Activity Report 2017

Project-Team AVIZ

Analysis and Visualization

RESEARCH CENTER
Saclay - Île-de-France

THEME
Interaction and visualization

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Project-Team AVIZ

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

Keywords:

Computer Science and Digital Science:

A1.3. - Distributed Systems
A1.3.1. - Blockchain
A3.1.4. - Uncertain data
A3.1.7. - Open data
A3.1.8. - Big data (production, storage, transfer)
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
A5.2. - Data visualization
A6.3.3. - Data processing

Other Research Topics and Application Domains:

B1. - Life sciences
B1.1. - Biology
B1.2. - Neuroscience and cognitive science
B9.4.5. - Data science
B9.5. - Humanities
B9.5.1. - Psychology
B9.5.3. - Economy, Finance
B9.5.6. - Archeology, History
B9.5.10. - Digital humanities

1. Personnel

Research Scientists

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

Post-Doctoral Fellows

Christoph Kinkeldey [Inria]
Tanja Blascheck [Inria, from Nov 2017]

PhD Students

Lonni Besançon [Univ Paris-Sud]
Evanthia Dimara [Inria, until Nov 2017]
Sarkis Halladjian [Inria, from Sep 2017]
Xiyao Wang [Inria, from Nov 2017]

Technical staff
Romain Di Vozzo [Inria]

Interns
Guillaume Rumor [Inria, from Apr 2017 until Sep 2017]
Xiyao Wang [Inria, from Apr 2017 until Sep 2017]

Administrative Assistant
Katia Evrat [Inria]

Visiting Scientists
Paolo Buono [University of Bari Aldo Moro, until Feb 2017]
Jaemin Jo [Seoul National University, until Feb 2017]
Paola Tatiana Llerena Valdivia [USP - Universidade de São Paulo, until Jul 2017]
Nicola Pezzotti [Delft University, from Apr 2017 until Jun 2017]
Catherine Plaisant [University of Maryland, from May 2017 until Jul 2017]
Vanessa Serrano Molinero [IQS School of Management. Universitat Ramon Llull, from Jun 2017 until Sep 2017]

External Collaborators
Evelyne Lutton [INRA]
Frédéric Vernier [Université Paris-Sud]

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.

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) [49], graphic designers such as Bertin [38] and Tufte [48], and HCI researchers in the field of Information Visualization [37].

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 [42] and Triesman's "preattentive processing" theory [47]. 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 [40]. 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 [39]. 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 [46], [45], [43], [44], [41]. 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

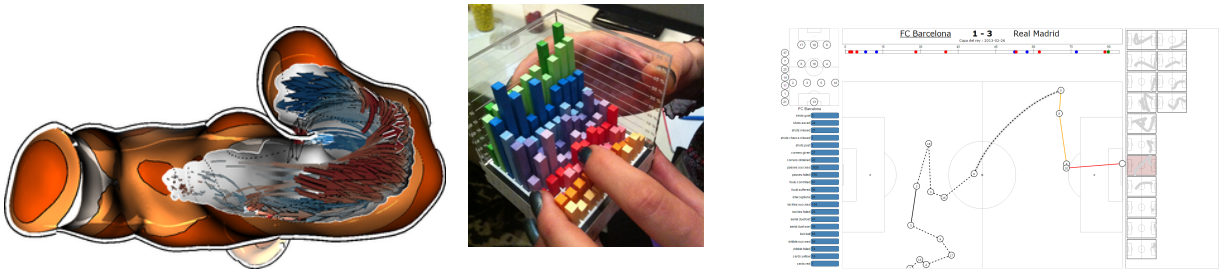

Figure 1. Example novel visualization techniques and tools developed by the team. Left: a non-photorealistic rendering technique that visualizes blood flow and vessel thickness. Middle:a physical visualization showing economic indicators for several countries, right: SoccerStories a tool for visualizing soccer games.

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.

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 2010, 2012, 2014, 2016) 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. 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 empower humans to make use of data using different types of display media and to enhance how they can understand and visually and interactively explore information. 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. 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.

4. Highlights of the Year

4.1. Highlights of the Year

4.1.1. Awards

BEST PAPERS AWARDS:

[20]
J. ZHAO, M. GLUECK, P. ISENBERG, F. CHEVALIER, A. KHAN. *Supporting Handoff in Asynchronous Collaborative Sensemaking Using Knowledge-Transfer Graphs*, in "IEEE Transactions on Visualization and Computer Graphics", 2018, vol. 24, n° 1, pp. 340-350 [*DOI :* 10.1109/TVCG.2017.2745279], https://hal.inria.fr/hal-01565560

[6]
E. DIMARA, A. BEZERIANOS, P. DRAGICEVIC. *The Attraction Effect in Information Visualization*, in "IEEE Transactions on Visualization and Computer Graphics", 2017, vol. 23, n° 1 [*DOI :* 10.1109/TVCG.2016.2598594], https://hal.inria.fr/hal-01355750

5. New Software and Platforms

5.1. 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 and building upon the AnHALytics processing chain, Cartolabe provides the user with a map of the thematics, authors and articles and their dynamics along time. 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

- Contact: Philippe Caillou
- URL: http://cartolabe.lri.fr/

5.2. 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.

