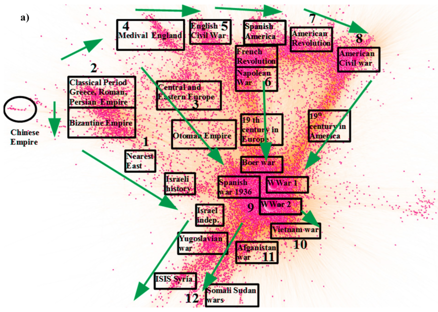


(a) Color displays book annotation frequency (b) Color represents emerging hot spots

Figure 3.12: Space-Time Cube for multiple objects: Pausanias's 10 books [6, p. 7].



(a) Visualizing coherences between events



(b) Temporal process in graphs

Figure 3.13: Examples for analyzing historical coherences [1, p. 5] [5, p. 4]

3.5 Coherences between Events

Robert Allen proposes the idea that history itself may be seen as a tapestry of interwoven events. When analyzing the causations of events, the problem arises of only fragmentary evidence, which furthermore may be unreliable. To analyze possible causes of events, he focused on communicating the coherences between events for gaining insights into the possible causations. He introduced the idea of *Trends* as related actions of a set of entities and *Threads* as a chain of events. He proposes that Trends as the collective behavior of many individuals may cause events [1].

Trends are visualized in the top or bottom of the main display as fans (Figure 3.13a). The fan's opening is either left or right, dependent on an increase or decrease of the corresponding behavior. Events are centered in the view, ordered by their chronological occurrence. To show their temporal dimension, a timeline at the top of the main window exists. The timeline consists of two parts. The lower part shows the concrete times of the events at equal intervals to avoid visual clutter. The upper part represents a chronological timeline. These two timelines are connected with lines showing the relation of the actual temporal occurrence to the event intervals. Further, Allen introduces the idea of enriching the visualization with the spatial component using a map [1].

In section 3.2 we have seen that events can be represented as nodes in a graph to display their relations. While visualizing these relations gives a hint of the events' coherence, the temporal dimension is not directly pictured. Dzwinel et al. proposed that using arrows indicates the temporal process in such a graph, as shown in Figure 3.13b [5]. Thus, arrows in graph visualizations may also highlight Allen's Threads.

4 Impact on HifiBot

In our project group "HifiBot" we want to answer questions about the lives of historical figures with visualizations. Our scope is focused on answering questions about a few persons. The generated visualization should display the aspects of the person's life and enable analysis and comparison of their biographies. As data source we use Gottschalk et al.'s knowledge graph "EventKG" [7].

Biographical data consists of many data dimensions and offers multiple visualization possibilities, showing different aspects of the historical person's life. Because of our limited scope, we will not focus on prosopographical research. Therefore prosopographical tools like Khulusi et al.'s [8], or Leskinen et al.'s statistical evaluations [10] are not as relevant for us as biographical views (Figure 3.1) [10] and combination of multi-dimensional Space-Time Cubes (Figure 3.2c) [13]. Whereas linked Space-Time Cubes would allow a direct overview of all aspects of a person's life and allow a comparison of a few biographies, the handling for non-expert users is unfamiliar. Also, the amount of information in our data source differs for distinct persons. Thus, we would have to consider several corner cases, like missing data dimensions or time intervals. Combining a timeline and map would be more beneficial for our goals because users are more acquainted with them and because we would not need to consider as many effects of missing data.

Displaying historical items will probably not have a high impact on our project as they are not our prior use case. So specialized visualizations as shown in section 3.4 will probably not be in our scope. However, as they have similar information as biographical data, we could switch the perspective of our visualizations from figures to items. In this case, again a combination of map and timeline visualization would be beneficial for showing most properties of these objects. When we want to integrate them into a biographical visualization, we can link them to other biographical properties and display them on demand.

