A Compound Approach for Interactive Visualization of Time-Oriented Data

Tim Lammarsch*

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

ABSTRACT

Many real-world Visual Analytics applications involve time-oriented data. I am working in a research project related to this challenge where I am responsible for the interactive visualization part. My goal are interactive visualizations to explore such time-oriented data according to the user tasks while considering the structure of time. Time is composed of many granularities that are likely to have crucial influence on the formation of the data. The challenge is to integrate the granularities into a detailed compound view on the data, like the compound eye of insects integrates many images into one view. Other members of our team are experts in temporal data mining and user centered design. The goal is to combine our research topics to an integrated system that helps domain experts to get more insight from their time-oriented data.

Index Terms: I.3.6 [Computing Methodologies]: Computer Graphics—Methodology and Techniques; H.5.m [Information Systems]: Information Interfaces And Presentation (e.g., HCI)—Miscellaneous

1 RESEARCH PROBLEMS AND STATE OF THE ART

Application domains where time-oriented-data occur include commerce, health care, public security, and others. These data are usually multivariate, resulting from heterogeneous data sources. In many cases, the structure of time has strongly influenced the events the data results from. The user tasks are complex and involve many abstract questions. By studying surveys of visualizations for time-oriented data like the one by Aigner [1], it becomes apparent that most current work at visualizing time-oriented data is focused on solving one or more of the pressing tasks, but most visualizations neglect the structure of time. In the following, this structure is discussed, as well as what we consider the most important research topics in developing interactive visualizations.

1.1 The Structure of Time

Time is fairly different from other data dimensions. It has an inherent structure which results from social as well as natural contexts. This structure is interwoven to the non-time-oriented aspects of a time-oriented dataset, creating a complex multi-level system that is difficult to visualize. Regarding the structure of time, Information Visualization (InfoVis) experts have to consider a large number of aspects. These aspects can be classified according to domain, primitives, determinacy, perspectives, and calendars [5]. As humans are confronted with the structure of time on a daily basis, it is in our nature to consider it, but at the same time it is difficult to become aware of it. However, awareness of one's action is mandatory for scientific engagement. One aspect that is especially worth exploring is the calendar aspect. In InfoVis, granularity is often considered as nothing more than a parameter of discretization. Temporal data mining has sparked deep research regarding the interaction of a vast number of temporal granularities [2]. If these are based on a natural context, like the change of seasons, they are usually regular, but granularities based on social context can also be irregular, e.g., easter time. They play an important role in many datasets from real-world applications, like customer data from shops.

1.2 Interactive Visualization

User interaction is one of the most important elements of InfoVis, or even the "heart" as Spence states [9]. User interaction is even more important in Visual Analytics, as studies like the one by Saraiya et al. [7] shows: users preferred inferior visualizations with interaction over superior static visualizations. The basic interactions in visualizations of time-oriented data are interval selections, like zooming and panning, but also others like detail on demand or brushing. Most interactions are not tailored particularly for time-oriented data. E.g., if a user analyzes a day and wants to see a day one month later, she often has to go forward 28–31 days, because the visualization is at day scale. It would be easier to just go forward one month, without having to think about details. If another user wants to zoom out to one month, he has not only to respect different month lengths, but also consider that the day viewed before might not be in the center of the month. Still, it is most likely the user wants to see the month that contains the day, from the first day to the last day. These examples show that it is important for interactive visualizations to respect the structure of time.

1.3 The Visualization Process

A widely used visualization process has been described by Card et al. [3] as Visualization Reference Model. This reference model is thoughtfully designed to be universally valid for all kinds of interactive visualization. To describe more specific visualization tasks, it is helpful to adapt it and design a more detailed model for the visualization process. It is important to give a closer description of the provisions for the structure of time. E.g., the mapping of values to visual variables should be separable by granularities, giving the design a larger degree of flexibility.

2 RESEARCH QUESTIONS

How can interactive visualization be used to explore time-oriented data according to the user tasks while considering the structure of time?

Which existing visualizations can be used if the structure of time is important?

How can visualizations emphasize the structure of time itself and not only capitalize on the data?

