Interactively Exploring Time-Oriented Data

Wolfgang Aigner **Silvia Miksch**

Alessio Bertone **Alexander Rind**

Tim Lammarsch

Dept. of Information and Knowledge Engineering (ike),
Danube University Krems, Austria

{wolfgang.aigner, alessio.bertone, tim.lammarsch,
alexander.rind, silvia.miksch}@donau-uni.ac.at

www.donau-uni.ac.at/ike

CHI 2009, April 4 – 9, 2009, Boston, MA, USA
ACM 978-1-60558-246-7/09/04.

Abstract
Time is an important data dimension with distinct characteristics that is common across many application domains. This demands specialized methods in order to support proper analysis and visualization to explore trends, patterns, and relationships in different kinds of time-oriented data. The human perceptual system is highly sophisticated and specifically suited to spot visual patterns. For this reason, visualization is successfully applied in aiding these tasks and to date a variety of different visualization methods for time-oriented data exist. However, these methods could be improved by accounting for the special characteristics of time. The main aim of our current research is to account for the complex structures of time in visual representations, analysis, and the visualization process. Especially important are interaction methods that aid analysts when dealing with time-oriented data in visualization systems.

Keywords
Information Visualization, Visual Analytics, Interactive Visual Analysis, Time, Time-Oriented Data

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

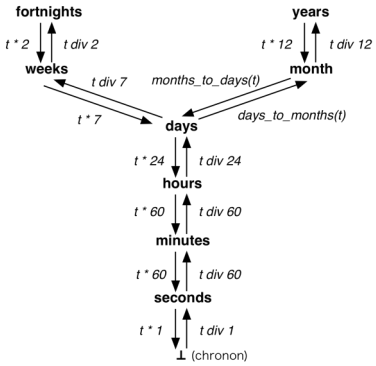

figure 1: Example for some structures of time of the Gregorian calendar.

Introduction

Time is an important data dimension that is common across many application domains, like transport, call centers, retail, production, health care, police, or financial services. Exploring trends, patterns, and relationships are particularly important tasks when dealing with time-oriented data and information. Visualization has been applied to present, explore, and analyze such kind of data for a long time and early representations trace back to the 11th century [10].

In contrast to other quantitative data dimensions that are usually "flat", time has inherent semantic structures, which increase its complexity dramatically. Especially the hierarchical structure of granularities in time, as for example minutes, hours, days, weeks, months, is unlike most other quantitative dimensions. Specifically, time comprises different forms of divisions (e.g., 60 minutes resemble one hour while 24 hours resemble one day) and granularities are combined to form calendar systems (e.g., Gregorian, Business, or Academic calendars). Moreover, time contains natural cycles and re-occurrences, as for example seasons, but also social (often irregular) cycles, like holidays or school breaks. Therefore, *time-oriented data need to be treated differently from other kinds of data and demand appropriate interaction, visual and analytical methods to analyze them.*

To tackle these issues, our research work focuses on the following areas:

- Modeling time and time-oriented data
- Visualization of time-oriented data (in particular the integration of the structure of time and the representation of temporal uncertainties)
- Visualization process of time-oriented data
- Interaction methods for time-oriented data
- Integration of analytical and interactive visual methods that take the structures of time into account
- User-centered development and evaluation of Visual Analytics methods

In the following, we will give a short overview of our past, current, and future research activities in the field of interactive visualization of time-oriented data.

Past Research

CareVis—Integrated visualization of computerized medical treatment plans and patient data

Visualization support for patient data analysis is mostly limited to the representation of directly measured data. Contextual information on performed treatment steps is an important source to find reasons and explanations for certain phenomena in the measured patient data, but is mostly spared out in the analysis process. By the development of *CareVis*, we aimed to fill this gap via integrating classical data visualization and visualization of treatment information [4]. The tightly coupled views use visualization methods well-known to domain experts and are supported by task-specific interaction methods.

PlanningLines—Novel glyphs for representing temporal uncertainties

Planning future activities is a task that we have to face constantly. Since the future is inherently connected with possible uncertainties, delays, and the unforeseen we have learned to deal with this circumstances in everyday life. However, support for temporal indeterminacies is not very well integrated in current

figure 2: Gravi++—Interactive exploration of high-dimensional temporal data [6].

methods, techniques, and tools. To represent and visualize temporal uncertainty concerning the starting and ending times and the duration of actions or events, we have developed novel glyphs, called *PlanningLines* to support project managers in their difficult planning and controlling tasks [5].

Gravi++—Interactive exploration of high-dimensional temporal data

Psychotherapists face the challenge of large amounts of survey data gathered over the course of time in cognitive behavioral therapy. In order to support their task of finding predictors for likely future therapy outcome of anorectic girls, the interactive visualization method *Gravi++* has been developed that utilizes a highly interactive interface for data exploration [6].

Current and Future Research

Systematic view on interactive visualization of time-oriented data

It is enormously difficult to consider all aspects involved when visualizing time-oriented data. Time itself has many theoretical and practical aspects. For instance, time points and time intervals use different sets of temporal relations. Only if the characteristics of the data are taken into account it is possible to generate expressive visual representations and suited interaction methods. We developed a systematic view on the visualization of time-oriented data along four main strands [3]:

- Time: What characteristics of time are considered?
- Data: What is analyzed?
- Representation: How is it represented?
- Task: Which user tasks are supported?

