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Visualization of Time-Oriented Data

Springer

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To our families.

Foreword

Time is central to life. We are aware of time slipping away, being used well or poorly, or of having a great time. Thinking about time causes us to reflect on the biological evolution over millennia, our cultural heritage, and the biographies of great personalities. It also causes us to think personally about our early life or the business of the past week. But thinking about time is also a call to action, since inevitably we must think about the future – the small decisions about daily meetings, our plans for the next year, or our aspirations for the next decades.

Reflections on time for an individual can be facilitated by visual representations such as medical histories, vacation plans for a summer trip, or plans for five years of university study to obtain an advanced degree. These personal reflections are enough justification for research on temporal visualizations, but the history and plans of organizations, communities, and nations are also dramatically facilitated by powerful temporal visual tools that enable exploration and presentation. Even more complex problems emerge when researchers attempt to understand biological evolution, geological change, and cosmic scale events.

For the past 500 years circular clock faces have been the prime representation for time data. These emphasize the twelve or 24-hour cycles of days, but some clocks include week-day, month or year indicators as well. For longer time periods, time lines are the most widely used, by historians as well as geologists and cosmologists.

The rise of computer display screens opened up new opportunities for time displays, challenging but not displacing the elegant circular clock face. Digital time displays are neatly discrete, clear and compact, but make time intervals harder to understand and compare. Increased use of linear time displays on computers has come with new opportunities for showing multiple time points, intervals, and future events. However, a big benefit of using computer displays is that multiple temporal variables can be shown above or below, or on the same time line. These kinds of overviews pack far more information in a compact space than was previously possible, while affording interactive exploration by zooming and filtering. Users can then see if the variables move in the same or opposite directions, or if one movement consistently precedes the other, suggesting causality.

These rich possibilities have payoffs in many domains including medical histories, financial or economic trends, and scientific analyses of many kinds. However, the design of interfaces to present and manipulate these increasingly complex and large temporal datasets has a dramatic impact on the users' efficacy in making discoveries, confirming hypotheses, and presenting results to others.

This book on Visualization of Time-Oriented Data by Aigner, Miksch, Schumann and Tominski represents an important contribution for researchers, practitioners, designers, and developers of temporal interfaces as it focuses attention on this topic, drawing together results from many sources, describing inspirational prototypes, and providing thoughtful insights about existing designs. While I was charmed by the historical review, especially the inclusion of Duchamp and Picasso's work, the numerous examples throughout the book showed the range of possibilities that have been tried – successes as well as failures. The analysis of the user tasks and interaction widgets made for valuable reading, provoking many thoughts about the work that remains to be done.

In summary, this book is not only about work that has been done, but it is also a call to action, to build better systems, to help decision makers, and to make a better world.

University of Maryland, *Ben Shneiderman*
February 2011

Preface

Time is an exceptional dimension. We recognize this every day: when we are waiting for a train, time seems to run at a snail's pace, but the hours we spend in a bar with a good friend pass by so quickly. There are times when one can wait endlessly for something to happen, and there are times when one is overwhelmed by events occurring in quick succession. Or it can happen that the weather forecast has predicted a nice and sunny summer day, but our barbecue has to be canceled due to a sudden heavy thunderstorm. Our perception of the world around us and our understanding of relations and models that drive our everyday life are profoundly dependent on the notion of time.

As visualization researchers, we are intrigued by the question of how this important dimension can be represented visually in order to help people understand the temporal trends, correlations, and patterns that lie hidden in data. Most data are related to a temporal context; time is often inherent in the space in which the data have been collected or in the model with which the data have been generated. Seen from the data perspective, the importance of time is reflected in established self-contained research fields around temporal databases or temporal data mining. However, there is no such sub-field in visualization, although generating expressive visual representations of time-oriented data is hardly possible without appropriately accounting for the dimension of time.

When we first met, we had all already collected experience in visualizing time and time-oriented data, be it from participating in corresponding research projects or from developing visualization techniques and software tools. And the literature had already included a number of research papers on this topic at that time. Yet despite our experience and the many papers written, we recognized quite early in our collaboration that neither we nor the literature spoke a common (scientific) language. So there was a need for a systematic and structured view of this important aspect of visualization.