For highlighting relations between historical people and events, force-directed graphs (Figure 3.6a) [12] or arrows in a timeline (Figure 3.8a) [11] could be an option for us. Here, communicating the relation type to the user will be our main concern, as our relations are computed from Wikipedia links, which have different relationships. Sometimes the type may even be missing. Assuming we already display a timeline for the biographies, it would be easier to add relations to this visualization, similar to Lipka et al.'s work [11], instead of creating a new visualization for this use case.

When visualizing movement behavior, we will often have to deal with discontinuous data, as parts may be missing. As such, our options will mostly be limited to map visualizations, either by using markers on a map (Figure 3.1) [10] or animated, like Bielejec et al.'s work (Figure 3.10) [3].

As we are focused on persons and their life, showing coherence between events is also not part of our main goal. Also, our data source may not contain hints to causations like Trends. So we are limited to display the temporal process of events within a historical person's life. For this use case, we can find inspirations in using arrows to indicate temporal relations in graphs like Figure 3.13b [5]. If we have a timeline, we could also order the events chronologically or highlight their relations similar to Lipka et al.'s "Scaleable Timeline Visualization" (Figure 3.8a) [11].

As I have already indicated, we will have to deal with missing or uncertain data because of our data source. In the previously described examples, there were some ideas on how to communicate such uncertainty, especially in timeline visualizations, which we could also use in our work. One suggestion is using symbols, like triangles to point to the direction of the uncertainty when dealing with unprecise temporal descriptions like "before" or "after" as proposed by Khulusi et al. [8]. In case we do not know the temporal direction of the uncertainty, Lipka et al. proposed the idea of fuzzily draw the border of the visualized entity [11].

Another problem, which we probably will encounter when using timeline visualizations, is the visual clutter of displayed entities. To tackle this problem, we could take inspiration from Robert Allen, who used two timelines to visualize first the events with equal intervals and then showed their chronological order on the second one [1]. More commonly used are zooming operations, as Lipka et al. mentioned [11]. The implemented sorting algorithm, which he used in his timeline visualization (see Figure 3.8b), will probably take too much time because this is just one part of our visualization.

To sum it up, this research is highly relevant for our project, as it shows possibilities to visualize biographical historical data. Especially relevant for us will probably be the map and timeline visualizations. Also, we get hints at how to deal with uncertain data and visual clutter in timeline visualizations.

5 Conclusion

There are multiple ways to visualize historical figures and events. These visualizations can be divided into visualizations for biographies, relations, movement behavior, historical items, or coherences between events.

Visualizations for biographies are the most diverse. They consist of maps and timelines, multiple Space-Time Cubes, or combine several timelines with different scales. For prosopographical research, they may be enriched with diagrams for statistical analysis. The different visualization is linked to communicate the interconnectedness of the multidimensional biographical data.

Historical items have similar complex data dimensions as biographies, as only the viewpoint is switched to objects instead of persons. It reaches from combining maps and timelines to specialized Space-Time Cubes. As before, interactions like linking, filtering, and selecting and showing details on demand play an important role.

Relations between historical figures and events are mostly displayed with force-directed graphs. They offer possibilities to show different relationship types in the edges color or link details to the nodes and edges. Filtering and selecting enables exploration of sub-networks. Next to graphs, relationships between people and events can be indicated by arrows in timeline visualizations, where the temporal dimension is better displayed.

For visualizing movement behavior, it is necessary to distinguish between continuous and discontinuous data. Continuous movement behavior can be translated into trajectories, which can either be visualized two-dimensional on a map or three-dimensional inside a Space-Time Cube, where the temporal aspect is highlighted. Discontinuous movement data can be displayed on maps, where they are either animated to show the time or indicated with markers.

Historians often research causations for historical events. Visualizations can help in this research by highlighting the temporal process of events with arrows in graphs or order them in a timeline visualization. To further support the analysis, influences can be indicated by fans.

