TIMELINES, TEMPORAL RESOLUTION, TEMPORAL ZOOM AND TIME GEOGRAPHY

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ABSTRACT

The timeline is introduced as main interaction device, and as the binding element to explore the different 'levels' of time related to spatio-temporal data. The timeline is always linked to the map and potentially other graphics. The objective is to improve access and provide exploratory functions to get a better understanding of the temporal patterns in the data. The different timeline-function such as temporal zoom and the linking different types of time together are discussed. The cultural heritage world is taken as a sample environment to demonstrate the useful possibilities of the timeline. Here the space-time-cube is introduced as a medium to present and explore search results. Finally some other applications are discussed.

INTRODUCTION

A large variety of (cartographic) representation methods exists to display spatio-temporal events. Often these result in well designed (interactive) sets of small multiples or cartographic animations. However, the interaction with the data's temporal component is not always straightforward. In this paper the timeline is introduced for this purpose. Here a timeline is defined as a display of events along a line according a certain chronological order. The objective is to give an overview of events in relation to time and potentially each other. Often the timeline is displayed as a straight line but it could also be a circle, or even a spiral (see figure 1). The choice will depend on the nature of events in relation to time. Do we deal with linear, cyclic or branching time or with discrete or continuous time? Also the chronological density of the events does play a role. Examples of the basic timeline are often found in encyclopaedia where a person is placed in perspective of persons and events in his/her lifetime. A spiral shaped timeline can be useful for a geological timeline since the further back in time less is information is known. Several variation have been developed such as planar spiral techniques (Carlis and Konstan, 1998) and the circle view (Keim et al., 2004). Of course it is assumed timelines are interactive as discussed in Allen (1995) Karem (1994) Harrison et al. (1994) and can for instance be experienced at [url 1].

However, sometimes there is such huge amount of events to display or an unbalance in the position of events along the timeline the basic visual representations do not work and other solutions have to be found. Silva and Catarci (2002) present an extensive survey of the main visual techniques for interactive exploration of time-oriented information that incorporate many alternatives for the timeline. They discuss techniques such as the fish-eye approach, the perspective wall (MacKinlay et al., 1991) and a logarithmic transformations among others. Timelines are used in all kind of disciplines as soon as temporal data is at hand. Examples are medical data, personal histories (Plaisant et al., 1998), analysis of video data, and debugging software.

In this paper the focus is upon the use of the timeline in relation to geospatial temporal data and the link to the map. The objective is to improve access and provide exploratory functions to get a better understanding of the temporal patterns in the data. The use of the timeline in relation of maps is not new. You might find them in for instance atlases that have history as a theme. The slider of a media player, when playing a cartographic animation, is also an example, and allows one to move forward or backward in time. The timeline has been described as legend of an animation (Kraak et al., 1997), and this idea has also been elaborated as time-line and time-wheel in the Tempest project (Edsall and Peuquet, 1997), where the link between the individual components of geospatial data (location, attribute and time) is made explicit. Several graphic alternatives are discussed in (Edsall et al., 2000), and recently the timeline concept is also used to explore events (Beard, 2004).

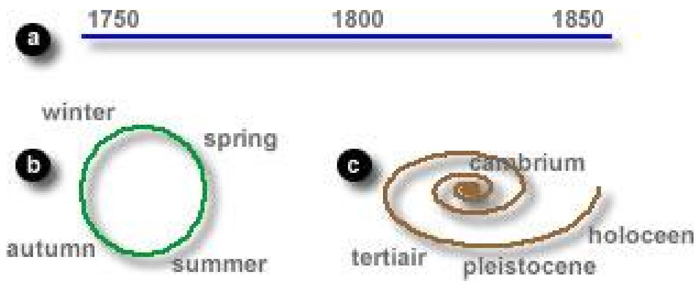

Figure 1. Basic appearances of a timeline: a) the straight line (linear time - years); b) the circle (cyclic time - seasons); c) spiral (skewed time - geology).

