

RESEARCH CENTRE

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ACTIVITY REPORT

Project-Team

AVIZ

Analysis and VisualiZation

IN COLLABORATION WITH: Laboratoire Interdisciplinaire des Sciences du
Numérique

DOMAIN

Perception, Cognition and Interaction

THEME

Interaction and visualization

Inria

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Project-Team AVIZ

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- A3.3. – Data and knowledge analysis
 - A3.3.1. – On-line analytical processing
 - A3.3.3. – Big data analysis
 - A3.5.1. – Analysis of large graphs
- A5.1. – Human-Computer Interaction
 - A5.1.1. – Engineering of interactive systems
 - A5.1.2. – Evaluation of interactive systems
 - A5.1.6. – Tangible interfaces
 - A5.1.8. – 3D User Interfaces
 - A5.1.9. – User and perceptual studies
- A5.2. – Data visualization
 - A5.6.1. – Virtual reality
 - A5.6.2. – Augmented reality
- A6.3.3. – Data processing
- A9.6. – Decision support

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- B1. – Life sciences
 - B1.1. – Biology
 - B1.2. – Neuroscience and cognitive science
- B9.5.6. – Data science
- B9.6. – Humanities
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 - B9.6.3. – Economy, Finance
 - B9.6.6. – Archeology, History
 - B9.6.10. – Digital humanities

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2 Overall objectives

2.1 Objectives

Aviz (Analysis and VisualiZation) is a multidisciplinary project that seeks to improve data exploration methods, techniques, and tools based on Interactive Visualization. Visualization, in general, refers to the graphical representation of data or concepts to aid access, distribution or explanations of data. Card et al. give a general definition for visualization as

“the use of computer-supported, interactive, visual representations of data to amplify cognition.” [54]

Taking this definition, visualization is a means of creating visual aids that lead to insight in the underlying data sets. It is not about producing nice pictures but about making data understandable and explorable so that visualizations help viewers gain knowledge about the data. It is about aiding the process of forming a mental model for the acquired data and so helping the viewer to understand underlying concepts, patterns, and connections within the data [78]. In particular, visualization has the goal to improve humans' sensemaking of complex data by taking advantage of the capabilities of their vision system: visual information can be processed in parallel and with a high bandwidth into the human cognitive centers [85]. Ware defines five advantages of visualization [85]:

1. **Comprehension:** Supports the comprehension of large amounts of data.
2. **Pattern Perception:** Previously unnoticed properties of data may emerge.
3. **Problem Analysis:** Problems within the data may become immediately apparent.
4. **Adaptability:** facilitates understanding of large- and small-scale features of data.
5. **Interpretation:** Hypothesis formulation is facilitated.

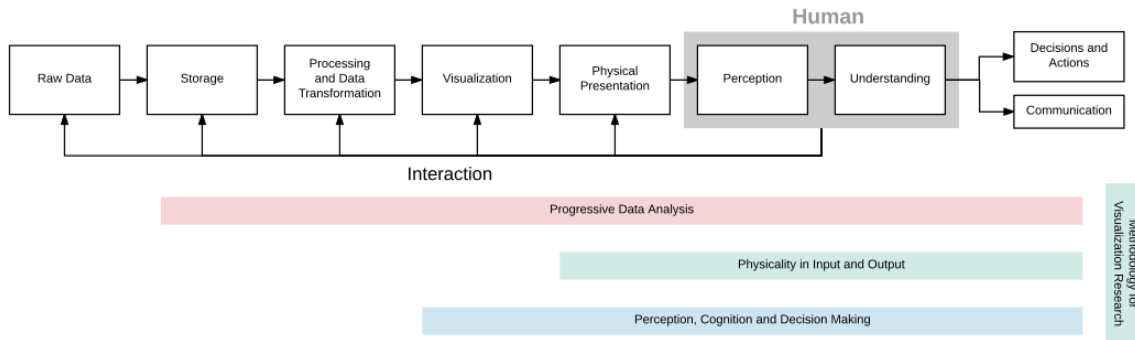


Figure 1: The conceptual Data Analysis Pipeline related to four of the themes of AVIZ.

Three main areas of visualization have evolved in the computer science community: *Scientific Visualization*, *Information Visualization*, and *Visual Analytics*. Scientific visualization is primarily concerned with displaying real or simulated scientific data. Basic visualization techniques for this area include surface rendering, volume rendering, and animation. Typical examples include processing of satellite photographs, fluid flows, or medical data. Datasets in information visualization typically come from large information spaces or information systems and are both structured or unstructured. Examples include network data, multi-dimensional tables of abstract measurements, or unstructured data such as text. Visual analytics, finally, is concerned with augmenting human-led data exploration with automatic techniques such as machine learning. The Aviz team has expertise in all three areas of visualization.

As shown in Figure 1, visualization deals with the data analysis pipeline and research in visualization has been addressing all the stages with less emphasis on the two initial ones and the last one. In its initial incarnation, Aviz has been focusing on *interaction* in combination with visualization, physical presentation, and perception. We now want to expand our research to wider questions, both in the human-side and in the system side. For the human side, we want to better understand human perception and cognition to improve the visualization techniques, so as to better convey information to the human brain. We also want to better understand the human biases to overcome them when possible, or provide methods to avoid them otherwise.

On the system side, we want to expand the scope of visualization that is currently limited to relatively small datasets and relatively simple analytical methods. To achieve *scalability* in visualization, we will focus on a paradigm shift: *progressive data analysis*. Long-running computations currently hamper the exploration and visualization process because human's attention is limited by latency constraints. We want to design exploratory systems that provide continuous feedback and allow interactions at any time during computation. The new progressive data analysis paradigm offers these capabilities, but to be usable, it requires the whole analytical pipeline to be re-implemented, and visualization and interaction techniques to be adapted.

2.2 Research Themes

Aviz's research on Visualization and Visual Analytics is organized around five research themes, described in more detail in the next section. Instead of addressing point problems, each research theme will address several stages of the visualization pipeline in a holistic manner, as summarized in Figure 1.

1. Progressive Data Analysis and Scalability will address visualization scalability problems. Existing data analysis systems (such as Tableau [79], R [74], or Python with its data analysis ecosystem [64]) are not scalable for exploratory analysis because their latency is not controllable. This theme will lay out the foundations of progressive data analysis systems, which generate estimates of the results and updates the analyst continuously at a bounded pace. It will focus on all the stages of the data analysis pipeline: data management mechanisms, data analysis modules, as well as visualizations, perception, understanding, and decision making [2].

2. Physicality in Input and Output will seek to better understand the benefits of physicality for information. Although beyond-desktop environments for visualization are generating more and more

interest, theories and empirical data are lacking. This theme will consolidate the nascent areas of data physicalization, situated visualization, and immersive visualization.

3. Perception, Cognition, and Decision Making will study how we perceive and understand visualizations in order to develop generalized guidelines for optimizing effectiveness. It will generalize results obtained with simple charts to more complex visualizations of large datasets, establish theories on the use of abstraction in visualization, and contribute new empirical knowledge on decision making with visualizations.

4. Methodologies for Visualization Research will develop new methods to ground the study of the above scientific questions, and to benefit visualization more generally. This theme will develop evidence-based strategies for communicating quantitative empirical findings, and will promote methodological discussions and open research practices within the field.

5. Visualization Techniques. This research direction is more general than the ones above. We study several dedicated visualization approaches that intersect with our major goals above but address more generic issues related to creative visualizations and interactions in general.

3 Research program

3.1 Research Axis 1: Progressive Data Analysis and Scalability

Permanent involved: Jean-Daniel Fekete

Scalability is a major issue in visualization, although the problem has never been well defined until recently [5] and has received less attention in visualization than in other data-science related domains.

While data analysis has made tremendous progress in scalability in the last decade, this progress has only benefited “confirmatory” analysis or model-based computation; progress in data exploration has lagged behind. Existing data analysis systems do not support data exploration at scale because, for large amounts of data or for expensive computations, their latency is not controllable: computations can take minutes, hours, even days and months. Cognitive psychologists have shown that humans’ cognitive capabilities degrade when latency increases [71, 77]. Miller [71] points out that the feedback of a system should remain below 10 seconds to maintain the user’s attention. Therefore, to try to limit the latency, analysts currently resort to complex, inefficient, and unsatisfactory strategies, such as sampling with its issues related to representativity.

To address the scalability problem under controlled latency, instead of performing each computation in one long step that forces the analyst to wait for an unbounded amount of time, a progressive system generates estimates of the results and updates the analyst continuously at a bounded pace. The process continues until the computation is complete, or it stops early if the analyst considers that the quality of the estimates is sufficient to make a decision. During the process, a progressive system allows users to *monitor* the computation with visualizations and *steer* it with interactions.

While the topic of progressive data analysis has started to emerge in the late 90’s, it has remained marginal practically because it touches three fields of computer science that are traditionally separate: data management, data analysis, and visualization. Research on progressive data analysis remains fragmented; the solutions proposed are partial and the different solutions cannot always be combined. We have organized a Dagstuhl seminar on Progressive Data Analysis and Visualization [55, 80] that acknowledged the harm of this topical separation and devised a research agenda. Aviz will participate in this agenda with specific assets and published a book about the topic [2].

Aviz is actively working on designing and implementing the ProgressiVis language that is natively progressive [56]. The language relies on a Python interpreter but its execution semantics is different in the sense that all the operations that would take time to execute are performed progressively. The ProgressiVis system touches all the stages of the conceptual data analysis pipeline of Figure 1; it integrates data management mechanisms, data analysis modules, as well as visualizations, perception, understanding, and decision making. Aviz will strengthen its work on the implementation of a natively progressive data science system. Such a system will lead to the following research topics:

1. Progressive language kernel and data management mechanisms
2. Progressive algorithms and computation strategies

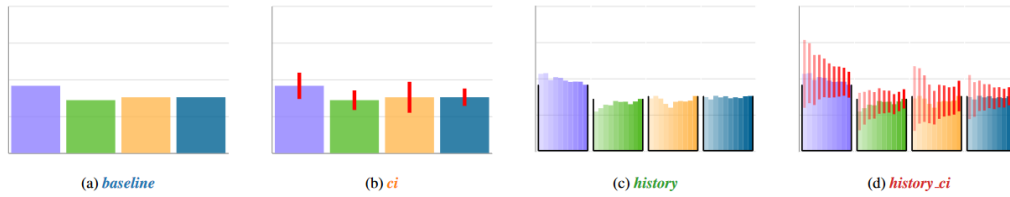


Figure 2: Examples of progressive bar charts we studied. All the bar charts represent the same data at one step of the progression. For our proposed new designs (c) and (d), opacity and position along the X-axis encode the recency of the updates; opaque bars on the right represent more recent updates, and transparent bars on the left represent older updates.

