Activity Report 2019

Project-Team AVIZ

Analysis and Visualization

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Project-Team AVIZ

Creation of the Team: 2007 February 08, updated into Project-Team: 2008 January 01

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1. Team, Visitors, External Collaborators

Research Scientists
Jean-Daniel Fekete [Team leader, Inria, Senior Researcher, HDR]
Tobias Isenberg [Team leader, Inria, Senior Researcher, HDR]
Pierre Dragicevic [Inria, Researcher]

Steve Haroz [Inria, Starting Research Position]
Petra Isenberg [Inria, Researcher]
Catherine Plaisant [Inria, International Chair, Advanced Research Position]

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Qing Chen [École polytechnique, Post-Doctoral Fellow]
Paola Tatiana Llerena Valdivia [Inria, Post-Doctoral Fellow]
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Yuheng Feng [Inria, from Apr 2019 until Sep 2019]
Yumin Hong [Inria, from Mar 2019 until Sep 2019]
Alexandra Ibarra Cuesta [Inria, until Mar 2019]
Kejin Jin [Inria, from Mar 2019 until Aug 2019]

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Katia Evrat [Inria, Administrative Assistant]

Visiting Scientists
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Paolo Buono [University of Bari, from Aug 2019 until Sep 2019]
Claudio Silva [New York University, until Jul 2019]

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Evelyne Lutton [INRA]
Frédéric Vernier [Univ Paris-Sud]
Christoph Kinkeldey [Freie Universität Berlin]

2. Overall Objectives

2.1. Objectives

Aviz (Analysis and VIsualiZation) is a multidisciplinary project that seeks to improve visual exploration and analysis of large, complex datasets by tightly integrating analysis methods with interactive visualization.

Our work has the potential to affect practically all human activities for and during which data is collected and managed and subsequently needs to be understood. Often data-related activities are characterized by access to new data for which we have little or no prior knowledge of its inner structure and content. In these cases, we need to interactively *explore* the data first to gain insights and eventually be able to act upon the data contents. Interactive visual analysis is particularly useful in these cases where automatic analysis approaches fail and human capabilities need to be exploited and augmented.

Within this research scope Aviz focuses on five research themes:

- Methods to visualize and smoothly navigate through large datasets;
- Efficient analysis methods to reduce huge datasets to visualizable size;
- Visualization interaction using novel capabilities and modalities;
- Evaluation methods to assess the effectiveness of visualization and analysis methods and their usability;
- Engineering tools for building visual analytics systems that can access, search, visualize and analyze large datasets with smooth, interactive response.

2.2. Research Themes

Aviz's research on Visual Analytics is organized around five main Research Themes:

Methods to visualize and smoothly navigate through large data sets: Large data sets challenge current visualization and analysis methods. Understanding the structure of a graph with one million vertices is not just a matter of displaying the vertices on a screen and connecting them with lines. Current screens only have around two million pixels. Understanding a large graph requires both data reduction to visualize the whole and navigation techniques coupled with suitable representations to see the details. These representations, aggregation functions, navigation and interaction techniques must be chosen as a coordinated whole to be effective and fit the user's mental map.

Aviz designs new visualization representations and interactions to efficiently navigate and manipulate large data sets.

Efficient analysis methods to reduce huge data sets to visualizable size: Designing analysis components with interaction in mind has strong implications for both the algorithms and the processes they use. Some data reduction algorithms are suited to the principle of sampling, then extrapolating, assessing the quality and incrementally enhancing the computation: for example, all the linear reductions such as PCA, Factorial Analysis, and SVM, as well as general MDS and Self Organizing Maps. Aviz investigates the possible analysis processes according to the analyzed data types.

Visualization interaction using novel capabilities and modalities: The importance of interaction to Visualization and, in particular, to the interplay between interactivity and cognition is widely recognized. However, information visualization interactions have yet to take full advantage of these new possibilities in interaction technologies, as they largely still employ the traditional desktop, mouse, and keyboard setup of WIMP (Windows, Icons, Menus, and a Pointer) interfaces. At Aviz we investigate in particular interaction through tangible and touch-based interfaces to data.

Evaluation methods to assess their effectiveness and usability: For several reasons appropriate evaluation of visual analytics solutions is not trivial. First, visual analytics tools are often designed to be applicable to a variety of disciplines, for various different data sources, and data characteristics, and because of this variety it is hard to make general statements. Second, in visual analytics the specificity of humans, their work environment, and the data analysis tasks, form a multi-faceted evaluation context which is difficult to control and generalize. This means that recommendations for visual analytics solutions are never absolute, but depend on their context.

In our work we systematically connect evaluation approaches to visual analytics research—we strive to develop and use both novel as well as establish mixed-methods evaluation approaches to derive recommendations on the use of visual analytics tools and techniques. Aviz regularly published user studies of visual analytics and interaction techniques and takes part in dedicated workshops on evaluation.

Engineering tools: for building visual analytics systems that can access, search, visualize and analyze large data sets with smooth, interactive response.

Currently, databases, data analysis and visualization all use the concept of data tables made of tuples and linked by relations. However, databases are storage-oriented and do not describe the data types precisely. Analytical systems describe the data types precisely, but their data storage and computation model are not suited to interactive visualization. Visualization systems use in-memory data tables tailored for fast display and filtering, but their interactions with external analysis programs and databases are often slow.

Aviz seeks to merge three fields: databases, data analysis and visualization. Part of this merging involves using common abstractions and interoperable components. This is a long-term challenge, but it is a necessity because generic, loosely-coupled combinations will not achieve interactive performance. First progress has already been made [10].

Aviz's approach is holistic: these five themes are facets of building an analysis process optimized for discovery. All the systems and techniques Aviz designs support the process of understanding data and forming insights while minimizing disruptions during navigation and interaction.

3. Research Program

3.1. Scientific Foundations

The scientific foundations of Visual Analytics lie primarily in the domains of Visualization and Data Mining. Indirectly, it inherits from other established domains such as graphic design, Exploratory Data Analysis (EDA), statistics, Artificial Intelligence (AI), Human-Computer Interaction (HCI), and Psychology.

The use of graphic representation to understand abstract data is a goal Visual Analytics shares with Tukey's Exploratory Data Analysis (EDA) [67], graphic designers such as Bertin [54] and Tufte [66], and HCI researchers in the field of Information Visualization [53].

EDA is complementary to classical statistical analysis. Classical statistics starts from a *problem*, gathers *data*, designs a *model* and performs an *analysis* to reach a *conclusion* about whether the data follows the model. While EDA also starts with a problem and data, it is most useful *before* we have a model; rather, we perform visual analysis to discover what kind of model might apply to it. However, statistical validation is not always required with EDA; since often the results of visual analysis are sufficiently clear-cut that statistics are unnecessary.

Visual Analytics relies on a process similar to EDA, but expands its scope to include more sophisticated graphics and areas where considerable automated analysis is required before the visual analysis takes place. This richer data analysis has its roots in the domain of Data Mining, while the advanced graphics and interactive exploration techniques come from the scientific fields of Data Visualization and HCI, as well as the expertise of professions such as cartography and graphic designers who have long worked to create effective methods for graphically conveying information.

