Future Challenges and Unsolved Problems in Health Visualization

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Abstract

With the growing popularity of wearable devices, health-related sensors, electronic health records (EHR), population health records (PopHR), computational biology and simulation, imaging data such as CT and MRI scans, and X-rays, the volume of digital health data is growing rapidly. Large volumes of heterogeneous health data require advanced visualization and visual analytics systems to uncover valuable insight buried in complex sources of data. As a rapidly evolving sub-field of visualization and visual analytics, many interactive health visualization systems have been proposed, developed, and evaluated by clinicians to support effective clinical analysis and decision making. Despite the growing progress in the field, many challenges and unsolved problems remain. The health-related problems that we face today are a clear sign of the growing need to progress in this area. This panel presents an open discussion of the top future challenges and unsolved problems in health and health-related visualization. The panel features experts with a range of different backgrounds covering a variety of health-related perspectives. This panel provides a valuable overview of health-related visualization revealing both mature areas and future research directions.

1. Introduction and Motivation: Description of Topic

In some ways, the growing variety and volume of health-related data is a reflection of the growing need to address the complex health challenges posed by our modern day and age. We are witness to great progress on a number of health-related fronts including the growing popularity of wearable devices that monitor health, e.g., Fitbits, to the reduced costs and advancements of blood-glucose monitors, to the growing collection of electronic health records (EHRs), to the ever-expanding volume of computational biology simulations, to advancements in high-resolution scanning devices such as CT, and MRI scanners. However, with the advances in hardware and software comes new challenges, such as the growing complexity and volume of heterogeneous health data.

This panel brings together a range of experts to discuss an urgent topic of growing importance: future challenges and unsolved problems in interactive health visualization. It promises a lively introduction and discussion of solved and future research directions in this important field.

2. Intended Audience

This panel will appeal to all visualization researchers with an interest in visual analysis and visualization of health data. It is a topic with very broad appeal.

3. Why this panel at Eurovis 2025?

This is an important and timely theme for the visualization research community that addresses interesting, difficult and challenging questions. To the best of our knowledge, no such panel has ever been presented. This central topic touches on the experience and interest of every researcher in visualization. It is not only of interest to the Eurovis community if the lessons learned can be transferred to the other events in the future. It should be especially interesting for both experienced researchers and newcomers to the field. There is a wide variety of opinions on this topic within the visualization research community. We think a panel addressing the topic of contributions in visualization research will form the basis of lively discussions for the panel and more from the audience.

4. Panel Format and Logistics

Each panelist will present their positions addressing each topics and/or question posed in the introduction.

† Organizer

DOI: 10.2312/evt.20251119

- The introductory remarks will be made by the panel organizer. His introduction will last for 5 minutes.
- He will chair the panel and he himself is not a panelist.
- Each panelist will be given approximately 10 minutes to present their perspectives on the topic, for a total of approximately one hour of presentations.
- This will provide approximately 35 minutes of audience participation in the discussion.
- All panelists will have the opportunity to offer a summary view at the end of the panel (1 minute each).

The panel chair will solicit audience feedback after the position statements have been delivered. The panel format will also be described in the panel opening.

4.1. Equipment Needed

No special equipment is needed for this panel.

4.2. Panel Position Statements

The panel consists of members from a diverse set of backgrounds spanning various demographics and different career stages.

Jürgen Bernard Together with finance, health is among those data-driven domains, where individuals engage deeply with digital information for critical decision-making the most–often in highly personal contexts. With advancements in sensor data, wearable devices, medical imaging, and personal health records, interactive visual data analysis offers new possibilities for personalized healthcare insights and decision support. However, scaling Visual Analytics solutions to broader audiences remains a challenge. Typically designed for expert users, VA must now simplify without oversimplifying. How can we design adaptive, transparent, and explainable visualization systems that benefit both clinicians and patients? Another key opportunity involves human diversity and personalization. Healthcare decisions are influenced by individual behaviors, personae, and subjective preferences. But how can we integrate tacit knowledge, patient emotions, and preferences–as valuable subjective data sources–into data-driven decision-making scenarios that traditionally rely more on objective data like sensor readings and health records? Beyond personalizations, the human health system itself is inherently complex. Diseases, symptoms, and treatments form intricate relationships, making multimodal and multifaceted data analysis crucial. Health-related data spans across qualitative and quantitative, structured and unstructured sources, requiring advanced relation discovery methods to help individuals draw meaningful conclusions and support informed decision-making.

Bernhard Preim A key challenge is visual data communication and narrative visualization, i.e., to create visualizations of medical data that are easy to perceive and to remember and that are considered as relevant and trustworthy. Such visualizations, either used as infographics, or being integrated in stories can help to inform about health related problems, diagnostic and early detection measures as well as novel treatment methods. Creating awareness for frequent health problems, their prevention and treatment without being too persuasive manipulating the audience is a challenge. The visualization community may contribute significantly to health communication by providing flexible toolkits to adapt disease-related stories to different target audiences, different settings and different output media. AI may play an essential role in this endeavor, e.g., to create relatable and believable patient characters and to adapt visuals to different contexts. The outcomes of narrative medical visualization are potentially valuable for patient education as well.