3. Progressive visualizations

4. Management of uncertainties, computed from the algorithms and conveyed to the analysts.

Language: ProgressiVis relies on a Python interpreter that is convenient for quick prototyping. We are using many internal mechanisms of the Python language to create a toolkit that allows programming progressive applications in a convenient way.

Algorithms: Existing libraries implementing algorithms are either “eager”, sometimes “online”, and more rarely “streaming”, but very few are compatible with our progressive paradigm. We already designed several progressive algorithms and want to further expand the range of algorithms we can support, and better understand how algorithms could be transformed into their progressive counterpart.

Progressive computation can trade speed, memory, and quality. When analysts want to compute rough estimates of their results quickly, several progressive algorithms offer parameters to control the tradeoffs. For example, our progressive k-nearest-neighbors algorithm [62] allows choosing the number of k-d-trees that influences the memory footprint, accuracy, and speed. Progressive data analysis also uses and adapts streaming algorithms, also called “data sketches” [57], that offer various tradeoffs between speed, memory, and quality.

Visualizations: Like algorithms need to be adapted or transformed, visualization techniques and user interfaces also need to be adapted to be used in a progressive setting.

For the visualization pipeline, including the rendering phase, there has been previous work related to progressive layout computation and progressive rendering. For example, in network visualization, there is an old tradition of using iterative force-directed solvers and showing their results progressively when computing complex graph layouts. We generalize this approach to all the visualizations. Progressive rendering is popular in the real-time computer graphics and gaming domains, but new in visualization. We are designing visualization techniques based on GPU and accelerated algorithms to better render aggregated visualizations, such as heatmaps and sampled visualizations.

We have also started to explore the problem of requirements for progressive user interfaces [51], leading the community of researchers to understand that progressive systems need to provide effective assessments of the quality of their results to allow analysts to make early decisions. This justifies the next research topic on the management of uncertainties. We have also started to propose new data models for managing aggregated visualizations [63]. We now continue our research to adapt existing visualization techniques and interactive environments to deal with progressive results and parameter steering.

Management of uncertainties: When performing exploratory data analysis on large data, analysts start by trying some algorithms with different parameters until they obtain useful results. Therefore, it is of paramount importance to be able to realize that a specific algorithm or a specific set of parameters is not leading to a useful result and to abort an analysis before it ends to explore other methods. On the other side, in many circumstances when data is “well-behaved”, progressive algorithms achieve very good results quickly, and analysts can make a decision before the end of the algorithms’ execution. The

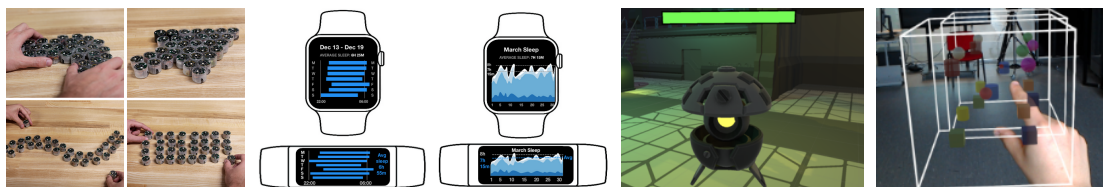


Figure 3: Example results from our work on Axis 2 for each of our focus areas.

assessment of a quality measure related to a computed result is a complex problem, already tackled by other communities (e.g., streaming, approximate queries).

Progressive Data Analysis adds two problems: (1) controlling uncertainty during progressive computations, and (2) conveying the results of this uncertainty in a way understandable by analysts, while avoiding possible cognitive biases such as priming and anchoring [65].

To control the uncertainty during the progression of a computation, methods related to Sequential Analysis [59] should be used. They are well-known in the area of clinical trials and have evolved recently to manage large amounts of data while controlling time or quality in Approximate Query Databases such as BlinkDB [50].

We have already shown that humans are quite good at deciding when to stop a progressive process to make an early decision using progressive bar charts [72] (Figure 2); humans are cognitively equipped to make sense of progressive processes. Additionally, visualization can help humans make sense of and interact with progressive processes, such as our new-history bar chart designs that help to render visually when a progressive process starts to converge, opening a new line of research to discover the possible forms of support.

3.2 Research Axis 2: Physicality in Input and Output

Permanents involved: Petra Isenberg, Tobias Isenberg, Jean-Daniel Fekete

During the last five years, we expanded our work on beyond-desktop environments for visualization. Our team has made contributions in the areas of data physicalization, visualization for wearable devices, situated and embedded visualization, and visualization in augmented reality.

Data Physicalization: Data physicalization is a rich and vast research area that studies the use of physical artifacts to convey data. It overlaps with a number of research areas including information/scientific visualization, visual analytics, tangible user interfaces, shape-changing interfaces, fabrication, as well as graphic design, architecture, and art. Physical data visualizations tap into our lifelong experience of perceiving and manipulating the physical world, either alone or with other people. Among the earliest man-made artifacts are physical representations of semantic concepts that provide physical metaphors that allow us to reason, remember, and communicate. With the advent of computers, we have substituted physical representations with pixels on a computer screen. The resurgence of physicalization as a research area, following our early definitions [61], asks what we have lost in this transformation. Certainly, a computer-based visualization allows us to zoom an image, transform variables in real time, and to zoom through virtual computer-based world. However, these representations can sever the relationship to the natural world, depriving us of the touch, feel, and emotion that comes from interacting with real objects. We studied several aspects of data physicalization including technical challenges of constructing physicalizations, potential benefits, and how historical examples could transfer to a modern world.

Visualization for Wearable and Mobile Devices: In the area of wearable and mobile-devices we engaged in device-driven research where we considered how small device form factors may influence how we need to design visualizations and how we can use them. Portable and wearable personal devices such as fitness tracking armbands, hand-held GPS trackers, smart watches, or mobile phones are very small displays that are capable of producing data themselves (through sensors), downloading it from other sources (through Wifi or Bluetooth), and displaying it immediately [67]. Often the data is shown in the form of visualizations that have to be adapted to the small display size. We consider very small visualizations that are often used on such devices under the term “micro visualization” and have been working towards a better understanding of the complexities involved in designing and using

micro visualizations but also studied the influence of the unique context of use of mobile devices on visualization use and design.

Situated and Embedded Data Representations: We study how embedding data visualizations in the context of the data sources can empower people to make effective use of their data in a variety of application contexts. Our goal in this work is to go beyond the traditional platforms of data analytics by using *situated data visualizations* on various types of non-traditional displays. In a situated data visualization, the data is directly visualized near the physical space, object, or person it originates from [86]. For example, a person may attach small e-ink displays embedded with sensors at various locations of their house or their workplace, to better understand their use of space, of equipment, or of energy resources. Or a person who wishes to exercise more may use an augmented reality device to visualize their past running performance in-place. New situated data visualizations like these can surface information in the environment—allowing viewers to interpret data in-context and take action in response to it [87].

Visualization using Augmented Reality Devices: Many datasets are 3D-spatial in nature and researchers and practitioners could benefit from seeing them in true 3D space. This is where immersive technologies shine, and the recent advances in VR and AR headset technologies have made such displays accessible to the general public—the lack of large dedicated VR installations such as a CAVE is not preventing the use of immersive rendering anymore. Nonetheless, the investigation of 3D datasets also frequently requires researchers to use tools such as scripted analysis and statistical evaluation, and such direction of investigation will continue to be a cornerstone of scientific work. In our investigations we are thus interested in looking at, in particular, hybrid setups that allow researchers to use the best of both worlds: traditional workstations combined with an AR overlay for stereoscopic rendering of 3D data [84].

3.3 Research Axis 3: Perception, Cognition and Decision-Making

Permanents involved: Petra Isenberg, Tobias Isenberg, Jean-Daniel Fekete, Florent Cabric

As we collect increasingly large amounts of data in fields such as climate science, finance, and medicine, the need to understand and communicate that data becomes more important. Data visualizations are often used to give an overview of information, however it can be challenging to predict whether these visualizations will be effective before spending resources to develop them. Consequently, researchers make use of experimental methods from visual perception and cognition to study how we perceive and understand visualizations in order to develop generalized guidelines for optimizing effectiveness. On this research axis we have three focus areas:

Perception of Visualizations in Novel Contexts. Novel technology and usage contexts have several characteristics for data visualizations that warrant a (re-)evaluation of how well people can perceive visualizations. Characteristics we were particularly interested in include:

- *Physical factors:* Many now common displays have characteristics that warrant (re-)evaluation of what we know about visualizations to be displayed on them. Small form factors of displays such as smartwatches and fitness bands are an obvious characteristic. Some screens deviate from the standard rectangular form we are familiar with and use a circular geometry, which is another interesting design constraint for visualization.
- *Data display mobility:* Data display mobility captures the movement of the display(s) containing visual representations of data. Fixed, movable, carryable, wearable, and independently moving displays can be differentiated along this dimension. We conducted some of our research on carryable devices, including mobile devices such as smartphones and tablets but also wearable displays such as smartwatches and head-mounted displays.
- *Context-of-use:* Many novel displays are used in contexts that are much unlike traditional office settings. Visualizations here may be subjected to different lighting conditions and viewers may only afford very quick glances at the displays themselves. For example, when in a car the driver can only afford very quick glances at the GPS before returning to the primary task of arriving safely.

Within this focus area we worked on some of these aspects; such as the need for quick glances, the display size of visualizations, the movement of viewers or the data, and the understanding of 3D augmented reality

spaces. We relied mostly on mixed-methods user studies where a quantitative analysis methodology was coupled with interviews or questionnaires.

Illustrative Visualization. This focus area takes inspiration from illustrators' decades to centuries of experience on perception and cognition to better portray scientific subject matter. Another input arises from the field of non-photorealistic rendering which has developed numerous techniques of stylizing images and other input data. Traditionally, illustrative visualization has thus been applied primarily to data with a concrete spatial mapping in 2D and, more frequently, in 3D space.

