Interacting with Semantics and Time

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Abstract. Time appears in many different semantic information systems like historical databases, multimedia systems or social communities as a common attribute. Beside the temporal information, the resources in these domains are categorized in a domain-specific schema and interconnected by semantic relations. Nevertheless, the high potential of these systems is not yet exhausted completely. Even today most of these knowledge systems present time-dependent semantic knowledge in textual form, what makes it difficult for the average user to understand temporal structures and dependencies. For bridging this gap between human and computer and for simplifying the exploration of time-dependent semantic knowledge, we developed a new interactive timeline visualization called SemaTime. The new designed temporal navigation concept offers an intuitive way for exploring and filtering time-depended resources. Additionally SemaTime offers navigation and visual filtering methods on the conceptual layer of the domain and is able to depict semantic relations. In this paper we describe the conceptual design of SemaTime and illustrate its application potentials in semantic search environments.

Keywords: Information Visualization, Semantic Visualization, Timeline Visualization, Semantic Search, Time-Dependent Ontology.

1 Introduction

In many different information systems time appears as a common attribute. For example the resources of historical databases contain timestamps for describing the chronological order of events [1], media files in multimedia systems are tagged with release dates [2] or profiles in social communities contain different time-dependent information about a certain person [3,4]. Additionally the resources in these systems are often specified by using semantic technologies which offer new possibilities for modeling and representing information in modern knowledge systems. Beside the categorization in a domain-specific schema, semantic description languages allow the modeling of relationships between different resources [5] and offer new potential for improving search mechanisms, navigation patterns and graphical user interfaces.

Nevertheless, the high potential of these information systems is not yet exhausted completely, in particular when it comes to imparting the contained information to the user. Even today most of these systems present time-dependent and semantic

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information in textual form, what makes it difficult for the average user to understand the temporal structure and dependencies between the resources. Graphical User Interfaces (GUI) and Information Visualizations (IV) can bridge this gap between human and computers and simplify the handling of complex time-dependent and semantic knowledge [6].

In this paper we present a novel interactive timeline visualization called SemaTime that is especially designed to present time-dependent semantic information to the user. This visualization is based on the well-known timeline metaphor that arranges time-dependent entities along a time-axis. The new designed temporal navigation concept offers an intuitive way for exploring and filtering temporal resources as well as simplified navigation mechanisms for the temporal dimension. The dual time-axis concept supports the user to find the demanded information faster and offers an orientation on the temporal selection. In order to prevent context-loss, an overview is integrated in the time-axis for visualizing context information of the currently selected time interval.

The remaining paper is structured as followed: In the next section we examine existing timeline visualizations and discuss their ability to visualize time-dependent semantic knowledge. Afterward we present the conceptual design of SemaTime and give a detailed description of its interaction and navigation mechanisms. We conclude this paper with an application scenario, where we illustrate the application potential of SemaTime in a semantic search environment.

2 Related Work

Nowadays there are many different approaches for visualizing time-dependent information (e.g. [7,8]). Most of these visualizations are based on timeline visualizations that arrange time-dependent entities along a time-axis. For example Allen [9] uses an interactive timeline for the chronological visualization of the content of a digital library. This timeline visualizes past events and periods. To indicate different categories, the visualized entities can be illustrated with different colors but the visualization of hierarchical categories or semantic relations is not supported by this approach. A widely used timeline visualization is SIMILE [10] and is used from Alonso et al. [11] to visualize search results. SIMILE provides the presentation of events and periods along a horizontal time axis and offers different navigation features and an overview function. The Context-Focus-Timeline [1] visualizes events on a vertical time-axis and is used in a History Event Browser. For every event further information can be displayed whereas the timeline offers a clear overview of the temporal context.

However for the visualization of time-dependent semantics the visualization should be able to present the domain-specific, hierarchical schema and semantic relations between the entities. One approach for visualizing these complex data structures is introduced by Plaisant et al. [12]. Lifelines is able to visualize different facets which are depicted as horizontal slices and optionally hierarchical structured. Lifelines even supports the visualization of semantic relations in an implicit way by highlighting related events or periods on demand. However there is no possibility for distinguishing different relation types or to understand the meaning of relations.