Which sub-processes are needed in a visual analytics application or visualizations that consider the structure of time?

3 METHOD OF RESEARCH

We are focusing on the development of visualizations in the context of the structure of time, in conjunction with time-specific user interactions. We are also compiling a structured collection of prototypical user tasks. For each visualization, the research process includes searching for ways to integrate the structure of time as well as user interaction, but also identification of the tasks that are supported by it. To do this, we have formed a group of experts in InfoVis, temporal data mining, and user centered design, from the

*e-mail: tim.lammarsch@donau-uni.ac.at

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university as well as corporate environment. Work shift scheduling and demand planning are important tasks in areas like commerce, health care and security. Our planned development steps are:

1. Finding or developing visualizations that make use of the structure of time and solve pressing real-world problems;
2. Integrating or improving the user interactions as well as data mining interactions in these visualizations;
3. Empirically analyzing the visualizations according to the user tasks;
4. Developing a framework based on the Visualization Reference Model that depicts these steps and implementing it inside a data management system for time-oriented data.

The effectiveness of interactive visualizations can be improved much by applying user-centered design. Therefore, other members of our team are accompanying the whole process by doing user studies. Their results are integrated seamlessly.

4 Work Performed so far

We have explored existing visualizations that already make use of the structure of time and assessed ways to improve them. Especially, we have made them more flexible regarding the time-oriented parameters. Here are two examples.

Cycle Plots have been introduced by Cleveland [4]. They inherently make use of the structure of time. Their main purpose is the detection of trends along a coarser granularity in cases where there are bigger differences between the granules of a finer granularity. We have successfully used them with different combinations of granularities.

Multi-Scale Plots have been developed by Shimabukuro et al. [8] in a work mainly focused on the combination of time-oriented and space-oriented data as a way to combine overview with detail in one visualization. The visualization makes strong use of the structure of time, allowing the combination of four granularities and their data content.

Our implementation is done as a web browser based application. Therefore, we have also researched platforms for interactive visualizations in that domain [6].

5 Next Working Steps

After assessing several visualizations for univariate time-oriented data we now want to expand our field of research to multivariate data. A big challenge is that visualizations usually need space and/or visual variables to show time itself. Showing the structure of time increases this need. Therefore, less space and visual variables are available for the data. Furthermore, multiple, but connected, datasets might be given at different granularities. There might also be a temporal shift between instances which are connected. A possible reason is that one is the cause for the other one. An increase in people counted at the entrance of a shop is likely, but not compulsory, to cause an increase in people counted at the checkout. We also want to integrate more user interaction. Some ideas:

- By selecting a specific granule (e.g., a day) in a multi-scale plot, the user could switch the view: instead of showing absolute values for the other granules, the differences to the selected one could be shown.
- Almost every interactive visualization can be improved with zooming and panning features. For time-oriented data, panning can almost always be considered and implemented as switching of granules while zooming can be considered and implemented as switching of granularities.

Another area we want to stress is the integration of data mining and interactive visualization. Some progress we have made in the area of data mining are currently in need of suitable visualizations. Other visualization ideas or improvements only work with data mining behind them:

- Our current implementation of multi-scale plots maps average values directly to color. It is better to use a classification similar to the one described by van Wijk and van Selow [10].
- Instead of grouping by a granularity in a cycle plot, it is possible to use a classification algorithm. The classes we have produced yet can also be regarded as complex granularities.

6 Conclusion

Many real-world applications of Visual Analytics involve time-oriented data. Current methods for temporal data mining and interactive visualizations cannot deal with all user tasks involved in the analysis of this data. Particulary, they often cannot deal with complex or abstract tasks that involve several questions at once. We have explored the state of the art and realized that there is insufficient support for the structure of time, especially the combination of several granularities to a compound view on the data. Becoming aware of the structure of time is a very promising base to improve interactive visualizations and create new ones. Several visualizations can be improved by incorporating the structure of time. The combination of different visualization techniques is also a viable field of research. We have laid out a way to deal with these issues and generate scientific progress that will spark research in these areas. By using a specialized variant of the Visualization Reference Model, we intend to classify at which parts of the visualization process specific parts of our work will be applicable.

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