Another main direction of research in this context is what the role of abstraction is in illustrative visualization [83, 82] as well as visualization in general, and specifically how we can provide dedicated means to control the abstraction being applied to visual representations of data. This means that we need to go beyond seeing abstraction only as a side-product of stylization as it has traditionally been viewed in many approaches in non-photorealistic rendering as well as illustrative visualization to date, and investigate how we can interactively adjust it to provide practitioners with a means to find the best visual representations for a given task. For example, we have investigated this question in the context of structural biology [89] and DNA nanostructures [68, 70, 69], but also want to expand this work to other application domains in the future.

Decision-Making with Visualizations. Human decision-making and cognitive biases are important research topics in the fields of psychology, economics and marketing. Visualization systems are increasingly used to support decision-making: large companies switch to visualization solutions to improve their decisions in a range of areas, where large sums of money or human lives are at stake. More and more, the ultimate goal of visualization is not to understand patterns in the data and get insights as was traditionally assumed, but to make good decisions. In order to fully understand how information visualizations can support decision-making, it is important to go beyond traditional evaluations based on data understanding, and study how visualizations interact with human judgment, human heuristics, and cognitive biases.

We pursue this important stream of research by investigating decision-making in the presence of uncertainty and incomplete information (in connection with the topics discussed in [subsection 3.1](#) and the use of visualizations to support social choice and group decisions in the presence of conflicts of interest. How cognitive biases interact with visual perception is also an important and difficult question that has remained largely unexplored.

3.4 Research Axis 4: Methodology for Visualization Research

Permanents involved: Petra Isenberg, Tobias Isenberg, Jean-Daniel Fekete

An important aspect of any scientific research is to establish and follow rigorous and effective methodologies for acquiring new knowledge. In the field of Visualization in particular, scientific discourse on the validity, use, and establishment of methodologies is important as the field is highly interdisciplinary, with diverse influences and opinions. It is important to establish, for example, what level of rigor the field should require of its methods, how to choose among established methods and methodologies, and how to best communicate the results of our empirical research. We focus our efforts on three main topics related to visualization research methodologies.

Promoting and Following Open Research Practices

For issues with open research practices to be addressed, educational materials and guidelines need to be written, so researchers have clarity about how to make their research more credible. Aviz members are working with the organizing bodies of the visualization research community to establish incentives for making research artifacts and potentially establish minimal requirements for openness in published articles. Meanwhile, it is important to continue measuring and cataloging openness in the field to monitor progress. The goal is to improve the credibility and applicability of the field's research.

Shaping the Scientific Visualization Community Aviz researchers are heavily involved in the organization structure of IEEE visualization conferences, the most prestigious conference in our field, by proposing workshops, tutorials, serving on various organizing committees, steering committees, editorial boards. We, in particular, aid the process by providing data collection and analysis services through the vispubdata.org dataset that we are collecting, cleaning, and making available to the community.

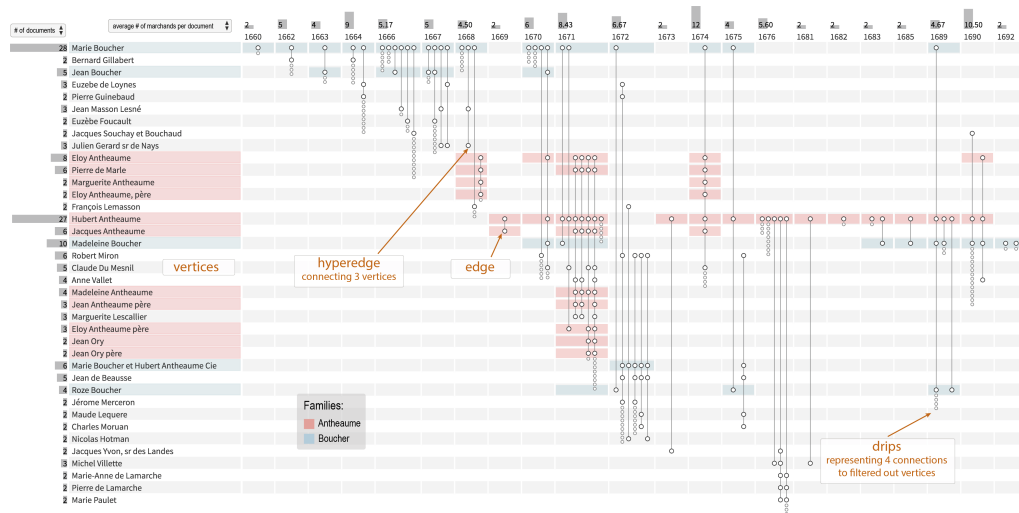


Figure 4: PAOHVis (for Parallel Aggregated Ordered Hypergraph), an innovative visualization technique to visualize dynamic hypergraphs [81].

The dataset has already been used in research (e. g., [66]) but also to shape the scientific community by proposing program committee members, new processes, and was used by the Visualization Restructuring Committee (ReViSe). We are also involved in the EuroVis community and participate at multiple levels to its organization and management.

3.5 Research Axis 5: Visualization Techniques

We study several dedicated visualization approaches that intersect with our major goals above. One such set of approaches, particularly needed at the intersection of AR and VR, are those that fundamentally require both 3D and 2D representations: how to combine 3D representations with 2D representations, how both are linked with each other (initial work: [75]), and how we need to design the interaction to most effectively and efficiently solve practical problems. The visualization field will benefit from a more fundamental and generalizable understanding of such hybrid 3D/2D environments. The individual research into the specific directions will provide a part of this understanding, but we also plan to arrive at a more theoretical understanding of this space. For this purpose we plan to formulate the properties of the respective components and their respective limitations and boundaries, how the individual components affect each other, and how the existing hybrid settings overcome the limitations and boundaries at the moment. Next, we aim to derive an interaction language to describe the current situation, to then be able to generalize the concepts to be able to inform the design of future interactive visualization systems.

We have also started to explore techniques to visualize dynamic hypergraphs [81] (see Figure 4) and their clustering [73]. These dynamic hypergraphs are very effective at representing, e.g., people mentioned in documents across time, such as publications, contracts, personal records, etc. This new line of research is stirring interest in the visualization community but also in very different communities, such as social history, cybersecurity, health monitoring for bridges, and linguistics. We are now continuing to improve the visualization technique to better scale, and to support aggregation using interactive and automated techniques. Our technique for clustering social networks (social hypergraphs) based on ensemble clustering [73] is also applicable to other structures (simple graphs and tabular data). We want to generalize it and scale it to larger ensembles.

4 Application domains

4.1 Natural Sciences

We often deal with data that is inherently three-dimensional in nature, for example, from fields such as biology, astronomy, or medicine. We work with experts from the respective natural sciences to create, for example, illustrative visualizations of scientific data, such as a continuous zooming technique from the nucleus of a cell all the way down to the atom configuration of the DNA, for example, for the application in education. Also our work with immersive technology is often applied to application cases from the natural sciences.

4.2 Social Sciences

We collaborate with social science researchers from EHESS Paris on the visualization of dynamic networks; they use our systems (GeneaQuilts [52], Vistorian [76], PAOHVis [81], PK-Clustering [73]) 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 was supported by the DataIA “HistorIA” project, and by the “IVAN” European project. We currently collaborate with PayAnalytics, an Icelandic company to visualize data to help companies close their gender pay gaps.

4.3 Medicine and Sports

We collaborate with the Health-Data-Hub on the analysis and visualization of French Social Security (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 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 getting a lot of traction from our partners in medicine, epidemiology, and the economy of health.

We are also collaborating with the “Assistance Publique - Hôpitaux de Paris” AP-HP with a newly funded project called URGE, aimed at improving the emergency services for the Parisian hospitals. See the [press announcement](#).

We collaborate with multiple researchers on projects that apply visualizations to the sports and personal health context. Specifically, we are interested in providing effective visualizations for fitness trackers that are worn during sports activities. We have done extensive research on micro visualizations for smartwatches where we focused on how quickly people can retrieve information from their trackers. In addition, we have been working on embedding situated visualizations in sports videos to aid audiences but also athletes and coaches in associating data with the sports activity itself. The current ANR grant SportsViz will focus on this topic where we will also collaborate with French sports associations through our collaborators at Ecole Central de Lyon.

5 Social and environmental responsibility

5.1 Impact of research results

Aviz’ work on illustrative visualization has the potential to be integrated into future teaching materials for students in schools, visitors in museums, or similar.

Aviz’ work on visualization of large documents corpora with [Cartolabe](#) is used to present the results of the French “Grand débat”, as well as other citizen expressions.

Aviz’ work on the gender pay gap aims at improving decision making for closing the adjusted pay gap.

Aviz' work on the visualization of climate change [29, 38] is meant to improve the public understanding of the information gathered by IPCC.

6 Highlights of the year

6.1 Awards

6.1.1 Paper Awards

Aviz received three honorable mentions:

- **Anne-Flore Cabouat, Tingying He, Petra Isenberg and Tobias Isenberg.** “PREVis: Perceived readability evaluation for visualizations.” [8]
- **Gabriela Molina Leon, Anastasia Bezerianos, Olivier Gladin and Petra Isenberg.** “Talk to the Wall: The Role of Speech Interaction in Collaborative Visual Analytics.” [14]
- Zack While, Tanja Blascheck, Yujie Gong, **Petra Isenberg** and Ali Sarvghad. “Glanceable Data Visualizations for Older Adults: Establishing Thresholds and Examining Disparities Between Age Groups.” [36]

6.1.2 Test Of Time Awards

Aviz received two Test Of Time Awards:

- Mohammad Ghoniem, **Jean-Daniel Fekete** and Philippe Castagliola. “A Comparison of the Readability of Graphs Using Node-Link and Matrix-Based Representations” [58] received the 20 years Test Of Time Award from IEEE VIS 2024
- Lingyun Yu, Konstantinos Efstathiou, **Petra Isenberg** and **Tobias Isenberg.** “Efficient Structure-Aware Selection Techniques for 3D Point Cloud Visualizations with 2DOF Input” [88] received the 12 years Test Of Time Award from IEEE VIS 2024.

6.1.3 Other Awards

Tobias Isenberg received a reviewing honorable mention award at EuroVis 2024.

7 New software, platforms, open data

7.1 New software

7.1.1 ProgressiVis

Name: progressive visualization and data analysis

Keywords: Progressive visualization, Visualization, Visual analytics

Functional Description: Instead of running algorithms to completion one after the other, as done in all existing scientific analysis systems, ProgressiVis modules run in short batches, each batch being only allowed to run for a specific quantum of time - typically 1 second - producing a usable result in the end, and yielding control to the next module. To perform the whole computation, ProgressiVis loops over the modules as many times as necessary to converge to a result that the analyst considers satisfactory.

