Interactive Information Visualization to Explore Temporal Data

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ABSTRACT
Information Visualization is mainly concerned with the representation of non-physical data like medical patient records or business data. Time is a very important data dimension in many domains that is different from others. A number of novel Information Visualization methods have been developed in order to facilitate the exploration of data across temporal contexts, but most of these methods are domain specific and only take application specific time aspects into account.

My thesis work aims for providing a general framework for supporting the interactive visual exploration of temporal data over a broad range of domains and applications.

The approach I chose for achieving this goal is based on the visualization reference model. This model will be extended by the denotation of temporal attributes via meta data along a versatile time model. Furthermore, interactive overview visualizations of temporal data sets will be provided as starting point for the visual exploration process. The design of user interfaces and visualization methods will be performed using Interaction Design and Usability Engineering methods.

Author Keywords
Information visualization, temporal data, visualization reference model, meta data, doctoral consortium.

DESCRIPTION OF THE RESEARCH PROBLEM
Information Visualization, in contrast to Scientific Visualization, focuses on abstract data and information where a natural mapping to the physical world may not exists (i.e. Databases, Networks, Documents, Time, Hierarchies). Interaction is an important feature of Information Visualization, allowing the user to explore and work with the data actively. Furthermore, Information Visualization puts forward emphasizing techniques like Focus + Context, Distortion, Highlighting, Overview + Detail, Filtering, or Brushing. [4,11] At a glance, Information Visualization can be characterized by the following definition: *"The use of computer-supported, interactive, visual representations of abstract data to amplify cognition."* [4]

Time is an outstanding data dimension, separate from 1-dimensional data as emphasized in Ben Shneiderman's Task by Data Type Taxonomy [9] that includes 1-dimensional, 2-dimensional, 3-dimensional, temporal, multi-dimensional, tree, and network data as basic data types. Time is an inherent data dimension in many domains like medical records, business data, biographical data, or planning data, and is central for the tasks of revealing trends, as well as indentifying patterns and relationships in the data.

A number of Information Visualization methods support the visualization of temporal data [1,6,10]. These methods are mostly bound to a particular feature of time (i.e. cyclical time) and are especially tailored for a specific application domain. Generally, most visualization methods treat time as just another data dimension, but the perception and influence of the temporal dimension is quite unique. *"It is now recognized that the initial approaches, just considering the time as an ordinal dimension in a 2D or 3D visualizations, are inadequate to capture the many characteristics of time-dependent information. More sophisticate and effective proposals have been recently presented. However, none of them aims at providing the user with a complete framework for visually managing temporal-related information."* [10]

This work is aimed to fill this gap and to provide a general framework for managing and visualizing temporal data in Information Visualization contexts. Moreover, the attempt to create such a framework is guided along the lines of the application domain medicine.

As basis for my thesis work, one main and four sub research questions have been formulated.

Research Questions

Main Question:

- How can Information Visualization be used to support the exploration process of time-oriented parameters with different data types to identify trends, pattern, and relationships?

Sub Questions:

- Are Information Visualization methods that are suited for this task generally applicable (application independent)?
- To what extent is the use of meta data suitable for this process?
- Which time- and meta-models support the exploration task?
- Can State-of-the-Art Interaction Design and Usability Engineering methods support the development process?

These questions cover the main areas of my intended research and will serve as means to evaluate the outcome of my work.

The upcoming section will highlight important theoretical background in terms of the visualization reference model, meta data considerations, time models, and User-Centered Design. After that, the chosen approach and work that has already been performed will be presented. Finally, a short summary of my proposal will be given.

THEORETICAL BACKGROUND

The Information Visualization process can be generalized and explained along the visualization reference model [4] (see Figure 1). This model includes basically a chain of transformations and mappings from raw data to a visual representation that is controlled by user interaction on different levels. In the first step, raw data is transformed into a generalized form, namely data tables. Then, we ascend from data to a visual form via the crucial step of applying a mapping from data tables to visual structures. Finally, these visual structures lead to views of the data by applying (different) view transformations. Descriptive information about data - meta data - is added in this process mainly at the data table stage. Meta data is an important source for choosing appropriate visualizations, i.e. based on the data types of parameters.

Relatively few research can be found on meta data aspects for Information Visualization or visualization in general. The key idea of integrating meta data in a systematic way is its application for a more efficient visualization of the data set. Nocke and Schumann published an article that aims to investigate meta data aspects for visualization purposes in a systematic, scientific way [7]. They present the following classification of meta data: *descriptive* (underlying properties of a data set), *derived* (extracted from a data set), and *historical* (origin of a data set).

When working with temporal data on a computer, time has to be represented along a suited data model or time model, respectively. Most importantly, such a model defines the used basic primitives as well as their interrelationships [2]. Several different approaches exist to model time (point-based, interval-based, discrete, continuous, branching, cyclical, etc.) [3,5]. Extensive research on different time models, representations of time, temporal logic and the like has been carried out mainly in the Database and Artificial Intelligence community.