The books of the cartographer Bertin and the graphic designer Tufte are full of rules drawn from their experience about how the meaning of data can be best conveyed visually. Their purpose is to find effective visual representation that describe a data set but also (mainly for Bertin) to discover structure in the data by using the right mappings from abstract dimensions in the data to visual ones.

For the last 25 years, the field of Human-Computer Interaction (HCI) has also shown that interacting with visual representations of data in a tight perception-action loop improves the time and level of understanding of data sets. Information Visualization is the branch of HCI that has studied visual representations suitable to understanding and interaction methods suitable to navigating and drilling down on data. The scientific foundations of Information Visualization come from theories about perception, action and interaction.

Several theories of perception are related to information visualization such as the "Gestalt" principles, Gibson's theory of visual perception [59] and Triesman's "preattentive processing" theory [65]. We use them extensively but they only have a limited accuracy for predicting the effectiveness of novel visual representations in interactive settings.

Information Visualization emerged from HCI when researchers realized that interaction greatly enhanced the perception of visual representations.

To be effective, interaction should take place in an interactive loop faster than 100ms. For small data sets, it is not difficult to guarantee that analysis, visualization and interaction steps occur in this time, permitting smooth data analysis and navigation. For larger data sets, more computation should be performed to reduce the data size to a size that may be visualized effectively.

In 2002, we showed that the practical limit of InfoVis was on the order of 1 million items displayed on a screen [57]. Although screen technologies have improved rapidly since then, eventually we will be limited by the physiology of our vision system: about 20 millions receptor cells (rods and cones) on the retina. Another problem will be the limits of human visual attention, as suggested by our 2006 study on change blindness in large and multiple displays [55]. Therefore, visualization alone cannot let us understand very large data sets. Other techniques such as aggregation or sampling must be used to reduce the visual complexity of the data to the scale of human perception.

Abstracting data to reduce its size to what humans can understand is the goal of Data Mining research. It uses data analysis and machine learning techniques. The scientific foundations of these techniques revolve around the idea of finding a good model for the data. Unfortunately, the more sophisticated techniques for finding models are complex, and the algorithms can take a long time to run, making them unsuitable for an interactive environment. Furthermore, some models are too complex for humans to understand; so the results of data mining can be difficult or impossible to understand directly.

Unlike pure Data Mining systems, a Visual Analytics system provides analysis algorithms and processes compatible with human perception and understandable to human cognition. The analysis should provide understandable results quickly, even if they are not ideal. Instead of running to a predefined threshold, algorithms and programs should be designed to allow trading speed for quality and show the tradeoffs interactively. This is not a temporary requirement: it will be with us even when computers are much faster, because good quality algorithms are at least quadratic in time (e.g. hierarchical clustering methods). Visual Analytics systems need different algorithms for different phases of the work that can trade speed for quality in an understandable way.

Designing novel interaction and visualization techniques to explore huge data sets is an important goal and requires solving hard problems, but how can we assess whether or not our techniques and systems provide real improvements? Without this answer, we cannot know if we are heading in the right direction. This is why we have been actively involved in the design of evaluation methods for information visualization [63], [62], [60], [61], [58]. For more complex systems, other methods are required. For these we want to focus on longitudinal evaluation methods while still trying to improve controlled experiments.

3.2. Innovation

We design novel visualization and interaction techniques (see, for example, Figure 1). Many of these techniques are also evaluated throughout the course of their respective research projects. We cover application domains such as sports analysis, digital humanities, fluid simulations, and biology. A focus of Aviz' work is the improvement of graph visualization and interaction with graphs. We further develop individual techniques for the design of tabular visualizations and different types of data charts. Another focus is the use of animation as a transition aid between different views of the data. We are also interested in applying techniques from illustrative visualization to visual representations and applications in information visualization as well as scientific visualization [8].

3.3. Evaluation Methods

Evaluation methods are required to assess the effectiveness and usability of visualization and analysis methods. Aviz typically uses traditional HCI evaluation methods, either quantitative (measuring speed and errors) or qualitative (understanding users tasks and activities). Moreover, Aviz is also contributing to the improvement of evaluation methods by reporting on the best practices in the field, by co-organizing workshops (BELIV
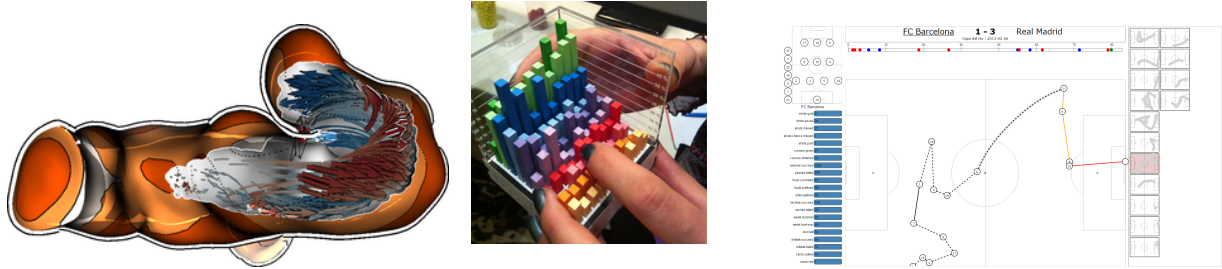
Figure 1. Example novel visualization techniques and tools developed by the team. Left: a non-photorealistic rendering technique that visualizes blood flow and vessel thickness. Middle: a physical visualization showing economic indicators for several countries, right: SoccerStories a tool for visualizing soccer games.

2010–2018) to exchange on novel evaluation methods, by improving our ways of reporting, interpreting and communicating statistical results, and by applying novel methodologies, for example to assess visualization literacy [3], [4].

3.4. Software Infrastructures

We want to understand the requirements that software and hardware architectures should provide to support exploratory analysis of large amounts of data. So far, "big data" has been focusing on issues related to storage management and predictive analysis: applying a well-known set of operations on large amounts of data. Visual Analytics is about exploration of data, with sometimes little knowledge of its structure or properties. Therefore, interactive exploration and analysis is needed to build knowledge and apply appropriate analyses; this knowledge and appropriateness is supported by visualizations. However, applying analytical operations on large data implies long-lasting computations, incompatible with interactions, and generates large amounts of results, impossible to visualize directly without aggregation or sampling. Visual Analytics has started to tackle these problems for specific applications but not in a general manner, leading to fragmentation of results and difficulties to reuse techniques from one application to the other. We are interested in abstracting-out the issues and finding general architectural models, patterns, and frameworks to address the Visual Analytics challenge in more generic ways.

3.5. Emerging Technologies

Figure 2. Example emerging technology solutions developed by the team for multi-display environments, wall displays, and token-based visualization.