ProgressiVis relies on well known Python libraries, such as numpy, scipy, Pandas, and Scikit-Learn.

URL: <https://github.com/progressivis/progressivis>

Contact: Jean Daniel Fekete

7.1.2 Cartolabe

Name: 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 topic identification, visualization techniques are used for a scalable 2D representation of the results.

Cartolabe has, in particular, been applied to the Grand Debat dataset (3M individual propositions from French Citizen, see <https://cartolabe.fr/map/debat>). The results were used to test both the scaling capabilities of Cartolabe and its flexibility to non-scientific and non-English corpora. We also added sub-map capabilities to display the result of a year/lab/word filtering as an online generated heatmap with only the filtered points to facilitate the exploration. Cartolabe has also been applied in 2020 to the COVID-19 Kaggle publication dataset (Cartolabe-COVID project) to explore these publications.

URL: <http://www.cartolabe.fr/>

Publication: [hal-02499006](https://hal.archives-ouvertes.fr/hal-02499006)

Contact: Philippe Caillou

Participants: Philippe Caillou, Jean Daniel Fekete, Michèle Sebag, Anne-Catherine Letournel, Hande Gozukan

Partners: LRI - Laboratoire de Recherche en Informatique, CNRS

7.1.3 SwimFlow

Name: Visualization tool for swimming analytics

Keywords: Data visualization, Video analysis

Functional Description: SwimFlow contains a set of basic features for prototyping visualizations in motion coupled with a video.

Release Contributions: Initial entry. This version includes restructured code designed by Ludovic David from the code initially written by Lijie Yao, PhD student in the Aviz team. It restructured the code to make it faster and more easily extensible.

URL: <https://gitlab.inria.fr/aviz/swimflow>

Contact: Petra Isenberg

7.1.4 ParcoursVis

Name: Visualization of Patient Pathways

Keywords: Visualization, Health, Progressive visualization

Scientific Description: We developed ParcoursVis, our Progressive Visual Analytics (PVA) tool to explore patients' care pathways at scale. Current tools to visualize temporal event sequences are restricted to datasets as large as a few thousand sequences to remain reactive. With ParcoursVis, we aim to visualize patients' care pathways stored in country-level databases, which can contain order of magnitudes higher of event sequences, at scale using a progressive architecture. PVA tools, instead of waiting for the whole computation to finish before rendering the final results, yield partial results each time the algorithm processes small chunks of data or iterations. This paradigm makes the tool reactive and quickens processes such as checking errors of a query.

Functional Description: ParcoursVis allow extracting a subset of the nationwide database from CNAMTS, transforming the raw data into meaningful medical events, and visualizing it interactively at scale via a web interface.

For the moment, ParcoursVis focuses on non-cancerous prostate adenoma. With this focus, our domain expert users extract meaningful high-level types of events (e.g., treatments and outcomes) that the patients undertake in their care pathways.

Using a progressive visualization method, ParcoursVis visualizes in an aggregated manner the care pathways of tens of millions of patients treated with thousands of events over decades, several orders of magnitude more than existing interactive systems.

URL: <https://www.aviz.fr/Research/ParcoursVis>

Contact: Jean Daniel Fekete

7.2 New platforms

7.2.1 Prepare the ProgressiVis Toolkit for a Wider Distribution

Participants: Jean-Daniel Fekete (*Inria, Paris-Saclay, correspondent*), Christian Poli (*Inria*), Nivan Ferreira (*Univ. Federal de Pernambuco, Brazil*).

The **ProgressiVis toolkit**, implementing a Progressive Data Analysis and Visualization language and environment, has been under heavy development for many years. We have finished its packaging so it can be easily installed by partners who want to experiment with the toolkit and the concept it supports. A **documentation is also available** (in progress), as well as several graphical and interactive widgets to support its use in modern notebooks.

With the new book on Progressive Data Analysis published [2], we want to push the ProgressiVis toolkit as an advanced proof-of-concept of progressive system architecture.

7.3 Open data

7.3.1 Vispubdata.org

Contributors: Petra Isenberg and Tobias Isenberg

Description: The AVIZ members are making available for research a dataset of IEEE VIS publications at vispubdata.org. This dataset is actively being used for research and conference organization.

Dataset DOI: [10.1109/TVCG.2016.2615308](https://doi.org/10.1109/TVCG.2016.2615308),

Project link: vispubdata.org/ and github.com/pisenberg/vispubdata/

Publications: [60]

Contact: [email:petra.isenberg@inria.fr](mailto:petra.isenberg@inria.fr)

7.3.2 Cartolabe

Contributors: Jean-Daniel Fekete, Hande Gözükan, Philippe Caillou

Description: Along with the Cartolabe system [53], we provide the results of our computations for the visualization of large text corpora.

Dataset DOI: [DOI:10.5281/zenodo.7432018](https://doi.org/10.5281/zenodo.7432018), [DOI:10.5281/zenodo.7858805](https://doi.org/10.5281/zenodo.7858805), [10.5281/zenodo.7569091](https://doi.org/10.5281/zenodo.7569091), [10.5281/zenodo.7323386](https://doi.org/10.5281/zenodo.7323386), [10.5281/zenodo.7322976](https://doi.org/10.5281/zenodo.7322976), [10.5281/zenodo.5718551](https://doi.org/10.5281/zenodo.5718551), [10.5281/zenodo.5718514](https://doi.org/10.5281/zenodo.5718514), [10.5281/zenodo.5718495](https://doi.org/10.5281/zenodo.5718495).

Project link: <https://zenodo.org/communities/cartolabe/>

Publications: [53]

Contact: email: Jean-Daniel.Fekete@inria.fr

7.3.3 State of Reproducibility Stamps for Visualization Research Papers

Contributors: Tobias Isenberg

Description: We have analyzed the contribution of visualization papers to the Graphics Replicability Stamp Initiative (GRSI, replicabilitystamp.org) and have made this data available on GitHub (github.com/tobiasisenberg/Visualization-Reproducibility). This dataset is planned to be updated at regular intervals and is also being integrated into the Vispubdata dataset (vispubdata.org).

Dataset DOI: [10.1109/BELIV64461.2024.00016](https://doi.org/10.1109/BELIV64461.2024.00016)

Project link: github.com/tobiasisenberg/Visualization-Reproducibility

Publications: [35]

Contact: email: tobias.isenberg@inria.fr

7.3.4 Perceived readability dataset

Contributors: Tobias Isenberg, Petra Isenberg, Tingying He and Anne-Flore Cabouat

Description: We collected experimental data on the perceived readability of 9 visualizations while developing and validating a Perceived Readability Evaluation scale for Visualizations (PREVis). We will concatenate future studies' results to provide the research community with a growing dataset of visualizations at different levels of perceived readability.

Dataset DOI: [10.1109/TVCG.2024.3456318](https://doi.org/10.1109/TVCG.2024.3456318),

Project link: osf.io/2g9qy, osf.io/2dcms

Publications: [8]

Contact: email: tobias.isenberg@inria.fr

7.3.5 IPCC WG1 Data

Contributors: Jean-Daniel Fekete, Lu Ying

Description: We created a github repository to provide all the information to reproduce the figures from the report of the IPCC WG1. The original data is available at <https://github.com/repro-ippcc/> but is not reproducible, lacking information, code, and data. We created the repository at <https://github.com/repro-ippcc/>; it improves the reproducibility of the original repository by completing the data, code, and instructions to install the running environments for each figure and to run the code.

Project link: [Github repository](#)

Publications: [38]

Contact: email: Jean-Daniel.Fekete@inria.fr

7.3.6 Open science

Aviz regularly shares full research material on the repository of the Center for Open Science to facilitate scrutiny, reuse, and replication:

- PREVis: Perceived Readability Evaluation for Visualizations [8] — OSF
- DiffFit: Visually-Guided Differentiable Fitting of Molecule Structures to a Cryo-EM Map [16] — OSF
- The Language of Infographics: Toward Understanding Conceptual Metaphor Use in Scientific Storytelling [20] — OSF
- SpatialTouch: Exploring Spatial Data Visualizations in Cross-reality [28] — OSF
- In Space, No One (but AI) Can Hear You Scream [46] — OSF
- Design Characterization for Black-and-White Textures in Visualization [3] — OSF
- A Survey of Designs for Combined 2D+3D Visual Representations [4] — OSF
- Visualizing and Comparing Machine Learning Predictions to Improve Human-AI Teaming on the Example of Cell Lineage [13] — OSF, OSF
- The State of Reproducibility Stamps for Visualization Research Papers [35] — OSF
- Virtual Reality Inspection of Chromatin 3D and 2D Data [18] — OSF
- V-Mail: 3D-Enabled Correspondence about Spatial Data on (Almost) All Your Devices [19] — OSF
- MeTACAST: Target- and Context-aware Spatial Selection in VR [27] — OSF
- Talk to the Wall: The Role of Speech Interaction in Collaborative Visual Analytics [14] — OSF
- Eleven Years of Gender Data Visualization: A Step Towards More Inclusive Gender Representation [1] — OSF
- Micro Visualizations on a Smartwatch: Assessing Reading Performance While Walking [33] — <https://osf.io/u78s6/>
- Eliciting Multimodal and Collaborative Interactions for Data Exploration on Large Vertical Displays [15] — OSF
- Glanceable Data Visualizations for Older Adults: Establishing Thresholds and Examining Disparities Between Age Groups [36] — OSF
- Designing for Visualization in Motion: Embedding Visualizations in Swimming Videos [6] — OSF
- A cognitive load approach to designing and evaluating data visualizations [47] — OSF

7.4 Graphics Replicability Stamp

In 2024, Aviz members received recognition for the replicability of their work from the **Graphics Replicability Stamp Initiative** for several of their journal publications:

- PREVis: Perceived Readability Evaluation for Visualizations [8] — **GRSI Stamp**
- Talk to the Wall: The Role of Speech Interaction in Collaborative Visual Analytics [14] — **GRSI Stamp**
- The Language of Infographics: Toward Understanding Conceptual Metaphor Use in Scientific Storytelling [20] — **GRSI Stamp**
- SpatialTouch: Exploring Spatial Data Visualizations in Cross-reality [28] — **GRSI Stamp**
- Design Characterization for Black-and-White Textures in Visualization [3] — **GRSI Stamp**

- A Survey of Designs for Combined 2D+3D Visual Representations [4] — [GRSI Stamp](#)
- Visualizing and Comparing Machine Learning Predictions to Improve Human-AI Teaming on the Example of Cell Lineage [13] — [GRSI Stamp](#)
- V-Mail: 3D-Enabled Correspondence about Spatial Data on (Almost) All Your Devices [19] — [GRSI Stamp](#)
- MeTACAST: Target- and Context-aware Spatial Selection in VR [27] — [GRSI Stamp](#)

8 New results

8.1 Visualization readability

Participants: Anne-Flore Cabouat (*Inria Paris-Saclay, correspondent*), Tingying He (*Inria Paris-Saclay*), Florent Cabric (*Inria Paris-Saclay*), Petra Isenberg (*Inria Paris-Saclay*), Tobias Isenberg (*Inria Paris-Saclay*).

