Visual analytics in healthcare – opportunities and research challenges

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As medical organizations modernize their operations, they are increasingly adopting electronic health records (EHRs) and deploying new health information technology systems that create, gather, and manage their information. As a result, the amount of data available to clinicians, administrators, and researchers in the healthcare system continues to grow at an unprecedented rate.[1] However, despite the substantial evidence showing the benefits of EHR adoption, e-prescriptions, and other components of health information exchanges, healthcare providers often report only modest improvements in their ability to make better decisions by using more comprehensive clinical information.[2,3]

The large volume of clinical data now being captured for each patient poses many challenges to (a) clinicians trying to combine data from different disparate systems and make sense of the patient's condition within the context of the patient's medical history, (b) administrators trying to make decisions grounded in data, (c) researchers trying to understand differences in population outcomes, and (d) patients trying to make use of their own medical data. In fact, despite the many hopes that access to more information would lead to more informed decisions, access to comprehensive and large-scale clinical data resources has instead made some analytical processes even more difficult.[4]

Visual analytics is an emerging discipline that has shown significant promise in addressing many of these information overload challenges. Visual analytics is the science of analytical reasoning facilitated by advanced interactive visual interfaces.[5] In order to facilitate reasoning over, and interpretation of, complex data, visual analytics techniques combine concepts from data mining, machine learning, human computing interaction, and human cognition. As the volume of health-related data continues to grow at unprecedented rates and new information systems are deployed to those already overrun with too much data, there is a need for exploring how visual analytics methods can be used to avoid information overload.

Information overload is the problem that arises when individuals try to analyze a number of variables that surpass the limits of human cognition.[6] Information overload often leads to users ignoring, overlooking, or misinterpreting crucial information. The information overload problem is widespread in the healthcare domain and can result in incorrect interpretations of data, wrong diagnoses, and missed warning signs of impending changes to patient conditions. The multi-modal and heterogeneous properties of EHR data together with the frequency of redundant, irrelevant, and subjective measures pose significant challenges to users trying to synthesize the information and obtain actionable insights.

Yet despite these challenges, the promise of big data in healthcare remains.[1] There is a critical need to support research and pilot projects to study effective ways of using visual analytics to support the analysis of large amounts of medical data. Currently new interactive interfaces are being developed to unlock the value of large-scale clinical databases for a wide variety of different tasks. For instance, visual analytics could help provide clinicians with more effective ways to combine the longitudinal clinical data with the patient-generated health data to better understand patient progression. Patients could be supported in understanding personalized wellness plans and comparing their health measurements against similar patients. Researchers could use visual analytics tools to help perform population-based analysis and obtain insights from large amounts of clinical data. Hospital administrators could use visual analytics to better understand the productivity of an organization, gaps in care, outcomes measurements, and patient satisfaction. Visual analytics systems—by combining advanced interactive visualization methods with statistical inference and correlation models—have the potential to support intuitive analysis for all of these user populations while masking the underlying complexity of the data.

This special focus issue of *JAMIA* is dedicated to new research, applications, case studies, and approaches that use visual analytics to support the analysis of complex clinical data.

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The issue provides a broad picture of active work in this area, including four research and applications papers, one review paper, two brief communications, and one case report.

First, West et al.[7] present a systematic review of innovative visual analytics approaches that have been proposed to illustrate EHR data. The review paper groups over 800 articles in different categories and is a great resource for readers who are interested in understanding what has been done in applying visual analytics in healthcare settings.

In the first of four research and application papers, Klimov et al.[8] present a data-driven temporal data mining system with an interactive visual analytics interface to support the analysis and exploration of renal-damage risk factors in type II diabetes patients. Second, Huang et al. present a system to visually analyze the polymorbidity associated with chronic kidney disease. The study uses a large-scale database with over 14 000 patients and a Sankey-style visualization tool to help clinicians predict the outcome of complex disease based on comorbidities the patients have developed.[9] Third, Hirsch et al.[10] present a system called HARVEST, an interactive temporal visualization for longitudinal patient record. The system implements a patient record summarizer by extracting content from patient notes, aggregating and presenting information from multiple care settings, and supporting clinicians by providing a flexible tool for reviewing patients' information. Finally, Soulakis et al.[11] discuss practical methods for employing network analysis to visualize and describe multidisciplinary, collaborative care for hospitalized heart failure patients. The authors used data for over 500 patients and describe the provider's collaboration network as a subset of collaborations within a complex graph with 1504 nodes and 83 998 edges.

In a comprehensive case study, Warner et al.[12] present a network visualization-based system to explore, analyze, and display the phenotypic patterns that may have remained occult or hidden in basic statistical and pairwise correlation analysis. The system allows clinicians and researchers to quickly generate hypotheses and gain deeper understanding of subpopulations.

Finally, two brief communications describe early results from a pair of visual analysis systems. First, Basole et al.[13] present an interactive system that uses visual analytics techniques to explore clinical data from 5784 pediatric asthma emergency department patients. The system makes cohort identification more efficient and possibly even more accurate that regular approaches. Second, Ratwani et al.[14] present a dashboard-based system that employs visualization techniques to more effectively explore patient safety event reports, find patterns, and analyze the correlation between different hospital organizations.

This special issue provides readers with a sample of the variety of work being performed around the world on the topic of visual analytics in healthcare. Researchers in this discipline are exploring a range of topics and a growing, vibrant research community has emerged.[15] Many challenges remain, but we believe that visual analytics techniques will become essential elements in the future of health informatics. As the articles in this issue demonstrate, these methods promise to allow users of all sorts—clinicians, researchers, administrators, patients, and more—to derive actionable, meaningful insights form the vast and complex data resources that the modern health system is now creating. Yet this issue also indirectly highlights some of the areas of informatics that need more attention. These include the visual exploration of unstructured data (e.g., text), the challenge of clinical or operational adoption, and the lack of standardized methods for evaluation, validation, and measurement of efficacy of visual analytics tools. These are all critical areas for future work.

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