We want to use different types of display media to empower humans to visually and interactively explore information, in order to better understand and exploit it. This includes novel display equipment and accompanying input techniques. The Aviz team specifically focuses on the exploration of the use of large displays in visualization contexts as well as emerging physical and tangible visualizations (e. g. [6], [5]). In terms of interaction modalities our work focuses on using touch and tangible interaction. Aviz participates to the Digiscope project that funds 11 wall-size displays at multiple places in the Paris area (see http://www.digiscope.fr), connected by telepresence equipment and a Fablab for creating devices. Aviz is in charge of creating and managing the Fablab, uses it to create physical visualizations, and is also using the local wall-size display (called WILD) to explore visualization on large screens. The team also investigates the perceptual, motor and cognitive implications of using such technologies for visualization.

3.6. Psychology

More cross-fertilization is needed between psychology and information visualization. The only key difference lies in their ultimate objective: understanding the human mind vs. helping to develop better tools. We focus on understanding and using findings from psychology to inform new tools for information visualization. In many cases, our work also extends previous work in psychology. Our approach to the psychology of information visualization is largely holistic and helps bridge gaps between perception, action and cognition in the context of information visualization. Our focus includes the perception of charts in general, perception in large display environments, collaboration, perception of animations, how action can support perception and cognition, and judgment under uncertainty (e. g. [9]).

4. Application Domains

4.1. Natural Sciences

As part of a CORDI PhD project, we collaborate with researchers at CERN on interactive data visualization using augmented reality, with the goal to better understand this new visualization environment and to support the physicists in analysing their 3D particle collision data. As part of another CORDI PhD project, we collaborate with researchers at the German Center for Climate Computation (DKRZ), to better understand collaborative data exploration and interaction in immersive analytics contexts. Finally, as part of the Inria IPL "Naviscope," we collaborate with researchers at INRA (as well as other Inria teams) on interactive visualization tools for the exploration of plant embryo development.

4.2. Social Sciences

We collaborate with social science researchers from EHESS Paris on the visualization of dynamic networks; they use our systems (GeneaQuilts [56], Vistorian [64], PAOHVis [7]) and teach them to students and researchers. Our tools are used daily by ethnographers and historians to study the evolution of social relations over time. In the social sciences, many datasets are gathered by individual researchers to answer a specific question, and automated analytical methods cannot be applied to these small datasets. Furthermore, the studies are often focused on specific persons or organizations and not always on the modeling or prediction of the behavior of large populations. The tools we design to visualize complex multivariate dynamic networks are unique and suited to typical research questions shared by a large number of researchers. This line of research is supported by the DataIA "HistorIA" project, and by the "IVAN" European project. We also collaborate on the BART initiative, a joint project with IRT-SystemX on the analysis and visualization of blockchain data, in collaboration with economists from Université Paris-Sud.

4.3. Medicine

We collaborate with CMAP/Polytechnique on the analysis and visualization of CNAM Data "parcours de santé" to help referent doctors and epidemiologists make sense of French health data. In particular, we are working on a subset of the CNAM Data focused on urinary problems, and we have received a very positive feedback from doctors who can see what happens to the patients treated in France vs. what they thought happened through the literature. This project is starting but is already getting a lot of traction from our partners in medicine, epidemiology, and economy of health.

5. Highlights of the Year

5.1. Highlights of the Year

- Aviz researchers contributed 36 publications this year. Amongst these 3 papers were presented at IEEE VIS, the largest international Visualization and Visual Analytics conference.
- Aviz researchers remained active in the research community. We organized one Dagstuhl seminar and one Shonan seminar, served in 8 different organizing committee roles, on 19 program committees, and on 5 different journal editorial board. We reviewed for 25 different conference venues and for 12 different journals. We also gave 26 invited talks and served on two different steering committees and a best PhD award committee and served on 10 different juries (for both PhD and Master students).
- Aviz researchers started two four-year ANR grants as principle investigators.

5.1.1. Awards

- Tobias Isenberg was named the Associate Editor of the Year for Elsevier Computers & Graphic.
- Pierre Dragicevic and his co-authors received a best paper award at ACM CHI .
- Natkamon Tovanich and his co-authors received the Honorable Mention poster award at EuroVis 2019 .

BEST PAPERS AWARDS:

[34]
P. DRAGICEVIC, Y. JANSEN, A. SARMA, M. KAY, F. CHEVALIER. *Increasing the Transparency of Research Papers with Explorable Multiverse Analyses*, in "CHI 2019 - The ACM CHI Conference on Human Factors in Computing Systems", Glasgow, United Kingdom, May 2019 [*DOI :* 10.1145/3290605.3300295], https://hal.inria.fr/hal-01976951

[51]
N. TOVANICH, N. HEULOT, J.-D. FEKETE, P. ISENBERG. *A Systematic Review of Online Bitcoin Visualizations*, 2019, Posters of the European Conference on Visualization (EuroVis), The poster received the Honorable Mention award at EuroVis 2019 [*DOI :* 10.2312/EURP.20191148], https://hal.archives-ouvertes.fr/hal-02155171

6. New Software and Platforms

6.1. Cartolabe

KEYWORD: Information visualization

FUNCTIONAL DESCRIPTION: The goal of Cartolabe is to build a visual map representing the scientific activity of an institution/university/domain from published articles and reports. Using the HAL Database, Cartolabe provides the user with a map of the thematics, authors and articles . ML techniques are used for dimensionality reduction, cluster and topics identification, visualisation techniques are used for a scalable 2D representation of the results.

NEWS OF THE YEAR: Improvement of the graphical interface

- Participants: Philippe Caillou, Jean-Daniel Fekete, Jonas Renault and Anne-Catherine Letournel
- Partners: LRI - Laboratoire de Recherche en Informatique - CNRS
- Contact: Philippe Caillou
- URL: http://www.cartolabe.fr/

6.2. BitConduite

BitConduite Bitcoin explorer

KEYWORDS: Data visualization - Clustering - Financial analysis - Cryptocurrency

FUNCTIONAL DESCRIPTION: BitConduite is a web-based visual tool that allows for a high level explorative analysis of the Bitcoin blockchain. It offers a data transformation back end that gives us an entity-based access to the blockchain data and a visualization front end that supports a novel high-level view on transactions over time. In particular, it facilitates the exploration of activity through filtering and clustering interactions. This gives analysts a new perspective on the data stored on the blockchain.

- Authors: Jean-Daniel Fekete, Petra Isenberg and Christoph Kinkeldey
- Contact: Petra Isenberg

6.3. PAOHvis

Parallel Aggregated Ordered Hypergraph Visualization

KEYWORDS: Dynamic networks - Hypergraphs

FUNCTIONAL DESCRIPTION: Parallel Aggregated Ordered Hypergraph (PAOH) is a novel technique to visualize dynamic hypergraphs [26]. Hypergraphs are a generalization of graphs where edges can connect more than two vertices. Hypergraphs can be used to model co-authorship networks with multiple authors per article, or networks of business partners. A dynamic hypergraph evolves over discrete time slots. A PAOH display represents vertices as parallel horizontal bars and hyperedges as vertical lines that connect two or more vertices. We believe that PAOH is the first technique with a highly readable representation of dynamic hypergraphs without overlaps. It is easy to learn and is well suited for medium size dynamic hypergraph networks such as those commonly generated by digital humanities projects - our driving application domain (see Fig. 3).