We present such a view in this book – for scientists conducting related research as well as for practitioners seeking information on how their time-oriented data can be visualized in order to achieve the bigger goal of understanding the data and gaining valuable insights. We arrived at the systematic view upon which this book is based

in the course of many discussions, and we admit that agreeing on it was not such an easy process. Naturally, there is still room for arguments to be made and for extensions of the view to be proposed. Nonetheless, we think that we have managed to lay the structural foundation of this area.

The practitioner will hopefully find the many examples that we give throughout the book useful. On top of this, the book offers a substantial survey of visualization techniques for time and time-oriented data. Our goal was to provide a review of existing work structured along the lines of our systematic view for easy visual reference. Each technique in the survey is accompanied by a short description, a visual impression of the technique, and corresponding categorization tags. But visual representations of time and time-oriented data are not an invention of the computer age. In fact, they have ancient roots, which will also be showcased in this book. A discussion of the closely related aspects of user interaction with visual representations and analytical methods for time-oriented data rounds off the book.

We now invite you to join us on a journey through time – or more specifically on a journey into the visual world of time and time-oriented data.

Vienna University of Technology &
University of Rostock,
February 2011

Wolfgang Aigner
Silvia Miksch
Heidrun Schumann
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About the Authors

Wolfgang Aigner is assistant professor at the Institute of Software Technology & Interactive Systems at Vienna University of Technology, Austria. He received his PhD in computer science in 2006 for his work on "Visualization of Time and Time-Oriented Information: Challenges and Conceptual Design". From 2006 to 2010 he was research associate and deputy head of the Department of Information and Knowledge Engineering at Danube University Krems, Austria. Wolfgang has authored and co-authored several dozens of peer-reviewed articles and served as reviewer and program committee member for various scientific conferences, symposia, and workshops. From 2003 he was involved in a number of basic and applied research projects at national and international levels. Moreover, he participated in consulting projects and worked as a freelancer in the IT domain. His main research interests include visual analytics and information visualization, human-computer interaction (HCI), usability, and user-centered design.

Silvia Miksch has been head of the Information and Knowledge Engineering research group, Institute of Software Technology & Interactive Systems, Vienna University of Technology since 1998. From 2006 to 2010 she was professor and head of the Department of Information and Knowledge Engineering at Danube University Krems, Austria. In April 2010 she established the awarded Laura Bassi Centre of Expertise "CVAST – Center for Visual Analytics Science and Technology (Design, Interact & Explore)" funded by the Federal Ministry of Economy, Family and Youth of the Republic of Austria. Silvia has acquired, led, and has been involved in several national and international research projects. She has served on various program committees of international scientific conferences and was conference paper co-chair of the IEEE Conferences on Visual Analytics Science and Technology (IEEE VAST 2010, 2011) at VisWeek. She has more than 180 scientific publications and her main research interests are information visualization, visual analytics, plan management, and time.

Heidrun Schumann is a professor at the Institute for Computer Science at the University of Rostock, Germany, where she heads the Computer Graphics Research Group. Her research and teaching activities cover a number of topics related to computer graphics, particularly including information visualization, visual analytics, and rendering. More specifically, she is interested in the visualization of structures and multivariate data in space and time, in the design of scalable visual interfaces, and in terrain rendering techniques. Her current research projects are funded by public agencies and industry and span from fundamental research (e.g., scalable visualization methods and visual interfaces for smart environments) to applied research (e.g., computer graphics in the cockpit and visualization of bio-medical data). Heidrun is co-author of the first German textbook on visualization.

Christian Tominski is a lecturer and researcher at the Institute for Computer Science at the University of Rostock, Germany. Together with his colleagues from the Computer Graphics Research Group, Christian has authored and co-authored several articles on new visualization and interaction concepts as well as on aspects related to the software engineering of information visualization techniques. His current research interests are the visualization of multivariate data in time and space, the visualization of graph structures, and the promising opportunities of utilizing novel display and interaction devices for visualization. He is particularly interested in the role of interaction for the visual exploration and analysis of data. Christian developed a number of visualization systems and tools, including the LandVis system for spatio-temporal data, the VisAxes tool for time-oriented data, and the graph visualization system CGV.

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