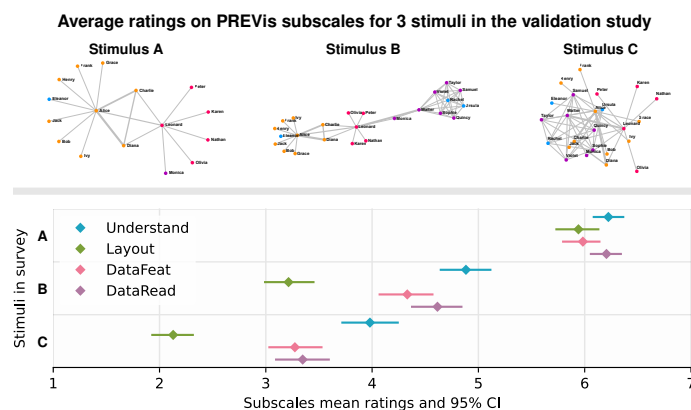


Figure 5: Average ratings (from 1 = “Strongly disagree” to 7 = “Strongly agree”) using the four PREVis subscales on three node-link visualizations of different readability levels (A > B > C)

Visualization readability is an important issue for researchers in our field, but it is not well-defined in existing literature, and we currently lack validated tools to measure it. We have identified four dimensions of visualization readability from a subjective standpoint, which we refer to as perceived readability, and we created scales to measure these dimensions. We also proposed a conceptual framework that links visualization readability to visualization literacy.

PREVis: Perceived Readability Evaluation for Visualization [8]. We developed and validated an instrument to measure the perceived readability in data visualization: PREVis. Researchers and practitioners can easily use this instrument as part of their evaluations to compare the perceived readability of different visual data representations. Our instrument can complement results from controlled experiments on user task performance or provide additional data during in-depth qualitative work such as design iterations when developing a new technique. Although readability is recognized as an essential quality of data visualizations, so far there has not been a unified definition of the construct in the context of visual representations. As a result, researchers often lack guidance for determining how to ask people to rate their perceived readability of a visualization. To address this issue, we engaged in a rigorous process to develop the first validated instrument targeted at the subjective readability of visual data representations. Our final instrument consists of 11 items across 4 dimensions: understandability, layout clarity, readability of data values, and readability of data patterns. We provide the questionnaire as a document with implementation guidelines on osf.io/9cg8j. Beyond this instrument, we contribute a

discussion of how researchers have previously assessed visualization readability, and an analysis of the factors underlying perceived readability in visual data representations.

Position paper: A case to study the relationship between data visualization readability and visualization literacy [30]. In this position paper we argue that improving visualization literacy evaluation tools is important for defining and understanding the concept of readability in data visualizations. Only with reliable and relevant measures can we assess how a potential factor affects a reader's performance; accordingly, only with appropriate measuring instruments can we start to investigate the tight web of interactions between individual characteristics, features of the visual design, and reading tasks requirements. As we slowly progress in our understanding of how people process information from data visualization, and based on these improved tools and other developments, we can further develop theoretical foundations in data visualization.

8.2 Visualization for the domain of fitness and sports

Participants: Lijie Yao (*Inria Paris-Saclay now Xi'an Jiaotong-Liverpool University, correspondent*), Junxiu Tang (*Zhejiang University, Inria Paris-Saclay*), Petra Isenberg (*Inria Paris-Saclay, correspondent*), Romain Vuillemot (*Ecole Centrale de Lyon*), Tanja Blascheck (*University of Stuttgart*), Ali Sarvghad (*University of Massachusetts Amherst*), Zack While (*University of Massachusetts Amherst*).

We have conducted research in two directions.

8.2.1 How to improve visualizations for fitness trackers



Figure 6: Stimuli from a user study showing proportion representations related to goals for calories burned, step count, and active minutes as bar charts and radial bar charts.

We were specifically interested in understanding how people perceive visualizations on fitness trackers. In a first paper [36], we present results of a replication study on smartwatch visualizations with adults aged 65 and older. Smartwatches pose challenges to this population: fonts and visualizations are often small and meant to be seen at a glance. We replicated a study that investigated how visualization type and number of data points affect glanceable perception. We observe strong evidence of differences for participants aged 75 and older, sparking interesting questions regarding the study of visualization and older adults.

In a second project [33], we assessed how different walking trajectories (straight line, circular, and infinity) and speeds (2 km/h, 4 km/h, and 6 km/h) influence the accuracy and response time of participants reading micro visualizations on a smartwatch. We showed our participants common watch face micro visualizations including date, time, weather information, and four complications showing progress charts of fitness data. Our findings suggest that while walking trajectories did not significantly affect reading performance, overall walking activity, especially at high speeds, hurt reading accuracy and, to some extent, response time.

8.2.2 Embedded visualizations for sports

In a second stream of research we investigated how to design visualizations to be embedded into sports videos or AR video streams. We specifically worked on shorter workshops and opinion pieces as first explorations into the topic of first-person visualizations for use during sports activities [32, 34]. In

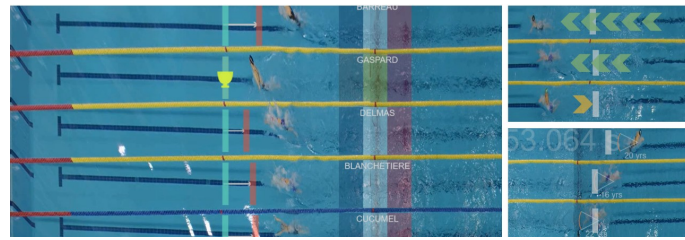


Figure 7: Embedded representations added to a swimming video of the 2021 French Championship using our technology probe. These show dynamically updating visualizations that move with the swimmers: distance to the leader and predicted winner (left), speed distance to a personal record (top right), and current speed and swimmers' ages (bottom right). The left and bottom right images also show stationary embedded representations of the swimmers' names, nationality, and elapsed time.

addition, we published a full journal paper on our exploration of visualizations for swimming videos [6]. Our work makes several contributions in identifying opportunities for visualizations to be added to swimming competition coverage but, most importantly, in identifying requirements and challenges for designing situated visualizations in motion. Our investigations include the analysis of a survey with swimming enthusiasts on their motion-related information needs, an ideation workshop to collect designs and elicit design challenges, the design of a technology probe that allows to create embedded visualizations in motion based on real data, and an evaluation with visualization designers that aimed to understand the benefits of designing directly on videos

8.3 Progressive Data Analysis: Roadmap and Research Agenda

Participants: Jean-Daniel Fekete (*Inria, Paris-Saclay, correspondent*).

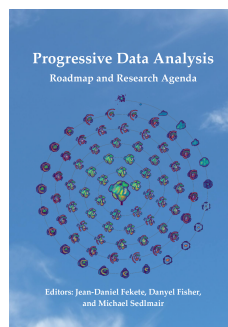


Figure 8: Progressive Data Analysis [2] book cover.

The book “Progressive Data Analysis: Roadmap and Research Agenda” [2] summarizes the current state of the art of the new research domain called Progressive Visual Analytics or Progressive Data Analysis. It has been written by 20 researchers in a few years and provides a summary of the research landscape in this new challenging domain, as well as a roadmap to tackle these challenges. See also the [Book's web site](#).

9 Bilateral contracts and grants with industry

9.1 Bilateral contracts with industry

Participants: Jean-Daniel Fekete, Katerina Batziakoudi.

CIFRE PhD fellowship of Katerina Batziakoudi with the Company Berger-Levrault (2023–2026).

Participants: Petra Isenberg, Florent Cabric.

Contract with PayAnalytics for joint work on the Inria exploratory action called “Equity Analytics” (2022-2024)

10 Partnerships and cooperations

10.1 International research visitors

10.1.1 Visits of international scientists

Other international visits to the team

Narges Mayhar

Status: Researcher

Institution of origin: University of Massachusetts Amherst

Country: USA

Dates: November 2024 – June 2025

Context of the visit: Sabbatical

Mobility program/type of mobility: sabbatical

Emanuele Marques Rodrigues Santos

Status: Researcher

Institution of origin: Universidade Federal do Ceará

Country: Brazil

Dates: January 2024 – February 2025

Context of the visit: Sabbatical

Mobility program/type of mobility: sabbatical

Tobias Rau

Status: PhD student

Institution of origin: University of Stuttgart

Country: Germany

Dates: September 2024 – December 2024

Context of the visit: collaboration on immersive interaction with 3D data

Mobility program/type of mobility: funded by Univ. Stuttgart

Filip Opálený

Status: PhD student

Institution of origin: Masaryk University

Country: Czech Republic

Dates: November 2024 – December 2024

Context of the visit: collaboration on the visualization of chromatin data

Mobility program/type of mobility: funded by Masaryk Univ.

Junxiu Tang

Status: PhD student

Institution of origin: Zhejiang University

Country: China

Dates: September 2023 – June 2024

Context of the visit: Work on visualization for sports video

Mobility program/type of mobility: CSC internship program

Karelia Alexandra Vilca Salinas

Status: PhD student

Institution of origin: University of São Paulo (USP)

Country: Brazil

Dates: March 2023 – January 2024

Context of the visit: PhD internship

Mobility program/type of mobility: Brazilian “Sandwich” PhD funding

Lu Ying

Status: PhD Student

Institution of origin: Zhejiang University

Country: China

Dates: January 2024 – September 2024

Context of the visit: PhD internship

Mobility program/type of mobility: China Scholarship Council (CSC)

Eliane Zambon Victorelli**Status:** PostDoc**Institution of origin:** University of São Paulo**Country:** Brazil**Dates:** May 2024 – July 2024**Context of the visit:** Joint research project on the development of a new research instrument for the evaluation of user experience with visual analytics systems.**Mobility program/type of mobility:** Research Internship Abroad funded by FAPESP**10.2 National initiatives****Program:** ANR PRC (ANR-19-CE33-0012)**Project acronym:** EMBER**Project title:** Situated Visualizations for Personal Analytics**Duration:** 2020 – 2025. Total funding: 712 k€**Coordinator:** Pierre Dragicevic**Other partners:** Inria Bordeaux, Sorbonne Université**Participants in AVIZ:****Participants:** Petra Isenberg.