- Contact: Petra Isenberg

6. New Results

6.1. HCI Requirements for Progressive Data Analysis

Participants: Jean-Daniel Fekete [correspondant], Sriram Karthik Badam, Niklas Elmqvist.

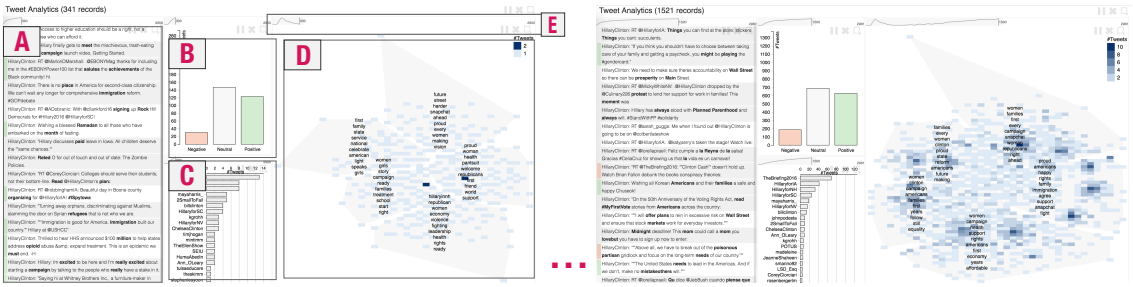

Figure 3. The InsightsFeed tool for progressive visual analytics of Twitter (left): (A) a list of tweets, (B) a sentiment chart, (C) user popularity chart, (D) a map from a 2D projection of tweets with important keywords highlighted in each region, and (E) feedback and controls over the progression and computations. (Right) The interface is progressively updated when more data is processed.

Progressive visual analytics (PVA) has emerged in recent years to manage the latency of data analysis systems. When analysis is performed progressively, rough estimates of the results are generated quickly and are then improved over time. Analysts can therefore monitor the progression of the results, steer the analysis algorithms, and make early decisions if the estimates provide a convincing picture. In this article, we describe interface design guidelines for helping users understand progressively updating results and make early decisions based on progressive estimates. To illustrate our ideas, we present a prototype PVA tool called INSIGHTSFEED for exploring Twitter data at scale. As validation, we investigate the tradeoffs of our tool when exploring a Twitter dataset in a user study. We report the usage patterns in making early decisions using the user interface, guiding computational methods, and exploring different subsets of the dataset, compared to sequential analysis without progression.

More on the project Web page: ProgressiveDataAnalysis.

6.2. Embedded Data Representations

Participants: Wesley Willett, Yvonne Jansen, Pierre Dragicevic [correspondant].

We introduced *embedded data representations*, the use of visual and physical representations of data that are deeply integrated with the physical spaces, objects, and entities to which the data refers. Technologies like lightweight wireless displays, mixed reality hardware, and autonomous vehicles are making it increasingly easier to display data in-context. While researchers and artists have already begun to create embedded data representations, the benefits, trade-offs, and even the language necessary to describe and compare these approaches remain unexplored. In our paper [18], we formalized the notion of physical data referents – the real-world entities and spaces to which data corresponds – and examined the relationship between referents and the visual and physical representations of their data. We differentiated situated representations, which display data in proximity to data referents, and embedded representations, which display data so that it spatially coincides with data referents. Drawing on examples from visualization, ubiquitous computing, and art, we explored the role of spatial indirection, scale, and interaction for embedded representations. We also examined the tradeoffs between non-situated, situated, and embedded data displays, including both visualizations and physicalizations. Based on our observations, we identified a variety of design challenges for embedded data representation, and suggested opportunities for future research and applications.

More on the project Web page: yvonnejansen.me/embedded.

6.3. Blinded with Science or Informed by Charts? A Replication Study

Participants: Pierre Dragicevic [correspondant], Yvonne Jansen.