Renata G. Raidou Despite the continuous flow of advancements in healthcare, I still feel we are doing so little in health visualization. While AI models "dominate the headlines", we risk (or even are) neglecting the real transformative power of visualization and visual analytics in healthcare. Why aren't we leveraging visualization's whole potential to democratize health knowledge, combat misinformation, and make complex medical insights accessible and actionable—not only for clinicians, but also for patients, the general public, and policy makers? But there's a deeper challenge: Has health visualization become a mere tool for data interpretation and how can it break its own niche? Can it rather engage and empower patients of all backgrounds, inform public debate, and influence policy? Can it become a bridge of inclusivity for underserved communities? As researchers in health visualization, we need to reclaim our narrative—not as an afterthought to AI, but as a powerful enabler of impact, inclusion, and insight in healthcare.

Anna Vilanova Many challenges have been addressed by medical visual analytics and visualization in the last decades, from analysis of individual data sets to cohort exploration and analysis. Despite this advancements the use of visualization in the medical domain is often still relegated to presentation goals rather than exploration for hypothesis generation or analysis. Healthcare systems collect large amounts of data that are handled from fully manual analysis with rather simplified forms of data representations, not addressing the complexity of it, or fully automatic methods using AI models that simplify the information and make direct or indirectly assumptions on the data. Assumptions that are often unknown to hold in reality. Generating extensive trial and error processes to identify adequate solutions. Heterogeneous information coming from wearable, lab results, questionnaires, images all combined with other sources that are often incomplete or error prone, complicate the generation of adequate solutions even further. Visual analytics can provide insight on the generated methods, the adequateness of the solutions, for example, for supporting AI model generation but also adoption through facilitating auditing of the models in the healthcare context. Explainable AI is seen as essential for this purpose, however, the complexity of the subject gab among the different disciplines involved, machine learning, human computer interaction, psychology, healthcare, pedagogy and visualization to address this matter is large. providing independent solutions that address parts of the puzzle independently, but do not cover a holistic solution. Would visual analytics be able to bridge that gabs?

David Borland Almost ten years ago I co-authored an IEEE CG&A Visualization Viewpoints article titled "Data-Driven Healthcare: Challenges and Opportunities for Interactive Visualization." In that article we noted that healthcare shares data-related problems with many other domains, such as data integration, ease

of use, and interpretability. However we also identified certain challenges that, if not wholly specific to healthcare, are of increased importance or made more challenging within that context: *breadth of use*—individualized care to population health application, *data complexity*—many patients, many variables, longitudinal data, heterogeneous sources, incomplete data, etc., and *statistical rigor*—finding "interesting" data patterns is not enough given stakes that are often life-or-death. The intervening years have certainly brought many advancements in these areas, although one related challenge we did not specifically address was adoption—how do we ensure that useful tools and techniques developed by the visualization community are integrated into real systems for real users? How do we design these tools in such a way that useful information is provided to both sophisticated and unsophisticated users in a manner that is easy to understand and does not overburden already busy workloads? In addition, one major change in the healthcare landscape is the advent of AI technologies, such as deep-learning based image analysis, and LLMs. These approaches have great potential to improve the state of healthcare, but also bring with them various hazards, such as issues of bias and trust, for which visualization can be an important tool for transparency.

5. List of Panel Members and Biographies

Jürgen Bernard is a non-tenured Assistant Professor of Computer Science at the University of Zurich (UZH), Switzerland, and associated with the Digital Society Initiative (DSI), Zurich. He is leading the Interactive Visual Data Analysis (IVDA) Group. Jürgen Bernard studied Computer Science with focus on Computer Graphics at the University of Technology of Darmstadt. His diploma thesis in 2009 was on visual-interactive cluster analysis using neural networks. He received his PhD Degree in 2015 on "Exploratory Search in Time-Oriented Primary Data", when he was with Fraunhofer IGD. In 2016, Jürgen Bernard started as a Post-doc researcher at TU Darmstadt at Interactive Graphics Systems Group, leading the Visual-Interactive Machine Learning Group. In 2019, he became a postdoctoral research fellow at the University of British Columbia, Vancouver, Canada, where he joined the InfoVis group, led by Professor Tamara Munzner. For his contributions in visualization research, Jürgen was awarded the EuroVis Young Researcher Award (2021) and the Eurographics Young Researcher Award (2022).