Abstract: The Ember project studies how situated data visualization systems can help people use their personal data (e.g., fitness and physiological data, energy consumption, banking transactions, online social activity, ...) for their own benefit. Although personal data is generated in many areas of daily life, it remains underused by individuals. Rarely is personal data subjected to an in-depth analysis and used to inform daily decisions. This research aims to empower individuals to improve their lives by helping them become advanced consumers of their own data. This research builds on the area of personal visual analytics, which focuses on giving the general public effective and accessible tools to get insights from their own data. Personal visual analytics is a nascent area of research, but has so far focused on scenarios where the data visualization is far removed from the source of the data it refers to. The goal of this project is to address the limitations of traditional platforms of personal data analytics by exploring the potential of situated data visualizations. In a situated data visualization, the data is directly visualized near the physical space, object, or person it refers to. Situated data visualizations have many potential benefits: they can surface information in the physical environment and allow viewers to interpret data in-context; they can be tailored to highlight spatial connections between data and the physical environment, making it easier to make decisions and act on the physical world in response to the insights gained; and they can embed data into physical environments so that it remains visible over time, making it easier to monitor changes, observe patterns over time and collaborate with other people. Website: ember.inria.fr/.

10.3 Other projects:**ParcoursVis****Program:** Post-doctoral funding**Project acronym:** ParcoursVis

Project title: ParcoursVis: Visualization of Patient Pathways

Duration: 2022 – 2025.

Coordinator: Jean-Daniel Fekete

Participants in AVIZ:

Participants: Jean-Daniel Fekete, Mickaël Sereno, Sungbok Shin.

Other partners: Health-Data-Hub

Abstract: The Aviz Team and the Health-Data-Hub (French Social Security) are interested in evaluating patient pathways for treatments. We are currently working on two main projects: (1) ParcoursVis and (2) ParcoursUrge. In ParcoursVis, doctors want to understand the differences between how treatments are de facto given around France and how they align with the official recommendations. In ParcoursUrge, we visualize the events that take place in the Emergency services of the Parisian hospitals to help doctors and hospitals optimize patient management. Both ParcoursVis and ParcoursUrge projects present several challenges, such as finding methodologies to effectively process large-scale data (multi-million patients with hundreds or thousands of events per patient). They transform raw data collected for prescription reimbursement or monitoring into an effective visualization. To visualize and interact with this high volume of data, we rely on Progressive Data Analysis. We visualize millions of patient events by aggregating them on the fly by "chunks", groups of 10,000 or so patients, iteratively. At each iteration, we update the visualization that quickly converges to the final result. This method allows aggregating and visualizing billions of patients with no noticeable delays, allowing smooth interactions at any time. We apply it to improve health at the country or regional level, a scale that was impossible to handle before.

URGE

Program: Inria-AP-HP Funding

Project acronym: URGE

Project title: URGE: Analysing and optimizing emergency patient pathways

Duration: 2022 – 2026.

Coordinator: Xavier Leroy (Inria) and Youri Yordanov (AP-HP, Inserm, Sorbonne Université)

Participants in AVIZ:

Participants: Jean-Daniel Fekete, Mickaël Sereno, Ambre Assor.

Other partners: Hôpital Saint Antoine, Sorbonne Université

Abstract: For more than 15 years, emergency departments have been facing a steady increase in their number of patients, leading to long periods of crowding, defined as the moments when health care demand exceeds the department's capacity to provide quality care within a reasonable time. The URGE project aims at developing mathematical analysis and numerical simulation tools for flows analysis of the emergency departments. Our objectives are to assess the performances of different organizations, to evaluate the impact of their evolutions and optimizations, starting from the triage step and until the end of the patient journey, in a risk-free environment. This project brings together teams from the AP-HP emergency departments, the Tropical team (Inria Saclay - CMAP, École polytechnique), the Aviz team (Inria Saclay - Université Paris-Saclay), the Dyogene team (Inria Paris - ENS), the "Observatoire des soins non programmés d'île de France" and the "plateforme de recherche Est Parisien" (AP-HP).

EquityAnalytics**Program:** Inria AeX**Project acronym:** EquityAnalytics**Project title:** EquityAnalytics**Duration:** 2022 – 2024.**Coordinator:** Petra Isenberg**Participants in AVIZ:****Participants:** Petra Isenberg, Florent Cabric.**Other partners:** PayAnalytics

Abstract: The goal of this project is to explore, develop, and test pay equity visual analytics solutions in order to give decision makers the power to eradicate adjusted gender pay gaps. We will develop new visual analytics solutions that summarize pay structures in a manner that clearly shows the changes that should be made in order for the pay structure to be fair and rational and that allows managers to evaluate recommended action plans, make informed decisions and monitor progress using a visual interactive user interface. We will collaborate with a startup company called PayAnalytics that provides access to real data and use cases.

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

Member of the organizing committees

- Florent Cabric: Alt.IHM Chair for IHM'24 conference
- Petra Isenberg: Young Researcher Award Committee for EuroVis
- Tobias Isenberg: tutorials and panels co-chair for EuroVis 2024, best posters committee member for CGVC 2024

Service

- Anne-Flore Cabouat: student volunteer for VIS 2024

11.1.2 Scientific events: selection

Chair of conference program committees

- Jean-Daniel Fekete: **HILDA** Workshop Co-Chair
Co-organizer of the EuroVA session on Progressive Data Analysis at EuroVA 2024, Odense, DK, May 27th
IEEE VIS Workshop on Progressive Data Analysis and Visualization, with Alex Ulmer, Jaemin Jo, and Michael Sedlmair, St. Pete Beach, Florida, Oct. 14

Member of the conference program committees

- Jean-Daniel Fekete: Undone Computer Science, IEEE VIS 2024, EDBT/ICDT International Workshop on Big Data Visual Exploration and Analytics
- Petra Isenberg: CHI 2024
- Tobias Isenberg: BELIV 2024, VCBM 2024 full papers, VCBM 2024 short papers, IEEE VIS 2024 short papers, EuroVis 2024 full papers, EuroVis 2024 short papers, EuroVis 2024 education papers

Reviewer

- Jean-Daniel Fekete: EuroVis 2024
- Florent Cabric: ACM CHI, IEEE VR
- Petra Isenberg: BELIV 2024, IEEE ISMAR 2024, IEEE VIS 2024, IEEE VIS short papers 2024
- Tobias Isenberg: BELIV 2024, EuroVis 2024 full papers, EuroVis 2024 short papers, EuroVis 2024 education papers, ACM CHI 2024, ISMAR 2024, VCBM 2024, IEEE VIS 2024 full papers, IEEE VIS 2024 short papers

11.1.3 Journal

Member of the editorial boards

- Jean-Daniel Fekete: IEEE TVCG, Member of the Scientific Committee of the French journal “Humanités Numériques”
- Jean-Daniel Fekete: Associate Editor-in-Chief IEEE Transactions on Visualization and Computer Graphics
- Petra Isenberg: Associate Editor-in-Chief IEEE Computer Graphics and Applications (CG&A), Associate Editor for Computer Graphics Forum
- Tobias Isenberg: Associate Editor for Elsevier Computers & Graphics, Associate Editor for Computer Graphics Forum

Reviewer - reviewing activities

- Jean-Daniel Fekete: IEEE Transaction on Visualization and Computer Graphics, EG Computer Graphics Forum
- Florent Cabric: IEEE Transaction on Visualization and Computer Graphics
- Petra Isenberg: IEEE Transaction on Visualization and Computer Graphics, EG Computer Graphics Forum, Interacting with Computers
- Tobias Isenberg: IEEE Transaction on Visualization and Computer Graphics, International Journal of Human - Computer Studies

11.1.4 Invited talks

- Jean-Daniel Fekete
 - *Improving IPCC Data Visualization with Traceability*, Keynote for [the 2024 Pernambuco Seminar on visualization and sustainability](#), Recife, Brazil, Oct. 21, 2024
 - Presentation of the book on Progressive Data Analysis at the EuroVA session on Progressive Data Analysis at EuroVA 2024, Odense, DK, May 27th, 2024

- *Scalability in Visualization and Visual Analytics with Progressive Data Analysis*, Keynote for **AVI 2024**, Arenzano (Genoa), Italy, Jun. 5, 2024
- *Visualisation de données : quelques avancées récentes*, Keynote for the **Chimiométrie 2024 conference**, Nantes, Feb. 27, 2024
- Petra Isenberg
 - *Bringing Data to Life: Embedded Visualizations for Pervasive and Mobile Data Exploration*. Keynote at CGVC 2024
 - *Visualization for Mobile Devices and Embedded Experiences*, Seminar University of Bremen, Germany
- Tobias Isenberg
 - *Visualization of Species Distributions based on Social Media Data and a Couple of Surprises and Insights*. Keynote at VCBM (September 2024)
 - *Thoughts on how to Effectively Explore Visual Representations in Mixed Reality*, University of Stuttgart, Germany (April 2024)

11.1.5 Leadership within the scientific community

- Jean-Daniel Fekete: Co-Chair of the IEEE VIS Area Curation Committee
- Petra Isenberg: member of the steering committee of the BELIV Workshop on Evaluation and Beyond—Methodological Approaches for Visualization, vice-chair of the IEEE VIS steering committee
- Tobias Isenberg: member of the steering committee of the BELIV Workshop on Evaluation and Beyond—Methodological Approaches for Visualization
- Florent Cabric (vice-chair) and Petra Isenberg (treasurer): members of ACM SIGCHI Paris Local Chapter.
- Florent Cabric: co-chair of joint Groupe Travail (GT) VISU for the Groupements De Recherche (GdR) Informatique Géométrique et graphique, la Réalité virtuelle et la Visualisation (IG-RV) and Interaction Humain-Machine (IHM).

