Visual Exploration of Time-Oriented Patient Data for Chronic Diseases: Design Study and Evaluation

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Abstract. Medical care, particularly for chronic diseases, accumulates a huge amount of patient data over extensive time periods that needs to be accessed and analyzed accordingly. Information Visualization methods hold great promises in turning data deluge into improved quality of medical care. Yet, patient data management systems mostly provide documents, form-based displays, or static visualizations. We present a design study of an interactive visualization system, called VisuExplore, to support long-term care and medical analysis of patients with chronic diseases. VisuExplore offers interaction techniques for effective exploration of time-oriented data and employs simple, but intuitive visualization techniques. It was developed in close cooperation with physicians. We conducted two user studies with nine physicians and 16 students, which indicate that our design is useful and appropriate for particular tasks.

Keywords: Information Visualization, time-oriented data, medical information systems, visual exploration, interaction techniques, user study.

1 Introduction

Modern medicine puts a huge amount of patient data at the attending physicians’ disposal. Particularly in chronic disease care, data accumulates over extensive periods of time and physicians need to access and analyze it accordingly. Ongoing data integration efforts might bridge the technical gap between different data stores but not the gap between data stores and human expertise. In an effort to turn data deluge into improved quality of medical care, we present a design study of an Information Visualization (InfoVis) system to support physicians in exploring time-oriented health care data of patients with chronic diseases.
Time and time-oriented data play an important role in health care, which is underlined by the definition of the electronic health record (EHR) as “the complete set of information that resides in electronic form and is related to the past, present and future health status or health care provided to a subject of care” [24]. In care for patients with chronic diseases and for analysis of such care, physicians often need to consult these records. While typical queries can be answered quickly, there are often situations that require deeper understanding of the recorded information (e.g., co-development of biometric variables, or how a change of therapy has affected patient status). In addition, physicians need to analyze multiple variables of different data types and irregular sampling. For such exploratory tasks, where they do not have a direct question but learn about the patient in their search, InfoVis holds great promise [10].

Current patient data management systems (PDMS), however, provide only a small part of what InfoVis has to offer for exploring time-oriented data. Often, patient data is available only in electronic documents or PDMS forms that show one examination at a time. This makes it hard to follow patient trends. Visualizations, if provided, are mostly static and do not allow powerful interactions. Furthermore, existing research for patient data visualization has engaged in different design studies that cannot be immediately transferred to our domain problem. These designs either focus on a single type of data (e.g., intervals) or special scenarios, like intensive care, which is mostly concerned with high-frequency, short-term data (cp. Sect. 2).

In close cooperation with physicians at a regional hospital, we have developed task-specific interaction and visualization methods for the diabetes outpatient clinic, called VisuExplore. Through our design, they can explore time-oriented data of a patient with chronic diseases in a coherent user interface. In order to represent variables of different structure, we visualize each variable or each group ofhomogeneously structured variables in a separate diagram. To provide a frame of reference, these diagrams are aligned to a common time axis. Tackling irregular and independent sampling, we draw items where they fit on the time axis. The use of simple and easy-to-understand visualization methods was requested by users and should make it easy for them to read and interpret the data. This is accompanied by an extensive set of interaction techniques that allows for flexible and effective exploration of the data. Providing a reasonable combination of simplicity and flexibility is a non-trivial achievement.

In general it is advisable to evaluate InfoVis systems with their target users. However, physicians at our partner hospitals have been very busy and we could recruit nine physicians for the usability investigation of VisuExplore. To complement this investigation, we repeated the user study with 16 students. With this combined approach we could back up the result and gain additional insights.

**Contribution.** This paper’s primary contribution is a design study of InfoVis methods for medicine. Design studies have been characterized very well by Munzner [20], who also called for more work of this type. Following this, we describe the diabetes outpatient clinic as accompanying domain problem and the user requirements guiding our work (Sect. 3). Next, we present the visual encoding