- Contact: Paola Tatiana Llerena Valdivia
- URL: https://aviz.fr/paohvis

6.4. AR Collaborative Visualization

KEYWORDS: Augmented reality - Collaborative science - Android

FUNCTIONAL DESCRIPTION: Allows to look at VTK datasets using AR-HMD (Microsoft HoloLens) in multi-users environments (i.e., one headset per user). A Multi-touch tablet is provided per user to manipulate the environment.

- Contact: Mickael Sereno

6.5. Platforms

6.5.1. Vispubdata.org

AVIZ members are making available for research a dataset of IEEE VIS publications at http://vispubdata.org. This dataset is actively being used for research and conference organization.
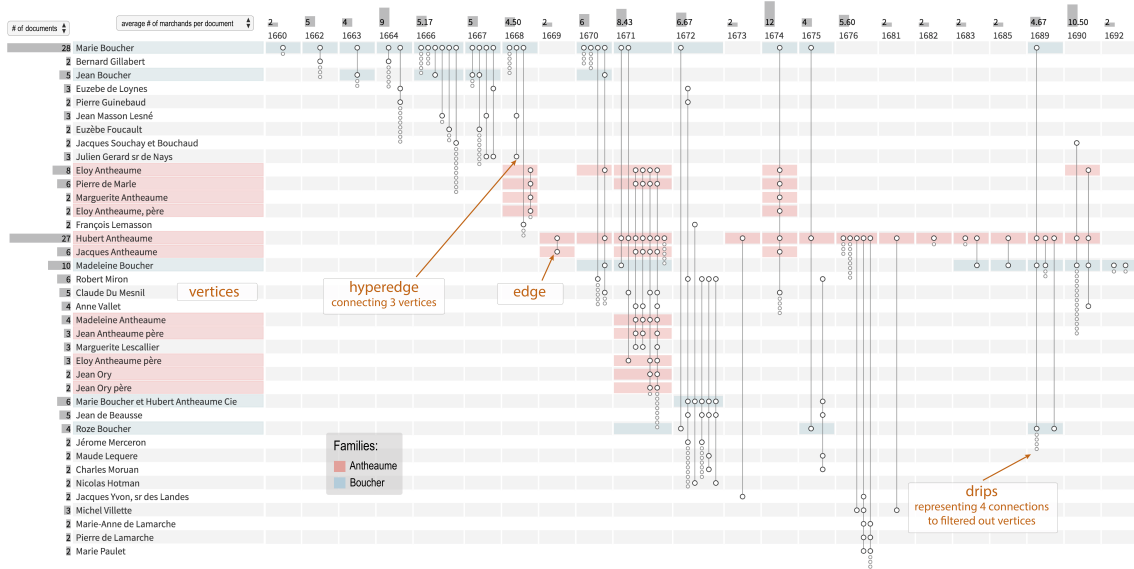
Figure 3. Using Dynamic Hypergraphs to Reveal the Evolution of the Business Network of a 17th Century French Woman Merchant
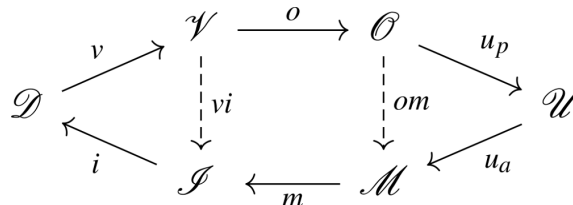

Figure 4. Illustration of the model of interaction directness.

7. New Results

7.1. A Model of Spatial Directness in Interactive Visualization

Participants: Stefan Bruckner [University of Bergen], Tobias Isenberg [correspondant], Timo Ropinski [University of Ulm], Alexander Wiebel [Hochschule Worms University of Applied Sciences].

We discuss the concept of directness in the context of spatial interaction with visualization [2] . In particular, we propose a model that allows practitioners to analyze and describe the spatial directness of interaction techniques, ultimately to be able to better understand interaction issues that may affect usability. To reach these goals, we distinguish between different types of directness (Figure 4). Each type of directness depends on a particular mapping between different spaces, for which we consider the data space, the visualization space, the output space, the user space, the manipulation space, and the interaction space. In addition to the introduction of the model itself, we also show how to apply it to several real-world interaction scenarios in visualization, and thus discuss the resulting types of spatial directness, without recommending either more direct or more indirect interaction techniques. In particular, we will demonstrate descriptive and evaluative usage of the proposed model, and also briefly discuss its generative usage.

More on the project Web page: https://tobias.isenberg.cc/VideosAndDemos/Bruckner2019MSD.

7.2. Increasing the Transparency of Research Papers with Explorable Multiverse Analyses

Participants: Pierre Dragicevic [correspondant], Yvonne Jansen [CNRS], Abhraneel Sarma [University of Michigan], Matthew Kay [University of Michigan], Fanny Chevalier [University of Toronto].
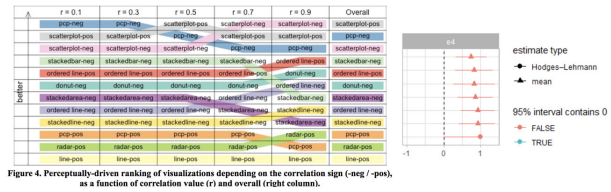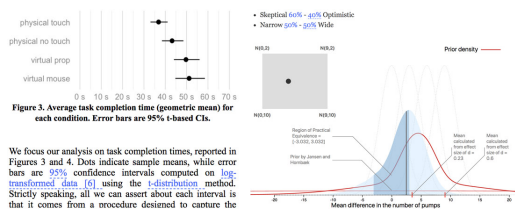
Figure 5. Examples of explorable multiverse analyses.

We presented explorable multiverse analysis reports, a new approach to statistical reporting where readers of research papers can explore alternative analysis options by interacting with the paper itself [34]. This approach draws from two recent ideas: i) multiverse analysis, a philosophy of statistical reporting where paper authors report the outcomes of many different statistical analyses in order to show how fragile or robust their findings are; and ii) explorable explanations, narratives that can be read as normal explanations but where the reader can also become active by dynamically changing some elements of the explanation. Based on five examples and a design space analysis, we showed how combining those two ideas can complement existing reporting approaches and constitute a step towards more transparent research papers. This work received a best paper award at ACM CHI.

More on the project Web page, including interactive demos: https://explorablemultiverse.github.io/.

7.3. Glanceable Visualizations for Smartwatches

Participants: Tanja Blascheck [correspondant], Lonni Besançon [Linköpping University], Anastasia Bezerianos, Bongshin Lee [Microsoft Research], Petra Isenberg.

Figure 6. Comparison of bar, donut, and radial bar charts on a smartwatch.