11.1.6 Scientific expertise

- Petra Isenberg: reviewer for multiple grant organizations (FWF, FWO, NSERC, Mitacs), hiring committees, promotion committees, and the Graphics Replicability Stamp committee
- Tobias Isenberg: member of ANR grant evaluation committee “Interaction Robotique” (CE33) for ANR’s AAPG 2024; reviewer for grant application (FWF)

11.2 Teaching - Supervision - Juries

11.2.1 Teaching

- Master: Jean-Daniel Fekete, Visual Data Analysis at the Parisian Master of Research in Computer Science with Julien Tierny. 25 hours. Joint Master with Univ. Paris-Cité, ENS Ulm, Univ. Paris-Saclay, Institut Polytechnique de Paris.
- Crash course: Jean-Daniel Fekete, on HCI and Visualization, 6h, to IRT SystemX
- Master: Petra Isenberg, Katerina Batziakoudi, “Interactive Information Visualization”, 36.5h equivalent TD (total, co-taught with Anastasia Bezerianos), M1/M2, Université Paris-Saclay, France.
- Master: Petra Isenberg, “Visual Analytics”, 60h equivalent TD (co-taught with Natkamon Tovanich), M2, Centrale Supélec.

- Licence: Tobias Isenberg, “Introduction to Computer Graphics”, 18h en équivalent TD, L3, Polytech Paris-Saclay, France.
- Master: Tobias Isenberg, Tingying He, “Data Visualization”, 36h en équivalent TD, M2, Centrale-Supélec, France.
- Master: Frédéric Vernier, class and lab class. “Information visualization”, 24h en équivalent TD, M2 ISC, Faculté des sciences d’Orsay. Université Paris-Saclay, France.
- Master: Frédéric Vernier, class and lab class. “Web development with node.js”, 21h en équivalent TD, M2 HCI, Faculté des sciences d’Orsay. Université Paris-Saclay, France.
- Licence: Frédéric Vernier, class and lab class. “Introduction to Computer Graphics”, 42h en équivalent TD, L1-MI, Faculté des sciences d’Orsay. Université Paris-Saclay, France.
- Licence: Frédéric Vernier, class and lab class. “Advanced Computer Graphics”, 36h en équivalent TD, L2-MI, Faculté des sciences d’Orsay. Université Paris-Saclay, France.
- Licence: Frédéric Vernier, class and lab class. “Web development”, 42h en équivalent TD, L3 computer sciences, Faculté des sciences d’Orsay. Univ. Paris-Saclay, France.
- BUT Informatique: Florent Cabric, class and lab class. “Analyse,” 22.5 heures en équivalent TD, 2nd year of BUT, IUT d’Orsay. Université Paris-Saclay, France.
- BUT Informatique: Florent Cabric, lab class. “Introduction aux bases de données et SQL,” 39 heures en équivalent TD, 1st year of BUT, IUT d’Orsay. Université Paris-Saclay, France.
- BUT Informatique: Florent Cabric, project supervision. “Création d’une base de données,” 10 heures en équivalent TD, 1st year of BUT, IUT d’Orsay. Université Paris-Saclay, France.

11.2.2 Supervision

- PhD in progress: Katerina Batziakoudi, *Visualization of budget and accounting data*, supervised by Jean-Daniel Fekete.
- PhD in progress: Anne-Flore Cabouat, *Readability of Visualizations*, Univ. Paris-Saclay, supervised by Petra Isenberg.
- PhD in progress: Lixiang Zhao, *Interaction Techniques for Spatial 3D data in VR and Mixed Reality*, Xi’an Jiaotong-Liverpool Univ. (China), co-supervised by Tobias Isenberg.
- PhD in progress: Yucheng Lu, *Hybrid Scientific Data Exploration*, Univ. Paris-Saclay, defense planned for December 2026, co-supervised by Tobias Isenberg.
- PhD in progress and visiting PhD student: Tobias Rau, *Interactive AR/VR Visualization of Molecular Simulation Data*, Univ. Stuttgart (Germany), co-supervised by Tobias Isenberg.
- PhD in progress: Deng Luo, *Abstraction of Visual Representations for DNA Nanotechnology and Protein Data*, KAUST (Saudi-Arabia), co-supervised by Tobias Isenberg.
- PhD completed: Tingying He, *A Design Space for Visual Data Mapping for Low-Color Displays*, Univ. Paris-Saclay, defended September 2024, co-supervised by Tobias Isenberg.
- Post-doctoral fellow: Ambre Assor, *Emergency department patients pathways and care optimization*, supervised by Jean-Daniel Fekete.
- Post-doctoral fellow: Sungbok Shin, *Progressive Visualization of Patient Pathways at Scale*, supervised by Jean-Daniel Fekete.
- Post-doctoral fellow: Florent Cabric, *Gender data visualization for reducing gender pay gap*, supervised by Petra Isenberg.

- Masters completed: Anne-Flore Cabouat, *A Validated Scale for Measuring the Readability of Visualizations*, Univ. Paris Cité, supervised by Tobias Isenberg and Petra Isenberg.
- Masters completed: Zihan Lu, *A Design Space of Semantically-Resonant Patterns*, Univ. Paris-Saclay, supervised by Tobias Isenberg and Tingying He.
- Visiting PhD Student: Karelia Alexandra Vilca Salinas, *Visual analytics for crime analysis*, co-supervised by Jean-Daniel Fekete.
- Visiting PhD Student: Lu Ying, *Improve the public understanding of the information gathered by IPCC*, co-supervised by Jean-Daniel Fekete.
- Visiting PhD Student: Filip Opálený, *Interaction with Chromatin Data Representations*, co-supervised by Tobias Isenberg.

11.2.3 Juries

- Jean-Daniel Fekete: Alex Ulmer, PhD, “Progressive Visual Analytics for Temporal Data”, Technische Universität Darmstadt, Nov. 19, 2024
- Petra Isenberg: PhD thesis examiner, Alexandre Battut, Université Paris-Saclay, jury president
- Petra Isenberg: PhD thesis reporter, Bradley Rey, University of British Columbia
- Petra Isenberg: HDR committee member, Dr. Benjamin Bach, University of Bordeaux/Inria
- Petra Isenberg: member of comité de suivi for Alan Gany, Université Paris-Saclay
- Petra Isenberg: member of comité de suivi for Yasaman Marandi, Université Paris-Saclay
- Petra Isenberg: member of comité de suivi for Anna Offenwanger, Université Paris-Saclay
- Tobias Isenberg: member of PhD jury for Charlotte Godard, Université PSL/École Normale Supérieure, France
- Tobias Isenberg: president of HDR jury for Dr. Mohamed El Beheiry, Institut Pasteur, France
- Tobias Isenberg: member of comité de suivi for Vincent Bonczak, Université Paris-Saclay

12 Scientific production

12.1 Major publications

- [1] F. Cabric, M. Vilborg Bjarnadóttir, M. Ling, G. Linda Rafnsdóttir and P. Isenberg. ‘Eleven Years of Gender Data Visualization: A Step Towards More Inclusive Gender Representation’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.1 (1st Jan. 2024), pp. 316–326. DOI: [10.1109/TVCG.2023.3327369](https://doi.org/10.1109/TVCG.2023.3327369). URL: <https://inria.hal.science/hal-04179018> (cit. on p. 16).
- [2] J.-D. Fekete, D. Fisher and M. Sedlmair, eds. *Progressive Data Analysis: Roadmap and Research Agenda*. Eurographics, 11th Nov. 2024, p. 231. DOI: [10.2312/pda.20242707](https://doi.org/10.2312/pda.20242707). URL: <https://inria.hal.science/hal-04776568> (cit. on pp. 4, 5, 14, 19).
- [3] T. He, Y. Zhong, P. Isenberg and T. Isenberg. ‘Design Characterization for Black-and-White Textures in Visualization’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.1 (1st Jan. 2024), pp. 1019–1029. DOI: [10.1109/TVCG.2023.3326941](https://doi.org/10.1109/TVCG.2023.3326941). URL: <https://hal.science/hal-04167900> (cit. on p. 16).
- [4] J. Hong, R. Hnatyshyn, E. A. D. Santos, R. Maciejewski and T. Isenberg. ‘A Survey of Designs for Combined 2D+3D Visual Representations’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.6 (1st June 2024), pp. 2888–2902. DOI: [10.1109/TVCG.2024.3388516](https://doi.org/10.1109/TVCG.2024.3388516). URL: <https://inria.hal.science/hal-04382271> (cit. on pp. 16, 17).

- [5] G. Richer, A. Pister, M. Abdelaal, J.-D. Fekete, M. Sedlmair and D. Weiskopf. ‘Scalability in Visualization’. In: *IEEE Transactions on Visualization and Computer Graphics* (29th Dec. 2022). DOI: [10.1109/TVCG.2022.3231230](https://doi.org/10.1109/TVCG.2022.3231230). URL: <https://hal.inria.fr/hal-03820394> (cit. on p. 5).
- [6] L. Yao, R. Vuillemot, A. Bezerianos and P. Isenberg. ‘Designing for Visualization in Motion: Embedding Visualizations in Swimming Videos’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.3 (Mar. 2024), pp. 1821–1836. DOI: [10.1109/tvcg.2023.3341990](https://doi.org/10.1109/tvcg.2023.3341990). URL: <https://hal.science/hal-04364838> (cit. on pp. 16, 19).