For our project map and timeline, visualizations seem the most relevant, as they can be used for most use cases. Also, techniques to communicate uncertain data like fuzzily drawn borders or displaying symbols may be interesting for us. Interactions further enable analysis and interconnectedness of data and should be incorporated when multiple visualizations are displayed.

List of Figures

Bibliography

[1] Allen, R.B.: Visualization, Causation, and History. In: Proceedings of the 2011 iConference, pp. 538–545 (2011)

[2] Arnold, T., Ayers, N., Madron, J., Nelson, R., Tilton, L.: Visualizing a Large Spatiotemporal Collection of Historic Photography with a Generous Interface (2020)

[3] Bielejec, F., Baele, G., Vrancken, B., Suchard, M.A., Rambaut, A., Lemey, P.: SpreaD3: Interactive Visualization of Spatiotemporal History and Trait Evolutionary Processes. Molecular biology and evolution **33**(8), 2167–2169 (2016)

[4] Buning, R.: Experimental Prosopographical Network Analysis and Visualization with 'Early Modern Letters Online'. In: DHBbenelux Conference, Belval, Luxembourg (2016)

[5] Dzwinel, W., Wcisło, R., Strzoda, M.: Ivga: Visualization of the Network of Historical Events. In: Proceedings of the 1st International Conference on Internet of Things and Machine Learning. IML '17, Association for Computing Machinery, New York, NY, USA (2017). https://doi.org/10.1145/3109761.3158412, `https://doi.org/10.1145/3109761.3158412`

[6] Foka, A., Barker, E., Konstantinidou, K., Mostofian, N., Demiroglu, O.C., Kiesling, B., Talatas, L.: Semantically Geo-Annotating an Ancient Greek "Travel Guide" Itineraries, Chronotopes, Networks, and Linked Data. In: Proceedings of the 4th ACM SIGSPATIAL Workshop on Geospatial Humanities. p. 1–9. GeoHumanities'20, Association for Computing Machinery, New York, NY, USA (2020). https://doi.org/10.1145/3423337.3429433, `https://doi.org/10.1145/3423337.3429433`

[7] Gottschalk, S., Demidova, E.: EventKG–the Hub of Event Knowledge on the Web–and Biographical Timeline Generation. Semantic Web **10**(6), 1039–1070 (2019)

[8] Khulusi, R., Kusnick, J., Focht, J., Jänicke, S.: An Interactive Chart of Biography. In: 2019 IEEE Pacific Visualization Symposium (PacificVis). pp. 257–266. IEEE (2019)

[9] Kraak, M.J., Kveladze, I.: Narrative of the annotated Space–Time Cube–revisiting a historical event. Journal of maps **13**(1), 56–61 (2017)

[10] Leskinen, P., Hyvönen, E.A., Tuominen, J.A., et al.: Analyzing and Visualizing Prosopographical Linked Data based on Biographies. In: Proceedings of the Second Conference on Biographical Data in a Digital World 2017 (BD2017). CEUR Workshop Proceedings (2018)

[11] Lipka, R.: Scalable Timeline Visualization. In: 2016 9th International Conference on Human System Interactions (HSI). pp. 150–156. IEEE (2016)

[12] Novak, J., Micheel, I., Melenhorst, M., Wieneke, L., Düring, M., Morón, J.G., Pasini, C., Tagliasacchi, M., Fraternali, P.: HistoGraph–A Visualization Tool for Collaborative Analysis of Networks from Historical Social Multimedia Collections. In: 2014 18th International Conference on Information Visualisation. pp. 241–250. IEEE (2014)

[13] Windhager, F., Federico, P., Salisu, S., Schlögl, M., Mayr, E.: A Synoptic Visualization Framework for the Multi-Perspective Study of Biography and Prosopography Data. In: Proceedings of the 2nd IEEE VIS Workshop on Visualization for the Digital Humanities (VIS4DH'17), Phoenix, AZ, USA. vol. 2 (2017)