Bui et al. introduce an interactive timeline visualization for depicting medical patient records in hospital information systems [13]. This timeline visualization uses a similar approach for visualizing hierarchical categories but is not able to visualize semantic relations. Another timeline visualization that supports the pictorial representation of hierarchical structured and time-dependent information is Timeline Trees [14] which is designed for visualizing sequences of transactions in information hierarchies. The hierarchical structure of the available data is depicted as horizontally oriented tree visualization. The nodes of the tree can be expanded or collapsed to support information filtering and to navigate through the hierarchical structure.

One of the first approaches for explicitly depicting semantic relations in timeline visualizations is introduced by Kumar et al. [15]. The tmVIEWER is able to visualize beside events and periods, relations as directed edges between time-dependent entities. However, this approach can only conditionally be applied to visualize semantic relations in a temporal domain because semantic relations may change in the course of time or may have a certain period of validity (e.g. “works_at”, “lives_in”, etc.). Jensen uses the same approach for depicting relations in the SemTime visualization [16]. SemTime also provides stacking of timelines and supports the visualization of flat categories in different layers which can be independently set to different time intervals.

Beside the introduced timeline visualizations there are several other approaches that are especially designed for a particular application or a specific kind of time-dependent information. For example the timeline visualization from Bade et al. [17] is especially designed for visualizing high-dimensional, time-oriented data and is used in the area of intensive care units e.g. for depicting fever curves of patients. André et al. introduce the timeline visualization Continuum [18] that comes with user-determined controls over the level of detail, a histogram function and a comparative split view. Furthermore Continuum is able to visualize time-dependent, hierarchically structured entities by nesting. However this approach is only suitable for visualizing hierarchies in which every node is time-dependent and for this reason it is not applicable for visualizing a general, hierarchical categorization.

3 The SemaTime User Interface

SemaTime is a visualization component of the SemaVis-Framework[1] [19], an adaptive visualization framework that contains different aspect-oriented visualizations [20, 21] for semantic knowledge. All components and visualizations are implemented in Adobe Flex[2] and can be connected with heterogeneous semantic data bases (for example via SPARQL). SemaVis also offers different functionalities for combining several visualization components to one knowledge cockpit [22] that offers different aspect oriented perspectives of the same information. In the following, we first explain the different parts of SemaTime and their basic functionality before describing the mechanisms in more detail.

[1] http://www.Semavis.com
[2] http://www.Adobe.com/products/flex

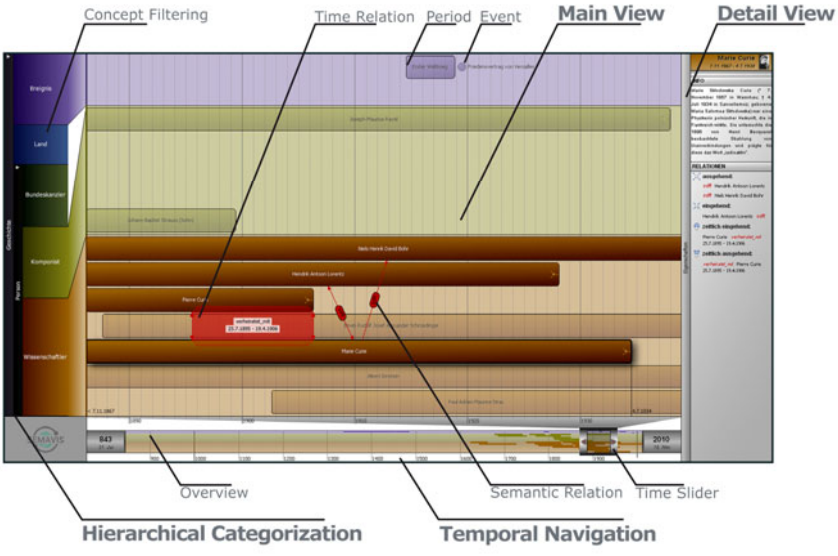

Fig. 1. The user interface of SemaTime is divided into four parts: Temporal Navigation (bottom), Hierarchical Categorization (left), Main View (center) and Detail View (right)

The user interface of SemaTime is designed like a common two-dimensional coordinate system (Fig. 1) in which the x-axis marks the temporal dimension and the y-axis represents the hierarchical categorization of the given domain. Figure 1 shows a screenshot of the SemaTime User Interface that is divided into the following four parts:

- The *Temporal Navigation Panel* at the bottom of the user interface is divided into two timescales. It offers an overview visualization and different methods for navigating in the temporal dimension.
- The *Hierarchical Categorization* of the domain is depicted as the y-axis on the left side of SemaTime. It divides the Main View in different horizontal slices and offers navigation and visual filtering methods on the conceptual layer of the domain.
- The *Main View* in the center of the user interface arranges time-dependent entities and relations between them according to their temporal information and corresponding category.
- The *Detail View* on the right side of the visualization offers further information about the selected entity e.g. descriptions, images or links to external sources.

3.1 Temporal Navigation

One of the essential parts of any visualization for time-dependent information is an appropriate navigation and filtering mechanism for the temporal dimension. On the one hand the user should be able to navigate through the temporal dimension and to explore time-dependent entities in a certain time interval of interest. On the other

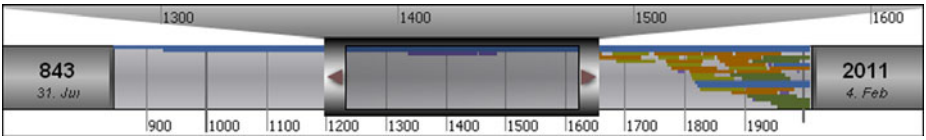

Fig. 2. The Temporal Navigation Panel in SemaTime offers two time axes for the navigation in the temporal dimension and overview visualization

hand an appropriate navigation function should assist the user in keeping the overview about the temporal information and offer an orientation on the current temporal selection.

The Temporal Navigation Panel at the bottom of SemaTime (Fig. 2) is divided into two timescales: (1) A global timescale over the complete time interval of the given data and (2) a selection scale over the currently selected time interval. The global scale contains a slider that allows the selection of a certain time interval and thus an adjustment of the selection scale. Additionally, the global time scale contains an overview visualization. So users can be aware of entities that are not visible in the Main View with the currently selected time interval.

For navigating in the temporal dimension and for selecting a certain time interval, SemaTime offers the following interactions: (1) A temporal zoom and (2) a temporal pan navigation. The temporal zoom allows the user to zoom in or out of the currently selected time interval by using the mouse wheel. So it is possible, to adjust the granularity regarding the temporal dimension and to view the information e.g. in centuries, decades or month. Since the temporal zoom influences both boundaries of the selected time interval, it is additionally possible to adjust the boundaries individually by dragging the left or right side of the time slider on the global scale. Thus it is easier to select a specific time interval and the navigation in the temporal dimension is facilitated for the users.

In contrast to the temporal zoom the pan navigation implemented in SemaTime allows the temporal navigation without influencing the temporal granularity. For this type of navigation there are two different interactions available. On the one hand the user is able to pan the selected area by dragging the time slider on the global scale either to the left or to the right side. The other option is to click and drag directly in the Main View.

3.2 Navigation and Filtering on the Conceptual Layer

Semantically modeled resources are categorized in a hierarchical domain-specific schema. This conceptual layer of the semantic structure divides the available information into knowledge spaces that cover a particular subject. SemaTime visualizes this categorization schema in the Hierarchical Categorization View (Fig. 3) to offer beside the temporal navigation, visual filtering and navigation mechanisms on the conceptual layer. So the user is able to navigate from an abstract level through the semantic knowledge space and locate specific resources of interest. This component of SemaTime divides the Main View into horizontal slices each of which corresponds

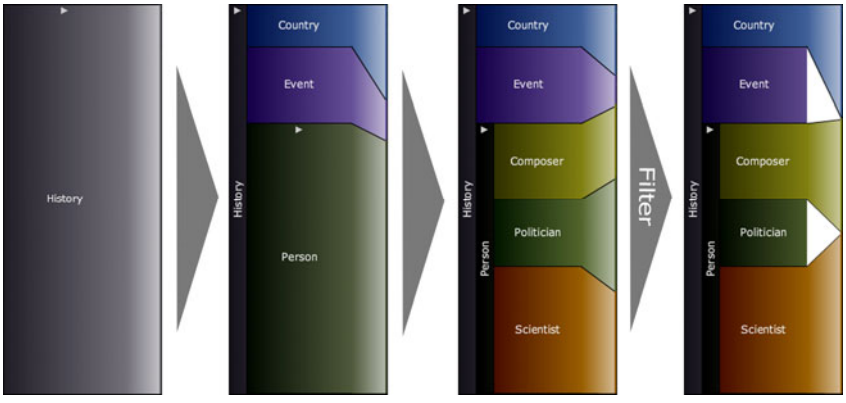

Fig. 3. The Hierarchical Categorization visualizes the domain-specific schema and offers navigation and filtering functions on the conceptual layer