The goal of this project is to study very small data visualizations, micro visualizations, in display contexts that can only dedicate minimal rendering space for data representations. Specifically, we define micro visualizations as small-scale visualizations that lack or have a limited set of reference structures such as labels, data axes, or grid lines and have a small physical footprint of a few 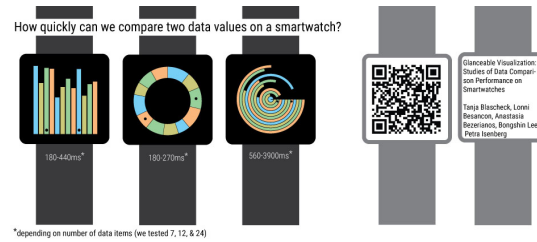square centimeters. Micro visualizations can be as simple as small unit-based visualizations such as a battery indicator but also include multi-dimensional visualizations such as star glyphs, small geographic visualizations or even small network visualizations. Although micro visualizations are essential to mobile visualization contexts, we know surprisingly little about their general visual and interaction design space or people's ability in interpreting micro visualizations. We will address this gap by proposing a common framework, conducting empirical studies to understand people's abilities to interpret these visualizations while in motion, and by developing a software toolkit to aid practitioners in developing micro visualizations for emerging mobile and wearable displays.

In summary, we aim at paving the way for a pervasive use of visualizations and thus a better and broader understanding of the complex world around us.

More information in related publications ([1],[48]) and on the project Web page: https://www.aviz.fr/smartwatchperception.

7.4. Hybrid Touch/Tangible Spatial 3D Data Selection

Participants: Lonni Besançon [Linköpping University], Mickael Sereno [correspondant], Lingyun Yu [Hangzhou Dianzi University], Mehdi Ammi [University of Paris 8], Tobias Isenberg.
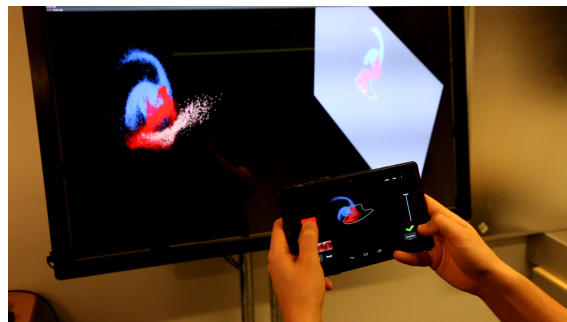

Figure 7. Illustration of Tangible Brush application which combines a spatial-aware multi-touch tablet and a remote large screen which shows different perspectives of the view shared with the tablet.

We discussed spatial selection techniques for three-dimensional datasets. Such 3D spatial selection is fundamental to exploratory data analysis. While 2D selection is efficient for datasets with explicit shapes and structures, it is less efficient for data without such properties.

We first proposed a new taxonomy of 3D selection techniques [12], focusing on the amount of control the user has to define the selection volume. We then described the 3D spatial selection technique Tangible Brush (Figure 7), which gives manual control over the final selection volume. It combines 2D touch with 6-DOF 3D tangible input to allow users to perform 3D selections in volumetric data. We use touch input to draw a 2D lasso, extruding it to a 3D selection volume based on the motion of a tangible, spatially-aware tablet. We described our approach and presented its quantitative and qualitative comparison to state-of-the-art structure-dependent selection. Our results show that, in addition to being dataset-independent, Tangible Brush is more accurate than existing dataset-dependent techniques, thus providing a trade-off between precision and effort.

7.5. Is there a reproducibility crisis around here? Maybe not, but we still need to change

Participants: Alex Holcombe [The University of Sydney], Charles Ludowici [The University of Sydney], Steve Haroz.

Those of us who study large effects may believe ourselves to be unaffected by the reproducibility problems that plague other areas [39]. However, we will argue that initiatives to address the reproducibility crisis, such as preregistration and data sharing, are worth adopting even under optimistic scenarios of high rates of replication success. We searched the text of articles published in the Journal of Vision from January through October of 2018 for URLs (our code is here: https://osf.io/cv6ed/) and examined them for raw data, experiment code, analysis code, and preregistrations. We also reviewed the articles' supplemental material. Of the 165 articles, approximately 12% provide raw data, 4% provide experiment code, and 5% provide analysis code. Only one article contained a preregistration. When feasible, preregistration is important because p-values are not interpretable unless the number of comparisons performed is known, and selective reporting appears to be common across fields. In the absence of preregistration, then, and in the context of the low rates of successful replication found across multiple fields, many claims in vision science are shrouded by uncertain credence. Sharing de-identified data, experiment code, and data analysis code not only increases credibility and ameliorates the negative impact of errors, it also accelerates science. Open practices allow researchers to build on others' work more quickly and with more confidence. Given our results and the broader context of concern by funders, evident in the recent NSF statement that "transparency is a necessary condition when designing scientifically valid research" and "pre-registration..." can help ensure the integrity and transparency of the proposed research", there is much to discuss.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

- Participants: Yuheng Feng, Jean-Daniel Fekete, Alejandro Ribs. Project title: *Visual Sensitivity Analysis for Ensembles of Curves*: The goal of this project is to investigates new progressive methods to compute PCA over large amounts of time-series in interactive time.

9. Partnerships and Cooperations

9.1. National Initiatives

- PCR ANR project EMBER "Situated Visualizations for Personal Analytics". Duration: 48 months. Total funding: 712 k€. Partners: Inria Saclay, Inria Bordeaux, Sorbonne Université. Coordinator: Pierre Dragicevic. See website: http://ember.inria.fr/.

- Naviscope Inria Project Lab on Image-guided NAvigation and VIsualization of large data sets in live cell imaging and microSCOPy; collaboration with several Inria project teams and external collaborators; this grant supports a PhD position and funds travel and equipment.

9.2. European Initiatives

9.2.1. Collaborations in European Programs, Except FP7 & H2020

Program: ANR PRCI

Project acronym: MicroVis

Project title: Micro visualizations for pervasive and mobile data exploration

Duration: 11/2019 - 08/2022

Coordinator: Petra Isenberg

Other partners: University of Stuttgart

Abstract: The goal of this joint Franco-German project is to study very small data visualizations, micro visualizations, in display contexts that can only dedicate minimal rendering space for data representations. We will study human perception of and interaction with micro visualizations given small as well as complex data. The increasing demand for data visualizations on small mobile devices such as fitness tracking armbands, smart watches, or mobile phones drives our research. Given this usage context, we focus on situations in which visualizations are used "on the go," while walking, riding a vehicle, or running. It is still unclear to which extent our knowledge of desktop-sized visualizations transfers to contexts that involve minimal display space, diverse viewing angles, and moving displays.