Examples of geo-related applications are history, archaeology, meteorology, planning among others. A historical event might seem to be a single event, but after drilling down in time (temporal zoom) it can be composed of multiple smaller events. An example is a war, its campaigns and individual battle, as shown in Figure 2. Napoleon's Russian campaign lasted just over half a year, the crossing of the River Berezina took a few days and the positioning of troops a few hours. The world of archaeology presents its own challenges as displayed in Figure 3. Here we do not only find data in multiple temporal resolutions but deal with different time scales. How for instance to visualize the relations between artefacts excavated at particular times found from different historical period at different locations, and different interpretations. Currently the field of cultural heritage gets more attention because museums, libraries and others put their collections on the web [url 2]. These collections can be of a very diverse nature. Access however, is not always that easy because the interface is not very user friendly and commonly provides only access via keywords. The timeline in relation to keywords and maps could potentially solve this problem.

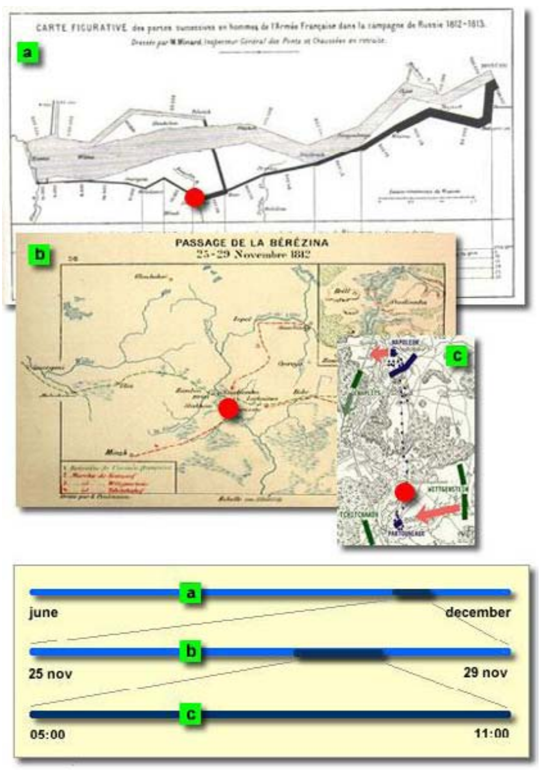

Figure 2. Temporal zoom. The timeline connects different levels of temporal resolution

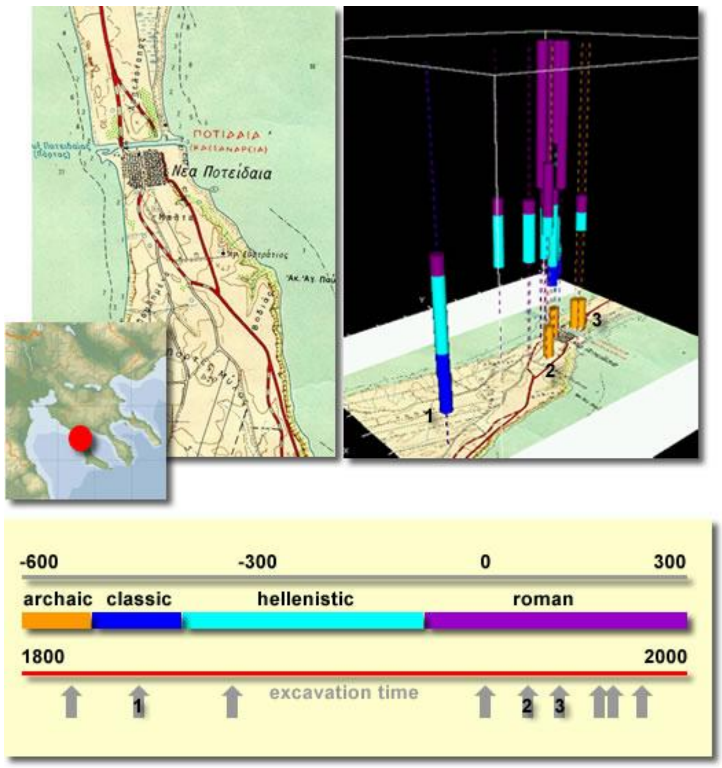

Figure 3. Multiple times. The timeline functions as a link between different types of time.