Visual Analytics--Integrating the outstanding visual capabilities of humans and the enormous processing power of computers

Capabilities to both generate and collect data have seen an explosive growth. The need for new methods and tools, which can intelligently and (semi-)automatically transform data into information and furthermore, synthesize knowledge are a core area of the emerging field of *Visual Analytics* [9]. To harness the potential power of a Visual Analytics approach to time and time-oriented data we proposed a conceptual framework that incorporates both, visualization & interaction as well as analytical & mining components [1][2].

In our current research project *DisCō*[1], we aim to develop novel Visual Analytics methods to visually as well as computationally analyze multivariate, time-oriented data and information to discover new and unexpected trends, patterns, and relationships. The main goals of the intertwined visual and analytical methods are to ensure high usability and good control of the integrated mining techniques by applying intuitive visualizations and visual interfaces.

Interaction and the Role of the User

User interactions are one of the most important elements in visualization or even the "heart" as Spence stated [8]. User interaction is even more important in Visual Analytics, as studies, like the one by Saraiya et al. [7] showed: users preferred inferior visualizations with interaction over superior static visualizations. Furthermore, visual representations provide only an initial direction to the data and its meaning, but

[1] www.donau-uni.ac.at/disco; last accessed: Dec 18, 2008

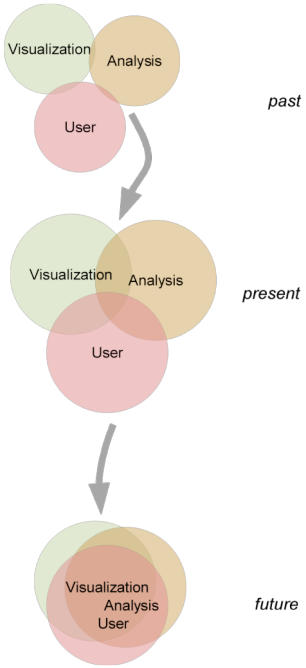

figure 3: To further advance a visually driven analysis of time-oriented data, it is necessary to integrate visual, analytical, and user-centered methods more tightly [1].

through the combination of visual representations and appropriate interaction mechanisms, the users achieve insights into the data [7]. Moreover, it is important that these methods are designed according to users' demands. Interacting directly with the visual representation and the analytical & mining methods provides more control and tighter feedback for the human analyst. This must also include interactive parameterization of both, visual and analytical methods. Navigation methods for large information spaces are decisive for analysis environments that support exploration. In parallel, they should allow for visual overviews as well as the ability to drill down into areas of interest while preserving orientation within the information space. Moreover, user's tasks and goals determine the adequate choice of visualization methods. For example, if we want to identify cycles in the data, suitable representations that reinforce the visual detection of periodic behavior need to be chosen.

In our current research project *VisuExplore*[2], we focus on the aspect of interaction to support medical personnel in their patient data analysis tasks. The project's objective is the development of a flexible, interactive visualization environment for time-oriented, medical data and information.

Conclusion

It is widely acknowledged that time is a unique data dimension with distinct characteristics. Many interactive systems deal with time-related aspects. However, these systems could be improved by considering the specifics of time and their implications in a broader sense.

[2] www.donau-uni.ac.at/VisuExplore; last accessed: Dec 18, 2008

References

[1] W. Aigner, S. Miksch, H. Schumann, and C. Tominski. Visual Methods for Analyzing Time-Oriented Data, IEEE *TVCG*, 14, 1 (2008), 47-60.

[2] W. Aigner, A. Bertone, S. Miksch, H. Schumann, and C. Tominski. Towards a Conceptual Framework for Visual Analytics of Time and Time-Oriented Data. Invited paper at *Winter Simulation Conf.* (2007).

[3] W. Aigner, S. Miksch, W. Müller, H. Schumann, and C. Tominski. Visualizing Time-Oriented Data - A Systematic View. *Computers & Graphics*, 31,3 (2007), 401–409.

[4] W. Aigner and S. Miksch. CareVis: Integrated Visualization of Computerized Protocols and Temporal Patient Data. *Artificial Intelligence in Medicine (AIIM)*, 37, 3 (2006), 203–218.

[5] W. Aigner, S. Miksch, B. Thurnher, and S. Biffl. PlanningLines: Novel Glyphs for Representing Temporal Uncertainties and their Evaluation. In *Proc. IV05*, IEEE Computer Society Press (2005), 457–463.

[6] K. Hinum, S. Miksch, W.Aigner, S. Ohmann, C. Popow, M. Pohl and M. Rester. Gravi++: Interactive Information Visualization to Explore Highly Structured Temporal Data, *Universal Computer Science*, 11 (2005), 1792-1805.

[7] P. Saraiya, C. North, V. Lam and K.A. Duca, An Insight-Based Longitudinal Study of Visual Analytics, IEEE *TVCG*, 12, 6 (2006), 1511-1522.

[8] R. Spence, *Information Visualization*, 2nd Ed., Pearson Education Limited, Essex, UK, 2007.

[9] J. J. Thomas and K. A. Cook. *Illuminating the Path: The Research and Development Agenda for Visual Analytics*. IEEE Computer Science, 2005.

[10] E. R. Tufte. *The Visual Display of Quantitative Information*. Graphics Press, Cheshire, CT, 1983.