Program: 2016 FWF–ANR Call for French-Austrian Joint Projects

Project acronym: ILLUSTRARE

Project title: Integrative Visual Abstraction of Molecular Data

Duration: 48 months

Coordinator: Tobias Isenberg and Ivan Viola

Other partners: TU Wien, Austria

Abstract: The essential building block of visualization is the phenomenon of visual abstraction. While visual abstraction is intuitively understood, there is no scientific theory associated with it that would be useful in the visualization synthesis process. Our central aim of this project is thus to gain better understanding of the visual abstraction characteristics. We lay down a hypothetical initial basis of theoretical foundations of visual abstractions in the proposal. We hypothesize that visual abstraction is a multidimensional phenomenon that can be spanned by axes of abstraction. Besides abstractions associated with a static structure we take a closer look at abstractions related to dynamics, procedures, and emergence of the structure. We also study abstraction characteristics related to multi-scale phenomena defined both in space and in time. This hypothetical basis is either supported or rejected by means of exemplary evidence from the specific application domain of structural biology. Structural biology data is very complex, it includes the aspect of emergence and it is defined over multiple scales. Furthermore, abstraction has led to key discoveries in biology, such as the organization of the DNA. We study the multiscale visual abstraction characteristics on the visualization of long nucleic strands and the abstractions that convey emerging phenomena on visualization of molecular machinery use cases. From these two fields we work toward a theory of visual abstraction in a bottom-up manner, investigating the validity of the theory in other application domains as well.

Program: CHIST-ERA

Project acronym: IVAN

Project title: Interactive and Visual Analysis of Networks

Duration: May 2018 - April 2021

Coordinator: Dr. Torsten Möller, Uni Wien, Austria

Other partners: EPFL, Switzerland, Inria France, Uni Wien, Austria

Abstract: The main goal of IVAN is to create a visual analysis system for the exploration of dynamic or time-dependent networks (from small to large scale). Our contributions will be in three principal areas:

1. novel algorithms for network clustering that are based on graph harmonic analysis and level-of-detail methods;

2. the development of novel similarity measures for networks and network clusters for the purpose of comparing multiple network clusterings and the grouping (clustering) of different network clusterings; and

3. a system for user-driven analysis of network clusterings supported by novel visual encodings and interaction techniques suitable for exploring dynamic networks and their clusterings in the presence of uncertainties due to noise and uncontrolled variations of network properties.

Our aim is to make these novel algorithms accessible to a broad range of users and researchers to enable reliable and informed decisions based on the network analysis.

9.2.2. Collaborations with Major European Organizations

The Bauhaus-Universität Weimar (Germany)

Steve Haroz collaborates with Florian Echtler to analyze research transparency in human-computer interaction.

Hasso Plattner Institute (Germany)

Pierre Dragicevic and Tobias Isenberg collaborate with Amir Semmo on stylization filters for facilitating the examination of disturbing visual content.

University of Zurich (Switzerland)

Pierre Dragicevic and Steve Haroz collaborate with Chat Wacharamanotham on transparent statistical reporting and efficient statistical communication.

KU Leuven (Belgium)

Pierre Dragicevic collaborates with Andrew Vande Moere on a survey on data physicalization.

Linköping University (Sweden)

Tobias Isenberg, Xiyao Wang, and Mickael Sereno collaborate with Lonni Besançon on interaction with 3D visualization.

University of Granada (Spain)

Tobias Isenberg collaborates with Domingo Martin and German Arroyo on digital stippling.

University of Roma (Italy), TU Darmstadt (Germany)

Jean-Daniel Fekete Fekete collaborates with Giuseppe Santucci, Carsten Binnig and colleagues on the design of database benchmarks to better support visualization;

University of Bari (Italy)

Jean-Daniel Fekete collaborates with Paolo Buono on hypergraph visualization;

University of Konstanz (Germany)

Petra Isenberg collaborated with Johannes Fuchs and Anastasia Bezerianos on visualization for teaching clustering algorithms.

9.3. International Initiatives

9.3.1. Inria Associate Teams Not Involved in an Inria International Labs

9.3.1.1. SEVEN

Title: Situated and Embedded Visualization for Data Analysis

International Partner (Institution - Laboratory - Researcher):

University of Calgary (Canada) - ILab - Wesley Willett

Start year: 2018

See also: http://aviz.fr/seven

The goal of this joint work between the Aviz team at Inria Saclay and the ILab at the University of Calgary is to develop and study situated data visualizations to address the limitations of traditional platforms of data analytics. In a situated data visualization, the data is directly visualized next to the physical space, object, or person it refers to. Situated data visualizations can surface information in the physical environment and allow viewers to interpret data in-context, monitor changes over time, make decisions, and act on the physical world in response to the insights gained. However, research on this topic remains scarce and limited in scope. We will build on our track record of successfull collaborations to jointly develop situated visualization as a novel research direction. The objective for the first year is to design and implement situated visualizations to support health and aging. Our joint work is expected to generate benefits at multiple levels, including to society and industry (by empowering individuals and professionals with technology), to the scientific community (by developing a new research direction), to the academic partners (by reinforcing existing research links and establishing them as leaders on the topic), and to students (by providing them with unique training opportunities with a diverse team of world-class researchers).

9.3.2. Inria International Partners

9.3.2.1. Informal International Partners

Microsoft Research: Petra Isenberg, Tobias Isenberg, and Tanja Blascheck regularly collaborate with Bong-shin Lee on topics related to non-desktop visualizations such as mobile visualization, ubiquitous visualization, or touch interaction for visualization.

University of Maryland: Catherine Plaisant regularly collaborates with various team members on projects related to temporal exploratory visualization.

9.3.3. Participation in Other International Programs

9.3.3.1. Inria International Chairs

IIC PLAISANT Catherine

Title: Visual Analytics for Exploratory Data Analysis

International Partner (Institution - Laboratory - Researcher):

University of Maryland (United States) - HCIL - Catherine Plaisant

Duration: 2018 - 2022

Start year: 2018

Visual Analytics for Exploratory Data Analysis: The project leverages Dr. Plaisants 30 years of experience in the design and evaluation of novel user interface and the longstanding synergies between my research activities and those of the AVIZ lab. It also builds on early collaborative activities having taken place between Maryland and Inria during a 2017 summer visit. The joint work particularly focuses on: event analysis, network analysis, and novel evaluation methods for visual analytics.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

- Catherine Plaisant (June–July): Invited professor from the University of Maryland, USA. Invited through a DigiCosme grant, Catherine Plaisant has spent two months with Aviz. We have launched two research projects, one on hypergraph visualization and one on tracing users to understand their use of visualization. Catherine Plaisant has interacted with all of the Aviz students and post-doctoral fellows, as well as with the permanent researchers.

- Paolo Buono, from the University of Bari, Italy (August–September): Paolo Buono has spent two months with Aviz working on the visualization of dynamic networks. He has collaborated with Paoa Valdivia, Catherine Plaisant, and Jean-Daniel Fekete for that project. He has also interacted with all the members of Aviz.

- Claudio Silva (August 2018 – June 2019): Sabbatical from New York University (USA). Also, invited professor through a DigiCosme grant for 3 months. Claudio Silva is spending one year with Aviz. We launched a bi-weekly seminar on explainable machine-learning with visualization.

- Wesley Willett and Lora Oehlberg (June): as part of the associated team SEVEN both professors came for a three-day workshop to Aviz during which we discussed designs for the noise project sensors and the associated data displays. We also worked in more depth on a survey article we plan to publish.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events: Organisation

10.1.1.1. General Chair, Scientific Chair

- Steve Haroz is a co-founder and co-organizer of Transparent Statistics in Human-Computer Interaction.

- Steve Haroz co-organized the Visualization for Communication 2019 workshop (http://viscomm.io).