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The timeline should be seen as a core element of an interface to assist answering temporal questions. It gives access to the data available at different temporal resolutions and allows for temporal zoom operations. The timeline is always linked to maps and other graphics such as time diagrams or time-geography's space-time-cube. If needed multiple time lines can exist in parallel when different types of time are involved in the display of the same event, such as the case with archaeology (Figure 3). The purpose of the suggested approach is allow for the simultaneously exploration of the data at different temporal resolutions for a better understanding of the phenomena at hand via a multitude of visualization options. In the following sections several cases will be discussed, starting with the application of the integrated timeline in the world of cultural heritage

CULTURAL HERITAGE: SEARCH AND ANSWER

Museums, libraries as well as archives are in a process of convergence, where traditional boundaries between them disappear. Not only archives, but also libraries host important collections of for instance digital images on the web, and archives have set up (virtual) museums to show the richness of the material they have in store. Today's technology offers possibilities to make individual collections accessible for both experts and layman. Currently extra effort is put into the creation of a combined data infrastructure that makes all relevant collections the Netherlands, and potentially abroad accessible in a single search operation. In this process standardised meta-data descriptions allow the search of inventories of archives, museum collections, and relevant literature by the use of a single keyword (Ross et al., 2005). However, most of current search options work via thematic keywords only. To fully benefit of the opportunities of the infrastructure access possibilities have to be extended. Often those searching the collections have questions beyond thematic keywords, and would prefer geographic or temporal options as well. Examples are 'Which items from the collection are relevant for the region where I live?', or 'Which items are related to the World War II?'. In other words next to questions related to *what* (themes) also those related to *where* (geography) and *when* (time) are relevant. In some solutions this need is recognized, and have made the geography accessible via keywords from a hierarchical thesaurus (such as country-province-municipality-neighbourhood-street). From a user perspective this is not always satisfactory. They might be unaware of the relevant administrative hierarchy or use geographic names outside the hierarchy of the thesaurus like 'Veluwe' or 'along the River IJssel'. In relation to time similar problems can be recognized. Periods like 'Renaissance' or 'Depression' might not exactly fit in hierarchical subdivisions, and are, just like many geographic description not necessarily very precise.

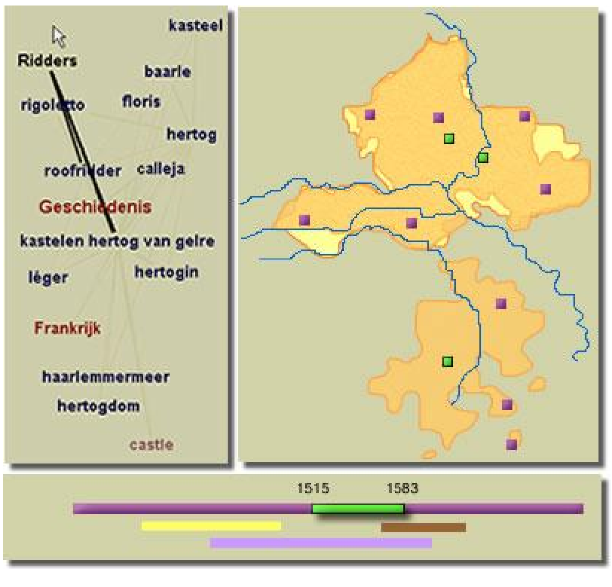

Figure 4. Potential look of an interface that contains three basic multiple linked views, one for each of the elementary question what, where, *and* when. *Action in one of the view will automatically affect the content of both other views.*