with a category in the hierarchy. By clicking on a node it is possible to expand or collapse the visualized categories and to filter specific nodes.

The sizes of the displayed categories are calculated relative to the amount of resources in a category. For instance the dataset in Figure 3 contains more persons than countries. Due to the layout algorithm of the Main View that calculates the minimal number of lines and displays every resource with the same height, the heights of categories in the Hierarchical Categorization View and the Main View are not identical. For this reason, a trapezoid view for connecting the Hierarchical Categorization View with the Main View is integrated to ensure ideal space filling and visual concept assignment in the Main View even if elements are filtered. To increase the user experience with SemaTime, the transitions during navigation or filtering procedures are smoothly animated.

3.3 Visualizing Time-Dependent Resources

The Main View in the center of SemaTime visualizes time-dependent resources and places them according to their temporal attributes and associated category. SemaTime differentiates between two different types of time-dependent resources: (1) Events and (2) periods. In contrast to periods, events are characterized by a single timestamp. They correspond to a specific date on which the event occurred. On the other hand, time periods are characterized by a unique starting and endpoint, whereby a certain time interval is defined. In order to assure a clear visibility for each temporal granularity and a visible differentiation of these two types, events are visualized as a circle and time periods are depicted as rectangles (Fig. 4). This representation has the advantage that events are still visible at large selected time intervals and are not visualized as thin lines. Figure 4 shows an example of an event (Treaty of Versailles) and a period (World War I) depicted in SemaTime. Since the exact time of a resource may be difficult to recognize in cases of large selected time intervals in the Main View, the user is able to display this information on demand. Therefore, the user

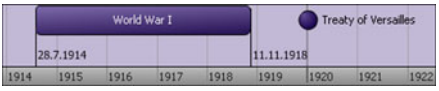

Fig. 4. Visualization of events and periods in SemaTime

selects an element by clicking or a mouse hover action whereby further information becomes visible (Fig. 4).

3.4 Visualization of Semantic Relations in a Temporal Environment

Semantic relations constitute the centerpiece of a semantically modeled domain. They are used to model links between resources and provide additional information about knowledge entities. In particular in time-dependent domains, semantic relations can be used to model causal dependencies. Commonly, a relation between two resources is defined by a direction and a type and is depicted by interconnecting the resources with a directed and labeled edge. However in a temporal domain it is also possible that a semantic relation is only valid for a certain time interval or changes in the course of time. Hence a semantic relation may contain temporal information that should be adequately represented. For this reason SemaTime distinguishes between time-dependent relations and static relations without time reference (Fig. 5).

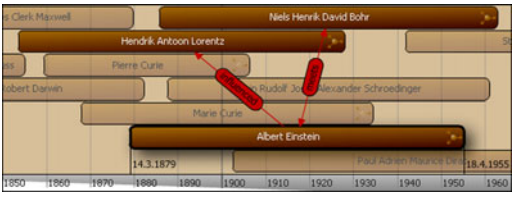

Fig. 5. Semantic relations without time reference

Time-dependent relations between two resources are depicted as a rectangle that denotes the temporal validity of the relation. The direction of the relation is visualized by arrows pointing to the related entity. The type of the relation and the temporal information are visualized in a label inside of the rectangle. Figure 6 shows an example of a bilateral, time-dependent relation. It is easy to recognize that Marie Curie was married with Pierre until his death in 1906 and vice versa.

Depending on the modeled domain and the application, the given semantic structure may contain a huge number of interconnections. The visualization of this structure may result in overlapping edges in particular in a temporal visualization in which the placement of resources is defined by temporal properties. For this reason, semantic relations in SemaTime will only be displayed on demand. Additionally, all semantically not related resources are reduced in their alpha values if a resource is selected with a mouse click. Thus the semantic surrounding of the selected resource is highlighted without losing the context in the temporal environment.