Bernhard Preim Bernhard Preim was born in 1969 in Magdeburg, Germany. He received the diploma in computer science in 1994 (minor in mathematics) and a Ph.D. in 1998 from the Otto-von-Guericke University of Magdeburg. In 1999 he moved to Bremen where he joined the staff of MeVis and directed the "Computer-aided Planning in Liver Surgery" group. In June 2002 he received the Habilitation degree (venia legendi) for computer science from the University of Bremen. Since Mars 2003 he is full professor for "Visualization" at the computer science department at the Otto-von-Guericke-University of Magdeburg, heading a research group focussed on medical visualization. He authored several textbooks: "Entwicklung interaktiver Systeme" (1999), "Visualization in Medicine" (Co-author Dirk Bartz, 2007), "Interaktive Systeme" (Co-author: R. Dachselt, 2010) and "Visual Computing in Medicine" (Co-author: C. Botha, 2013) and "Interaktive Systeme, Part 2" (Co-author: R. Dachselt, 2015) and "Visualization, Visual Analytics and Virtual Reality in Medicine" (Co-Authors: Renata Raidou, Noeska Smit and Kai Lawonn, 2023). Bernhard Preim founded the working group Medical Visualization in the German Society for Computer Science and served as speaker from 2003-2012. He was Co-Chair and Co-Organizer of the first and second Eurographics Workshop on Visual Computing in Biology and Medicine (VCBM) and lead the steering committee of that workshop until 2019.

He is the chair of the scientific advisory board of ICCAS (International Competence Center on Computer-Assisted Surgery, since 2010) and was a member of the advisory board of Institute for Surgical Training and Technology Leipzig (2012-2018). From 2011-2018 he was an associate editor of IEEE Transactions on Medical Imaging and and IEEE Transactions on Visualization and Graphics (2017-2022). He was paper co-chair of VMV 2012, EuroVis 2013 and Area Chair of IEEE VisWeek 2021. He was also regularly a Visiting Professor at the University of Bremen where he closely collaborates with Fraunhofer MEVIS (2003-2012) and was Visiting Professor at TU Vienna (2016).

Renata G. Raidou is Assistant Professor in Medical Visualization and Visual Analytics at TU Wien, Austria. She is a holder of the Dirk Bartz Prize for Visual Computing in Medicine (1st Place) at Eurographics 2017 and the Best PhD Award 2018 of the EuroVis Awards Programme. In 2022, she was awarded the EuroVis Young Researcher Award. She is currently on the Steering Committee of EG VCBM, GI-VCBM, and GI-Vis, and a Eurographics Junior Fellow. She has also been elected in the Executive Committee of Eurographics and acts as the Austrian representative in EASAC (European Academies' Science Advisory Council), a collaborative body for independent, evidence-based scientific advice to policymakers—specifically in the area "AI in Healthcare". Her research focus is on the interface between Visual Analytics, Image Processing, and Machine Learning.

Anna Vilanova Bartroli Prof Dr Anna Vilanova is full professor in visual analytics (vis.win.tue.nl) since October 2019, at the department of Mathematics and Computer Science, at the Eindhoven University of Technology (TU/e). She is also associated to the Electrical Engineering department within the Signal Processing Systems at TU/e. Previously she was associate professor for 6 years at the Computer Graphics and Visualization Group at EEMCS at the University of Delft, the Netherlands. From 2002 to August 2013, she was Assistant Professor at the Biomedical Image Analysis group of the Biomedical Engineering Department at TU/e. She is leading a research group in the subject of visual analytics and multivalued image analysis and visualization, focusing on Visual Analytics for high dimensional data and explainable AI. She focuses on Biomedical applications such as: Diffusion Weighted Imaging, 4D Flow and Pangenomics. In 2005, she was awarded a NWO-Veni personal grant with title "Visualization of global tensor information for diffusion tensor imaging". In 2013 she got a NWO-Aspasia. She is member of the international program committee of several conferences (e.g., IEEE Visualization and EUROGRAPHICS- EuroVis). She has been chair and editor of relevant conferences and journals in her field of research (e.g., EuroVis 2008, Computer and

Graphics, Computer Graphics Forum, IEEE Vis). She was member of the steering committee of IEEE VGTC EuroVis (2014 - 2018) and VCBM since 2018. She is elected member of the EUROGRAPHICS executive committee since 2015, vice president 2019-2022 and currently president of EUROGRAPHICS. She also became EUROGRAPHICS fellow in 2019. She is an elected member of the IEEE VIS Steering Committee (VSC) since 2021.

David Borland is an Assistant Director of Analytics and Data Science at the Renaissance Computing Institute (RENCI) at the University of North Carolina (UNC) at Chapel Hill, and helps lead the Visual Analysis and Communication Laboratory (VACLab) at UNC Chapel Hill. He has served on the American Medical Informatics Association (AMIA) Visual Analytics Working Group (VIS WG) Task Force on Evaluation, and has helped organize and has served on the program committee for the Visual Analytics in Healthcare (VAHC) workshop. He received his PhD in Computer Science from UNC Chapel Hill in 2007, where his dissertation work focused on volume rendering of medical images. He then worked as a consultant at Siemens Corporate Research, implementing his dissertation work for their medical imaging platform, before joining RENCI as a Senior Visualization Researcher in 2007. From 2010-2012 he worked with IDIBAPS and the EVENTLab at the University of Barcelona, developing VR scenarios and methods for virtual-embodiment, beforing returning to RENCI. His research focus includes data visualization, visual analytics, and image analysis, especially in biomedical domains, with an increasing focus on the integration of AI.