How would the timeline fit in the design and development of an interactive visual query and answer tool in a web environment that can deal with the *what, where* and *when* questions and that can function as an interface to access cultural heritage collections. A visual approach is selected because of the nature of the questions. After all, *what* might return pictures of objects, the *where* could be answered via maps and the *when* could be shown in a timeline. While searching a collection it is most unlikely a satisfactory answer will be found in a single pass. This argues for the integration of both the query and answer environment, and implies a tool that offers an iterative and interactive interface. Due to the interrelated characteristics of the *what, where*, and *when* the resulting tool will consist of an interactive multiple linked view environment that can deal with themes (keywords/icons), geography (maps), and timelines and their inter relations (see figure 2).

The actual search will not be the objective of the project, because here one can rely on existing tools such as the Aquabrowser [url 4], a catalogue research tool based on the principle of multi-dimensional scaling of thematic meta-information and can presents the results in a kind of interactive network diagram. Typing a keyword generates a network of related keywords as seen in figure 4. In the Aquabrowser clicking one of those related keyword would put this word in thew centre and generates a new network. In the viewer it generates timelines. That put the keyword in a temporal perspective. It is in use at various cultural heritage institutions and libraries. For the design of the tool the literature on recent developments in the field of information visualization can offer creative methods and techniques that lead to insight into large multivariate data (Shneiderman, 2002; Ware, 2004). In addition ideas and support can be derived from the cartographic and recent GISciences literature (Duckham et al., 2003; Gahegan, 2004). Here indications for a solution to properly deal with different levels of detail in the query and query accuracy could be found. This appears not to be a trivial problem. A user asking for items related to the Cold War will require a different answer then someone asking or autumn 1968. It will require thematic, geographic and temporal zoom capabilities. For the development the tool recent XML technology will be used adhering to the open source philosophy. From the very beginning the tool development will be done in close relation the cultural heritage partners to guarantee a user centred approach (Nielsen, 1994; Shneiderman, 1998).

The unique character of this approach is that it not only puts equal emphasis on each of the elementary search questions, but that it also allows for interaction between the three perspectives in an iterative process, and as such creates a great flexibility. This is realized by the interactively linked multiple views (Roberts, 2005). The expectation is that the tool will offer users an easier, intuitive and more structure approach in finding answers to search questions. For the *what*-question one can rely on many years of intensive development in the library world among others. The *where* question, central in geography, has not been fully elaborated in this particular context, but has received some attention in the world of map libraries ((Parry and Perkins, 2001); Alexandria Library, [url 3]. The tool could potentially get a position in the world of the geospatial data infrastructures. Here one is also working on improved data access mechanism (Groot and McLaughlin, 2000). In relation to *where* the research will pay special attention to the problem of how to deal with the vagueness in the extent of some of the geographic terms. For instance a simple question like 'where is Gelre?' cannot be simply answer for a particular year and will its extent will definitely change over time due to historical developments.

However, in this context the design and implementation of functionality to deal with the *when* is most exiting. A challenge is to deal with the different temporal notions behind terms like the Middle Ages the Golden Age, since they are used in a thematic or even geographic context that influence their meaning and as such their temporal location. For instance, in the Netherlands we learn that World War II ended May 5th, 1945, but the southern part of the county was liberated the year before. Part of the research will therefore deal with a temporal ontology to allow context sensitive used of temporal terminology in relation the timeline.