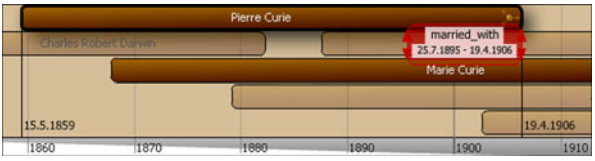

Fig. 6. Time-dependent relation in SemaTime

4 Visualization of Search Results in Semantic Domains

SemaTime was developed as a visualization component of the SemaVis Framework [19], a development of the Core-Technology-Cluster (CTC) Semantics Visualization and Innovative User Interfaces of THESEUS [23]. THESEUS is a 60-month program partially funded by the German Federal Ministry of Economics and Technology. The SemaVis Framework provides core technologies for visualization, editing and annotation of semantically annotated data. The main goal of SemaVis is the provision of core-technologies for heterogeneous users, data and application scenarios.

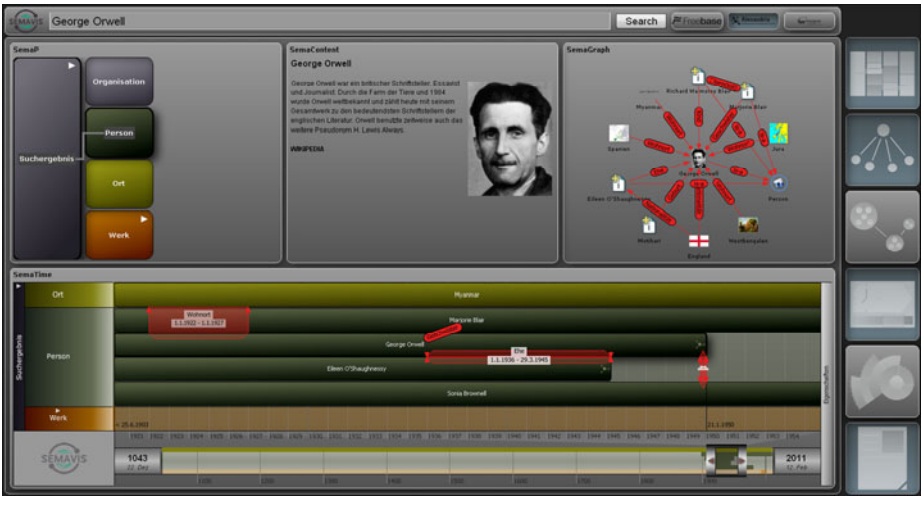

Fig.7. SemaTime in a semantic search scenario

Figure 7 shows SemaTime in an orchestrated knowledge cockpit [22] with other visualizations of the SemaVis-Framework (e.g. SeMap [21]) in a semantic search scenario. In this example the semantic knowledge base of the THESEUS Use Case ALEXANDRIA provided by neofonie[3] is searched for the author George Orwell and the results are visualized by the SemaVis technologies. In this scenario SemaTime offers beside the birth and death date, information about certain stages in his life. A time-dependent relation in this example depicts that he lived for a period of five years

[3] http://www.Neofonie.de

in Myanmar/Burma. Two other temporal relations present both of his marriages. And it is recognizable that he was married with Eileen O'Shaughnessy until her death in 1945. Additionally, to the demonstrated potential and benefit of visualizing search results with SemaTime, further information e.g. relations to non-temporal resources, a short description and images are illustrated with other visualizations of SemaVis.

5 Conclusion and Outlook

In this paper we introduced a novel interactive timeline visualization that visualizes the temporal structure and relations between resources of time-dependent semantic domains. The user interface of SemaTime includes a novel temporal navigation concept that offers an intuitive way for exploring and filtering temporal resources. Furthermore, the introduced visualization uses the domain-specific schema to offer visual filtering and navigation mechanisms on the conceptual layer. SemaTime can therefore save a lot of time during the search of temporal relationships and structures.

The further progress of this work includes a comprehensive evaluation that further examines the potentials and benefits of visualizing time-dependent semantics. In particular the future work includes a comparison with common presentations with respect to the discovery and analysis of time-dependent, semantically modeled resources.

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