- Petra Isenberg co-organized a Dagstuhl seminar on Mobile Data Visualization (https://www.dagstuhl.de/19292).

- Petra Isenberg co-organized a tutorial at the Ubicomp conference about Visualization for Ubicomp.

- Jean-Daniel Fekete co-organized a Shonan seminar on Interactive Visualization for Interpretable Machine Learning (https://shonan.nii.ac.jp/seminars/161/).

10.1.1.2. Member of the Organizing Committees

- Steve Haroz was Open Practices chair of the IEEE Information Visualization conference (until July 2019).

- Jean-Daniel Fekete was a member of the VGTC Best Thesis Award 2019.

- Tanja Blascheck was Video and Demo co-chair for ETRA 2019.

- Tanja Blascheck was Publicity chair for VISSOFT 2019.

- Petra Isenberg is a member of the IEEE reVISe committee 2019–2020.

- Petra Isenberg is the ACM SigCHI Paris Treasurer (2017–2019)

- Jean-Daniel Fekete was associate editor-in-chief of TVCG, liaison with the IEEE VIS paper chairs.

10.1.2. Scientific Events: Selection

10.1.2.1. Chair of Conference Program Committees

- Petra Isenberg was paper chair for IEEE Information Visualization

10.1.2.2. Member of the Conference Program Committees

- Jean-Daniel Fekete was a member of the program committee for VIS.
- Petra Isenberg was a member of the ACM CHI program committee.
- Tobias Isenberg was a member of the program committee for IEEE SciVis, IVAPP, ACM/Eurographics Expressive, TrustVis Workshop, EuroVis, ACM IUI, IEEE VR.
- Pierre Dragicevic was a member of the program committee for InfoVis.
- Paola Valdivia was a member of the program committee for Short Papers of VIS.
- Tanja Blascheck was a member of the program committee for VMV, LEVIA, VISSOFT, EuroVis Posters, EuroVis Short Papers, ETRA, ETVIS, VAST.

10.1.2.3. Reviewer

- Steve Haroz reviewed for CHI, VIS
- Jean-Daniel Fekete reviewed for CHI
- Tobias Isenberg reviewed for EuroVis, ACM/Eurographics Expressive, ACM IUI, ACM SIG-GRAPH, IEEE PacificVis, TrustVis, ACM UIST, IEEE VIS, IEEE VR
- Pierre Dragicevic reviewed for CHI, VIS, Interact, IHM
- Tanja Blascheck reviewed for LEVIA, VMV, VISSOFT, VAST, EuroVis, PacificVis, ETRA, ETVIS, CHI, EuroVA, PacificVAST, VAST Challenge, Vision X Vis, Vis Short Papers
- Paola Valdivia reviewed for Short Papers of VIS 2019
- Xiyao Wang reviewed for CHI, VR, ICMI, MobileHCI, Vis
- Petra Isenberg reviewed for CHI, EuroVis

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

- Pierre Dragicevic is member of the editorial board of the Journal of Perceptual Imaging (JPI) and the Springer Human–Computer Interaction Series (HCIS).
- Jean-Daniel Fekete is associate editor-in-chief of IEEE Transactions on Visualization and Computer Graphics.
- Petra Isenberg is associate editor of IEEE Transactions on Visualization and Computer Graphics.
- Petra Isenberg is associate editor-in-chief at IEEE Computer Graphics & Applications.
- Tobias Isenberg is member of the editorial board of Elsevier's Computers & Graphics journal.

10.1.3.2. Reviewer - Reviewing Activities

- Steve Haroz reviewed for Cognition, Advances in Methods and Practices in Psychological Science, and Meta-Psychology
- Jean-Daniel Fekete reviewed for TVCG
- Tobias Isenberg reviewed for C&G, TIIS, TVCG
- Pierre Dragicevic reviewed for TVCG, CG&A, IV, Behavior & Information Technology, JPI
- Tanja Blascheck reviewed for IWC, TOCCHI, TVCG
- Petra Isenberg reviewed for TVCG

10.1.4. Invited Talks

- Steve Haroz: "How the Brain Perceives and Remembers Quantities". Graphics Hunters Show Conference - Utrecht, The Netherlands.
- Steve Haroz: "How the Brain Perceives and Remembers Quantities". Ecole Normal Superior. Paris, France.

- Steve Haroz: "How the Brain Perceives and Remembers Quantities". Keynote at VisCrowd 2019. Clermont-Ferrand, France.

- Steve Haroz: "How the Brain Perceives and Remembers Quantities". Datarama 2019. Nantes, France.

- Steve Haroz: "Set Comparison Is Imprecise and Prone to Bias". VisXVision workshop at IEEE VIS 2019. Vancouver, Canada.

- Steve Haroz: "Transparency in Empirical Research". Panel talk at IEEE VIS 2019. Vancouver, Canada.

- Steve Haroz: "Using Open Science to Improve Credibility in Visualization, HCI, and Vision Science Research". SFB/TRR 161. Waldachtal, Germany.

- Jean-Daniel Fekete: "Practical Use Cases for Progressive Visual Analytics", Seminar at Shandong University, Qingdao, China, Nov. 26, 2019

- Jean-Daniel Fekete: "Dynamic Social Networks and Progressive Data Analysis", Seminar at Ochanomizu University, Tokyo, Japan, Nov. 22, 2019

- Jean-Daniel Fekete: "Advances in Network Visualization", Keynote at MARAMI 2019, Dijon, France, Nov. 8, 2019

- Jean-Daniel Fekete: "Multidimensional Projection at Scale on the Web: Tips and Tricks", Keynote of the HILDA 2019 Workshop, Amsterdam, The Netherlands, July 5th, 2019.

- Jean-Daniel Fekete: "Exploration visuelle d'hypergraphes dynamiques", Seminar at INED, Paris, France, June 18th, 2019.

- Jean-Daniel Fekete: "Données, humanité(s), démarche scientifique", Panel at Inria Scientific Days 2019, Lyon, France, June 6th, 2019.

- Jean-Daniel Fekete: "Analyzing the Evolution of Relationships with Dynamic Hypergraphs", Invited Talk, University of Delft, Delft, The Netherlands, Apr. 8th, 2019

- Jean-Daniel Fekete: "Analyzing the Evolution of Relationships with Dynamic Hypergraphs", Invited Talk, EHESS, Paris, France, Apr. 3, 2019

- Jean-Daniel Fekete: "Multidimensional Projection at Scale on the Web: Tips and Tricks", Invited Talk, VISUS Group, Univ. of Stuttgart, Stuttgart, Germany, Mar. 1, 2019

- Tobias Isenberg: "Interactive 3D Data Exploration", TU Dresden, Germany, Dec, 6, 2019

- Tobias Isenberg and Xiyao Wang: "VR and AR Visualizations in High-Energy Physics", Learning to Discover: Advanced Pattern Recognition Workshop, Institut Pascal, Orsay, France, Oct. 18, 2019

- Tobias Isenberg: "Carnivorous Plants and How to Visualize their Habitats based on Social Media Data", VieVisDays, TU Wien, Austria, Aug. 20, 2019

- Tobias Isenberg and Xiyao Wang: "Understanding TrackML Results with a Visualization System using a PC + HoloLens Hybrid", TrackML workshop at CERN, Geneva, Switzerland, Jul. 1, 2019

- Tobias Isenberg: "Illustrative Visualization and Interactive Exploration of Three-Dimensional Scientific Data", Synchrotron SOLEIL, France, May. 20, 2019

- Tobias Isenberg: "Illustrative Visualization and Interactive Exploration of Three-Dimensional Scientific Data", Shandong University, Qingdao, China, Feb. 24, 2019

- Tanja Blascheck: "Understanding Interactive Visualizations", Inria Sophia-Antipolis, Nice, France, January 2019.