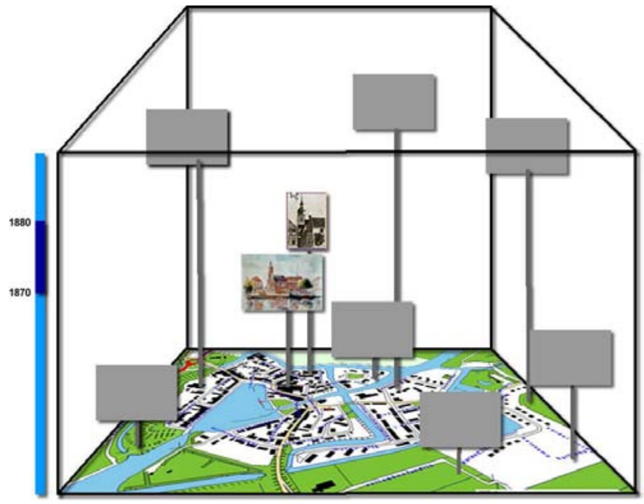

Figure 5. The space-time cube as interface to cultural heritage collections.

At the moment, the possibility to retrieve cultural heritage data through a thematic viewer such as the Aquabrowser has been met with great enthusiasm and is implemented at more and more collections. However, as stated above the dimensions of Time (*when*) and Space (*where*) are of equal importance to the selection process of relevant cultural heritage data as is the dimension of Theme (*what*). Therefore, a visual tool which offers a user access to digital cultural heritage data through these three dimensions alike will be even more suited to fill the need of a user (see figure 4). This holds true especially for cultural heritage data in which Theme is a less important issue than Time or Space, like for instance collections of digital images such as picture postcards. At the moment images in collections like "Gelderland in Beeld" [url 5] can be retrieved only through a hierarchical, geographical selection process. One cannot search for a specific theme, nor for a specific period of time. Assume that one has asked for all images of a particular city from the period 1870 – 1880. A solution would be to present the search results in a space-time cube (Kraak, 2003). The cube's bottom represents space - a map of the search area is displayed. Time is represented by the height of the cube - a timeline highlighting the selected period is given along this axis. The *what* can be represented directly in the cube, where the images are represented by grey rectangles. These float in the cube at the height of time period, and are linked to their location on the map by a thin line. The images that fulfil the search criteria are show as icons in on the rectangles, as can be seen in figure 5. Clicking the images will result in a full view of the image. It is also possible to click or select the others grey rectangles and reveal the image represented or to change the selected time period by moving the slider or extending the selected period.

SOME ALTERNATIVES

In this section few other application of the timeline are discussed. The timelines displayed in figure 6 intermediate between the map and a time-cartogram. The red and blue dots represent overnight camps. The map shows part of the retreat of Napoleon from Moscow and it can be seen that his progress was different every day. In the time-cartogram the distance equal time. Via the timeline the user can compare distance and time in both the map and cartogram and should result in a better understanding of the event.