12.2 Publications of the year

International journals

- [7] A. Assor, A. Prouzeau, P. Dragicevic and M. Hachet. ‘Augmented-Reality Waste Accumulation Visualizations’. In: *ACM Journal on Computing and Sustainable Societies* 2.11 (13th Jan. 2024), pp. 1–29. DOI: [10.1145/3636970](https://doi.org/10.1145/3636970). URL: <https://hal.science/hal-04399489>.
- [8] A.-F. Cabouat, T. He, P. Isenberg and T. Isenberg. ‘PREVis: Perceived Readability Evaluation for Visualizations’. In: *IEEE Transactions on Visualization and Computer Graphics* 31.1 (Jan. 2025), pp. 1083–1093. DOI: [10.1109/TVCG.2024.3456318](https://doi.org/10.1109/TVCG.2024.3456318). URL: <https://inria.hal.science/hal-04665390> (cit. on pp. 12, 15–17).
- [9] F. Cabric, M. Vilborg Bjarnadóttir, M. Ling, G. Linda Rafnsdóttir and P. Isenberg. ‘Eleven Years of Gender Data Visualization: A Step Towards More Inclusive Gender Representation’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.1 (1st Jan. 2024), pp. 316–326. DOI: [10.1109/TVCG.2023.3327369](https://doi.org/10.1109/TVCG.2023.3327369). URL: <https://inria.hal.science/hal-04179018>.
- [10] X. Chen, Y. Wang, H. Bao, K. Lu, J. Jo, C.-W. Fu and J.-D. Fekete. ‘Visualization-Driven Illumination for Density Plots’. In: *IEEE Transactions on Visualization and Computer Graphics* 31.2 (6th Jan. 2025), pp. 1631–1644. DOI: [10.1109/TVCG.2024.3495695](https://doi.org/10.1109/TVCG.2024.3495695). URL: <https://inria.hal.science/hal-04776837>.
- [11] T. He, Y. Zhong, P. Isenberg and T. Isenberg. ‘Design Characterization for Black-and-White Textures in Visualization’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.1 (1st Jan. 2024), pp. 1019–1029. DOI: [10.1109/TVCG.2023.3326941](https://doi.org/10.1109/TVCG.2023.3326941). URL: <https://hal.science/hal-04167900>.
- [12] J. Hong, R. Hnatyshyn, E. A. D. Santos, R. Maciejewski and T. Isenberg. ‘A Survey of Designs for Combined 2D+3D Visual Representations’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.6 (1st June 2024), pp. 2888–2902. DOI: [10.1109/TVCG.2024.3388516](https://doi.org/10.1109/TVCG.2024.3388516). URL: <https://inria.hal.science/hal-04382271>.
- [13] J. Hong, R. Maciejewski, A. Trubuil and T. Isenberg. ‘Visualizing and Comparing Machine Learning Predictions to Improve Human-AI Teaming on the Example of Cell Lineage’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.4 (1st Apr. 2024), pp. 1956–1969. DOI: [10.1109/TVCG.2023.3302308](https://doi.org/10.1109/TVCG.2023.3302308). URL: <https://inria.hal.science/hal-04212205> (cit. on pp. 16, 17).
- [14] G. M. León, A. Bezerianos, O. Gladin and P. Isenberg. ‘Talk to the Wall: The Role of Speech Interaction in Collaborative Visual Analytics’. In: *IEEE Transactions on Visualization and Computer Graphics* 31.1 (Jan. 2025), pp. 941–951. DOI: [10.1109/tvcg.2024.3456335](https://doi.org/10.1109/tvcg.2024.3456335). URL: <https://inria.hal.science/hal-04845442> (cit. on pp. 12, 16).
- [15] G. M. León, P. Isenberg and A. Breiter. ‘Eliciting Multimodal and Collaborative Interactions for Data Exploration on Large Vertical Displays’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.2 (1st Feb. 2024), pp. 1624–1637. DOI: [10.1109/TVCG.2023.3323150](https://doi.org/10.1109/TVCG.2023.3323150). URL: <https://inria.hal.science/hal-04365019> (cit. on p. 16).
- [16] D. Luo, Z. Alsuwaykit, D. Khan, O. Strnad, T. Isenberg and I. Viola. ‘DiffFit: Visually-Guided Differentiable Fitting of Molecule Structures to a Cryo-EM Map’. In: *IEEE Transactions on Visualization and Computer Graphics* 31.1 (Jan. 2025), pp. 558–568. DOI: [10.1109/TVCG.2024.3456404](https://doi.org/10.1109/TVCG.2024.3456404). URL: <https://inria.hal.science/hal-04665408> (cit. on p. 16).

- [17] D. Luo, Z. Alsuwaykit, D. Khan, O. Strnad, T. Isenberg and I. Viola. ‘Errata to “DiffFit: Visually-Guided Differentiable Fitting of Molecule Structures to a Cryo-EM Map”’. In: *IEEE Transactions on Visualization and Computer Graphics* 31.2 (Feb. 2025), pp. 1645–1646. DOI: [10.1109/TVCG.2024.3502911](https://doi.org/10.1109/TVCG.2024.3502911). URL: <https://inria.hal.science/hal-04869601>.
- [18] E. Molina, D. Kouřil, T. Isenberg, B. Kozlíková and P.-p. Vázquez. ‘Virtual reality inspection of chromatin 3D and 2D data’. In: *Computers and Graphics* 124 (1st Nov. 2024), article no. 104059, 11 pages. DOI: [10.1016/j.cag.2024.104059](https://doi.org/10.1016/j.cag.2024.104059). URL: <https://inria.hal.science/hal-04684828> (cit. on p. 16).
- [19] J. W. Nam, T. Isenberg and D. Keefe. ‘V-Mail: 3D-Enabled Correspondence about Spatial Data on (Almost) All Your Devices’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.4 (1st Apr. 2024), pp. 1853–1867. DOI: [10.1109/TVCG.2022.3229017](https://doi.org/10.1109/TVCG.2022.3229017). URL: <https://inria.hal.science/hal-03924707> (cit. on pp. 16, 17).
- [20] H. Pokojná, T. Isenberg, S. Bruckner, B. Kozlíková and L. Garrison. ‘The Language of Infographics: Toward Understanding Conceptual Metaphor Use in Scientific Storytelling’. In: *IEEE Transactions on Visualization and Computer Graphics* 31.1 (Jan. 2025), pp. 371–381. DOI: [10.1109/TVCG.2024.3456327](https://doi.org/10.1109/TVCG.2024.3456327). URL: <https://inria.hal.science/hal-04665428> (cit. on p. 16).
- [21] T. Rau, M. Koch, N. Pathmanathan, T. Isenberg, D. Weiskopf, M. Sedlmair, A. Köhn and K. Kurzhals. ‘Understanding Collaborative Learning of Molecular Structures in AR With Eye Tracking’. In: *IEEE Computer Graphics and Applications* 44.6 (Nov. 2024), pp. 39–51. DOI: [10.1109/MCG.2024.3503903](https://doi.org/10.1109/MCG.2024.3503903). URL: <https://inria.hal.science/hal-04873245>.
- [22] G. Richer, A. Pister, M. Abdelaal, J.-D. Fekete, M. Sedlmair and D. Weiskopf. ‘Scalability in Visualization’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.7 (Jan. 2024), pp. 3314–3330. DOI: [10.1109/TVCG.2022.3231230](https://doi.org/10.1109/TVCG.2022.3231230). URL: <https://inria.hal.science/hal-03820394>.
- [23] A. Ulmer, M. Angelini, J.-D. Fekete, J. Kohlhammer and T. May. ‘A Survey on Progressive Visualization’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.9 (1st Jan. 2024), pp. 6447–6467. DOI: [10.1109/TVCG.2023.3346641](https://doi.org/10.1109/TVCG.2023.3346641). URL: <https://inria.hal.science/hal-04361344>.
- [24] L. Yao. ‘Situated Visualization in Motion’. In: *IEEE Computer Graphics and Applications* 44.6 (7th Jan. 2025), pp. 142–150. DOI: [10.1109/MCG.2024.3462129](https://doi.org/10.1109/MCG.2024.3462129). URL: <https://hal.science/hal-04700820>.
- [25] L. Yao, F. Bucchieri, V. McArthur, A. Bezerianos and P. Isenberg. ‘User Experience of Visualizations in Motion: A Case Study and Design Considerations’. In: *IEEE Transactions on Visualization and Computer Graphics* 31.1 (Jan. 2025), pp. 174–184. DOI: [10.1109/tvcg.2024.3456319](https://doi.org/10.1109/tvcg.2024.3456319). URL: <https://hal.science/hal-04700819>.
- [26] L. Yao, R. Vuillemot, A. Bezerianos and P. Isenberg. ‘Designing for Visualization in Motion: Embedding Visualizations in Swimming Videos’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.3 (Mar. 2024), pp. 1821–1836. DOI: [10.1109/tvcg.2023.3341990](https://doi.org/10.1109/tvcg.2023.3341990). URL: <https://hal.science/hal-04364838>.
- [27] L. Zhao, T. Isenberg, F. Xie, H.-N. Liang and L. Yu. ‘MeTACAST: Target-and Context-aware Spatial Selection in VR’. In: *IEEE Transactions on Visualization and Computer Graphics* 30.1 (1st Jan. 2024), pp. 480–494. DOI: [10.1109/TVCG.2023.3326517](https://doi.org/10.1109/TVCG.2023.3326517). URL: <https://inria.hal.science/hal-04196163> (cit. on pp. 16, 17).
- [28] L. Zhao, T. Isenberg, F. Xie, H.-N. Liang and L. Yu. ‘SpatialTouch: Exploring Spatial Data Visualizations in Cross-reality’. In: *IEEE Transactions on Visualization and Computer Graphics* 31.1 (Jan. 2025), pp. 897–907. DOI: [10.1109/TVCG.2024.3456368](https://doi.org/10.1109/TVCG.2024.3456368). URL: <https://inria.hal.science/hal-04665449> (cit. on p. 16).

International peer-reviewed conferences

- [29] K. Batziakoudi, F. Cabric, S. Rey and J.-D. Fekete. ‘Designing Visualizations for Enhancing Carbon Numeracy’. In: *IEEE VIS 2024 Workshop on Visualization for Climate Action and Sustainability*. Virtual, United States, 14th Oct. 2024. URL: <https://inria.hal.science/hal-04744209> (cit. on p. 12).

- [30] A.-F. Cabouat, T. He, F. Cabric, T. Isenberg and P. Isenberg. 'Position paper: A case to study the relationship between data visualization readability and visualization literacy'. In: *ACM CHI'24*. CHI 2024 - Workshop Toward a More Comprehensive Understanding of Visualization Literacy. O'ahu (Honolulu), United States, May 2024. URL: <https://hal.science/hal-04523790> (cit. on p. 18).
- [31] F. Cabric and J.-D. Fekete. 'Plea for a Hybride IHM Conference'. In: *IHM 2024 - 35e Conférence Internationale Francophone sur l'Interaction Humain-Machine*. Vol. IHM'24 : Actes étendus de la 35ème conférence Francophone sur l'Interaction Humain-Machine. Paris, France, 25th Mar. 2024. URL: <https://hal.science/hal-04486645>.
- [32] A. Elshabasi, L. Yao, P. Isenberg, C. Perin and W. Willett. 'Collecting Information Needs for Egocentric Visualizations while Running'. In: *IEEE VIS Workshop on First-Person Visualizations for Outdoor Physical Activities: Challenges and Opportunities*. St. Pete Beach (Florida), United States, 13th Oct. 2024. DOI: [10.48550/arXiv.2409.06426](https://doi.org/10.48550/arXiv.2409.06426). URL: <https://hal.science/hal-04700822> (cit. on p. 18).
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