- Petra Isenberg: "Top Research Questions for Empirical Studies in Visualization", Panel statement given at IEEE VIS 2019, Vancouver, Canada.

- Petra Isenberg: "Physical, Contextual, and Full of Value? What do novel directions in Visualization teach us about judging the value of visualization?", GiCentre Seminar Talk, City, University of London, UK

- Petra Isenberg: "Physical, Contextual, and Full of Value? What do novel directions in Visualization teach us about judging the value of visualization?", Keynote at BioVis 2019 at the ISMB conference in Basel, Switzerland

10.1.5. Leadership within the Scientific Community

- Jean-Daniel Fekete was the chair of the EuroVis 2019 Best PhD Award.
- Petra Isenberg and Tobias Isenberg are members of the International Beliv workshop steering committee.
- Tobias Isenberg is a member of the steering comittee for ACM/Eurographics Expressive Graphics.

10.1.6. Research Administration

- Petra Isenberg was vice-president of the Inria Saclay CR hiring committee
- Pierre Dragicevic is Member of the Commission Consultative de Spécialistes de l'Université Paris-Sud (CCSU).
- Pierre Dragicevic is co-chair of the DataSense Axis of the Labex DigiCosme.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Master : Petra Isenberg, Interactive Information Visualization, 21h en equivalént, niveau (M1, M2), Univeristé Paris Sud, France.

Master : Petra Isenberg, Graphisme et Visualisation, 24h en equivalént TD, niveau (M2), Polytech Paris-Sud, France.

Master : Petra Isenberg, Visual Analytics, 48 equivalént, niveau (M2), CentraleSupelec, France.

Licence : Tobias Isenberg, "Introduction to Computer Graphics", 12h en équivalent TD, L3, Polytech Paris-Sud, France.

Master : Tobias Isenberg, "Photorealistic Rendering/Advanced Computer Graphics", 21h en équivalent TD, M1, Polytech Paris-Sud and Université Paris-Saclay, France.

10.2.2. Supervision

PhD in progress: Alexis Pister, *Exploration, analyse, interprétabilité de larges réseaux historiques*, Université Paris-Saclay, defense planned for 2022, Jean-Daniel Fekete, Christophe Prieur, Inria.

PhD in progress: Yuheng Feng, *Visualisation pour l'analyse progressive"*, Université Paris-Saclay, defense planned for 2022, Jean-Daniel Fekete, Université Paris-Saclay

PhD in progress: Mickaël Sereno, *Collaborative Data Exploration and Discussion Supported by AR*, Univ. Paris-Sud, defense planned for September 2021, Tobias Isenberg

PhD in progress: Xiyao Wang, *Augmented Reality Environments for the Interactive Exploration of 3D Data*, Univ. Paris-Sud, defense planned for October 2020, Tobias Isenberg

PhD in progress: Sarkis Halladjian, *Spatially Integrated Abstraction of Genetic Molecules*, Univ. Paris-Sud; defense planned for September 2020, Tobias Isenberg

PhD: Haichao Miao, *Geometric Abstraction for Effective Visualization and Modeling*, TU Wien, Austria, August 5, 2019, supervised by Ivan Viola, co-supervised by Ivan Barišic, Tobias Isenberg, and Eduard Gröller.

PhD in progress: Mohamad Alaul Islam: *MicroVisualization for mobile and ubiquitous data exploration*, Université Paris-Saclay, defense planned for 2022, Petra Isenberg and Jean-Daniel Fekete.

PhD in progress: Natkamon Tovanich: *Blockchain Visual Analytics*, defense planned for 2021, Université Paris-Saclay, Petra Isenberg and Jean-Daniel Fekete.

10.2.3. Juries

- Pierre Dragicevic: PhD proposal evaluation committee of Luiz Morais (Universidade Federal de Campina Grande, Brésil).
- Pierre Dragicevic: Reviewer for Hu Xi's M2 internship.
- Pierre Dragicevic: Co-Supervisor for Yumin Hong's M2 internship.
- Pierre Dragicevic: Reviewer for Talent Doctoral Fellowship Programme at the University of Copenhagen.
- Pierre Dragicevic: Reviewer for ATER 2019 applications at the Université Paris Saclay.
- Petra Isenberg: Reviewer for GRIOUI Fairouz M2 internship.
- Jean-Daniel Fekete: Member of the PhD committee of Dr. Philip Tchernavskij
- Jean-Daniel Fekete: Member of the PhD committee of Dr. Hugo Romat.
- Jean-Daniel Fekete: Member of the PhD committee of Dr. Sriram Karthik Badam.
- Jean-Daniel Fekete: Member of the PhD committee of Dr. Nicola Pezzotti.

10.3. Popularization

10.3.1. Articles and contents

- Steve Haroz's twitter account on a broad range of topics including open science, visualization, and visual perception have been viewed over 1.1 million times and received over 30,000 engagements in the form of clicks, likes, and retweets in 2019.
- Steve Haroz maintains a website cataloging openly accessible papers and research materials in visualization research. Open Access Vis has averaged 2,000 unique visitors per year for the past three years.
- Steve Haroz maintains a research website receiving 5,000 unique visitors and a blog on research receiving 2,000 unique visitors in 2019.
- Pierre Dragicevic and Yvonne Jansen: the data physicalization wiki and the List of Physical Visualizations and Related Artefacts (600 weekly visits) are continuously being updated.
- Matthew Brehmer wrote a Medium article "Visualizing Trends on Mobile Phones: Animation or Small Multiples?" on an Aviz co-authored publication https://medium.com/multiple-views-visualization-research-explained/mobiletrendvis-a948fa65bccd

10.3.2. Interventions

- Lonni Besançon gave a TEDx talk on work conducted at Aviz with Pierre Dragicevic and Tobias Isenberg [11]. Watch the talk here: https://www.youtube.com/watch?v=pDHomZ8FEoU.
- Jean-Daniel Fekete: Panel at Imaginascience 2019, « Faire parler les données : le défi de la data visualisation », Annecy, October 16, 2019

10.3.3. Creation of media or tools for science outreach

Petra Isenberg collaborated on research to develop a visualization tool to better understand clustering algorithms. The tool is available at https://educlust.dbvis.de/.

11. Bibliography

Major publications by the team in recent years

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Publications of the year

Articles in International Peer-Reviewed Journals

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