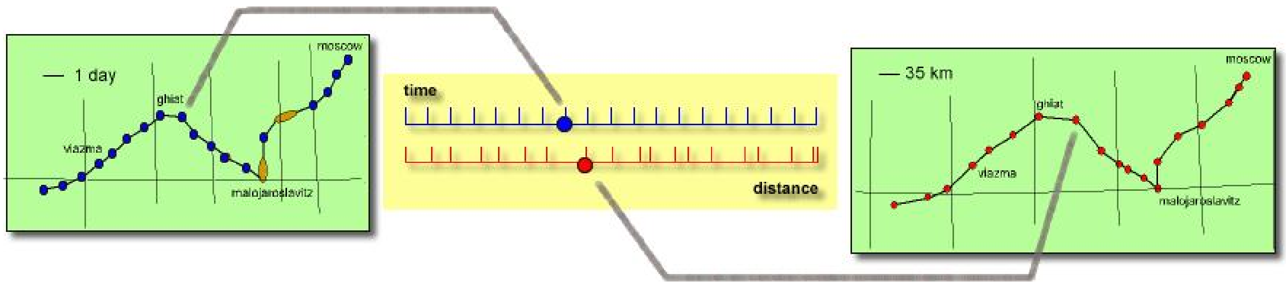

Figure 6. Timelines at work: interacting with maps and time-cartograms

A variation on the dynamic multiple view approach is the timeline in the shape of a Temporal Ordered space Matrix (TOSM) in combination with the map and parallel coordinate plot as illustrated in figure 7 (Vlag and Kraak, 2005). The map represents a coastal area at one point in time and displays the weakness of the coastal defence (red). The beach area is split in subsections, and for each of them is is indicated if extra sand is required. The PCP represent different variable that influence the decision process of indeed adding the sand. The timeline runs vertically and show for each of the subsections the corresponding values. The horizontal line is ordered in the direction of the coast from west to east. The ordering of space is not always as straightforward as in this example. The TOSM reveals a pattern over time that shows a shifting need for sand from west to east. It is possible to interact with the map, the PCP and the timeline.

CONCLUSION

This paper has demonstrated how the timeline as part of an interface to spatio-temporal data can improve both accesses to the data as well as offer extensive options to explore the data and understand temporal pattern or search results. In a geo-environment the timeline should always be linked to (multiple) map views and other views that display the attribute data in graphs and diagrams. The timeline can bind data of different temporal resolution or different kinds of time and can be combined with 'traditional' display methods for spatio-temporal data such as the animation and time geography's space-time-cube.

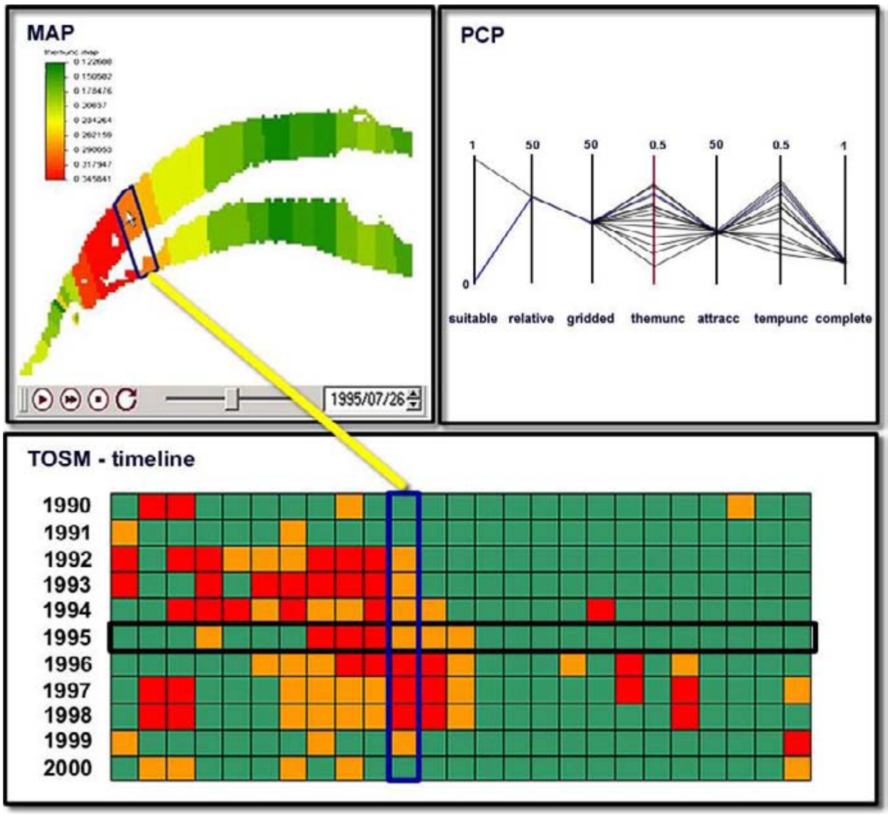

Figure 7. Timelines and visual analytics. The basics of spatio-temporal data combined via maps (where), parallel coordinate plot (what) and a timeline (when).

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