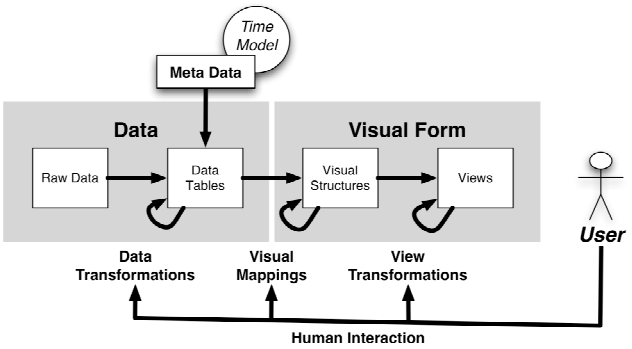

Figure 1. Visualization Reference Model (based on [4]).

User-Centered Design puts the user along with her goals, tasks, demands, and background in the center of the development process and involves her from the very beginning. Human-Computer Interaction, Interaction Design [8] and Usability Engineering are the main research areas concerned with these issues. Their main goal is to increase the quality of development by focussing onto real users' needs rather than speculations about them often ending in so-called "featurism".

CHOSEN APPROACH

In order to provide an application independent framework for supporting the exploration process of temporal data, an abstraction level that is general enough has to be found. The visualization reference model is such a general representation of the Information Visualization process, which I chose to work with. The basic idea is to expand this model in order to seamlessly integrate the visualization of temporal data in the process. The key aspect for this expansion is the use of meta data.

Basically, data tables of temporal data sets have time-oriented attributes. At this stage, these attributes are not recognized as being temporal by the system, often only make sense if put into relation (i.e. begin and end of an interval), and are treated just as any other attribute. Therefore, they need to be denoted as being temporal and their roles have to be defined. This is achieved by the means of meta data. In this sense, meta data records are data records associated with data table columns to denote temporal data as well as to represent additional information.

In order to perform this denotation, a basic time model for representing temporal data is needed. A model that is versatile enough to be suited for a broad range of applications and domains has to be found. Interval-based time models that support different granularities and indeterminacies as well as unanchored and anchored temporal primitives seem to be most appropriate here.

Moreover, the visualization process is enhanced by adding further meta data. One example for this kind of meta information are valid data ranges (attribute values that are out of this range could be considered as outliers or false

measurements) or abstractions (normal temperature vs. fever). The meta data model should be context-, task-, as well as user specific. A central characteristic is its support of context based constraints (i.e. a certain pulse rate might be normal for a new born infant, but is dangerously high for an adult).

Additionally to this enhancements of the visual reference model "behind the scenes", methods for meta data management will be provided as well as interactive overview visualizations of the temporal data sets that serve as starting point for further visual exploration.

We will use State-of-the-Art Usability Engineering methods to evaluate our designs and investigate if these methods can be applied "as-is" for the domain of information visualization development.

WORK PERFORMED SO FAR

The first step of my thesis work was to investigate the State-of-the-Art in Information Visualization for temporal data. Extensive literature research has been undertaken to gain an overview of available visualization approaches. Furthermore, a categorization scheme has been worked out and the investigated methods have been categorized along this scheme. Basically, the categorization includes supported tasks, representation issues, supported data types, multivariate visualizations, query support, and interactivity. The categorization matrix provides a compact and dense overview of visualization methods with respect to a broad range of characteristics. Currently, I am about to compile this overview and categorization in form of a State-of-the-Art report [1].

Parallel to the investigation of Information Visualization methods, several time models have been studied and considered. The temporal model "HMAP" of Combi and Pozzi looks quite promising for this purpose, but further considerations have to be undertaken.

Apart from theoretical thoughts and considerations about meta data in the visualization process, a meta data architecture for medical data was developed. This architecture contains simple descriptive meta data on parameters like data type and unit, but more importantly context sensitive constraints as well as handling of known parameter relationships. The architecture has been conceptualized, realized as XML DTD, and currently, a graphical editor for meta data management is created.

SUMMARY

The visualization reference model is used as basis for the goal of providing a general Information Visualization framework for the interactive exploration of temporal data. This model provides a level of abstraction that is needed in order to be able to create an application and domain independent framework.

The first steps towards this goal were the analysis and categorization of Information Visualization methods for temporal data and the investigation of time models. Furthermore, work has already been performed on meta data aspects by developing a meta data management architecture for medical data.

An important aspect of my thesis work will be to put forward a user-centered design methodology by applying Interaction Design and Usability Engineering methods.

The upcoming future tasks will be the completion of the State-of-the-Art report on Information Visualization methods and the selection of an appropriate time model. After that, the time- and meta-model needs to be tested and a prototype including meta data management will be implemented. Moreover, interactive overview visualizations will be conceptualized and prototypes created.

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