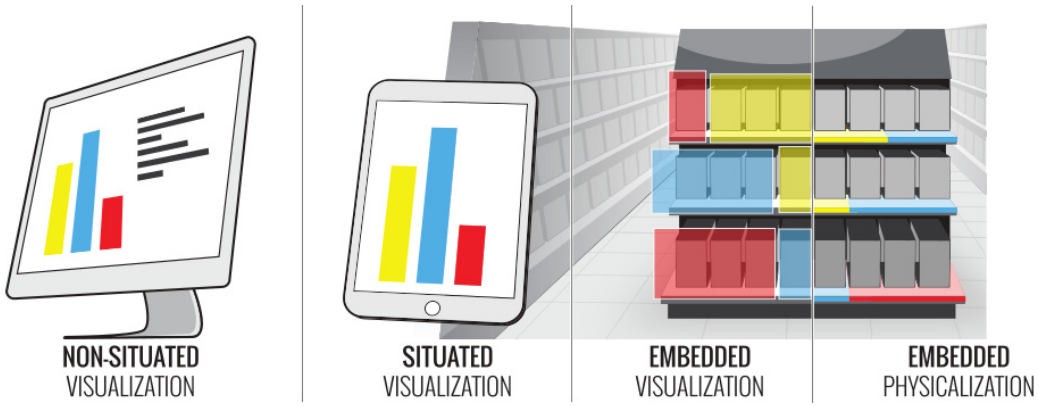

Figure 4. From left to right: A desktop setting with non-situated visualization. A situated visualization of the same data on a tablet in the store itself. An embedded visualization overlays the data on top of individual products as a heat map. An embedded physicalization displays data by changing properties of the shelves themselves.

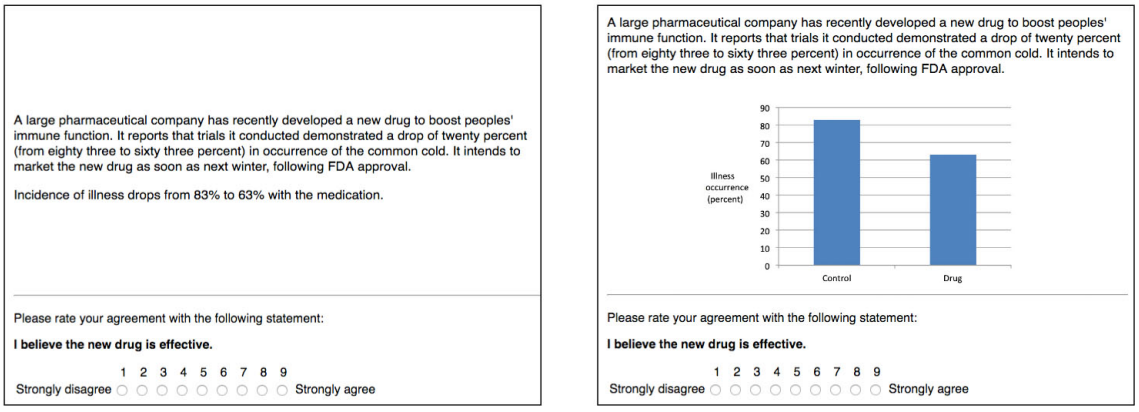

Figure 5. First page of our second experiment, replicating experiment 2 from Tal and Wansink. (a) no-chart condition, with an extra sentence repeating the two quantities with numerals; (b) chart condition: the extra sentence is replaced with a bar chart.

We provided a reappraisal of Tal and Wansink's study "Blinded with Science", where seemingly trivial charts were shown to increase belief in drug efficacy, presumably because charts are associated with science. Through a series of four replications conducted on two crowdsourcing platforms, we investigated an alternative explanation, namely, that the charts allowed participants to better assess the drug's efficacy. Considered together, our experiments suggested that the chart seems to have indeed promoted understanding, although the effect is likely very small. Meanwhile, we were unable to replicate the original study's findings, as text with chart appeared to be no more persuasive – and sometimes less persuasive – than text alone. This suggested that the effect may not be as robust as claimed and may need specific conditions to be reproduced. Regardless, within our experimental settings and considering our study as a whole (N = 623), the chart's contribution to understanding was clearly larger than its contribution to persuasion.

The main lesson from our study is that with charts, the peripheral route of persuasion cannot be studied independently from the central route: in order to establish that a chart biases judgment, it is necessary to also rigorously establish that it does not aid comprehension. Our replication also opens many relevant questions for infovis. Are charts really associated with science? More generally, what associations do charts or visualizations trigger depending on their visual design? When exactly is a chart trivial? Two arguments against minimalistic charts is that they take up space and they break the flow of the text. How do word-scale visualizations change these trade-offs?

Experimental material can be downloaded here: www.aviz.fr/blinded.

6.4. Vispubdata

Participants: Petra Isenberg [correspondant], Florian Heimerl, Steffen Koch, Tobias Isenberg, Panpan Xu, Charles Stolper, Michael Sedlmair, Torsten Möller, John Stasko.

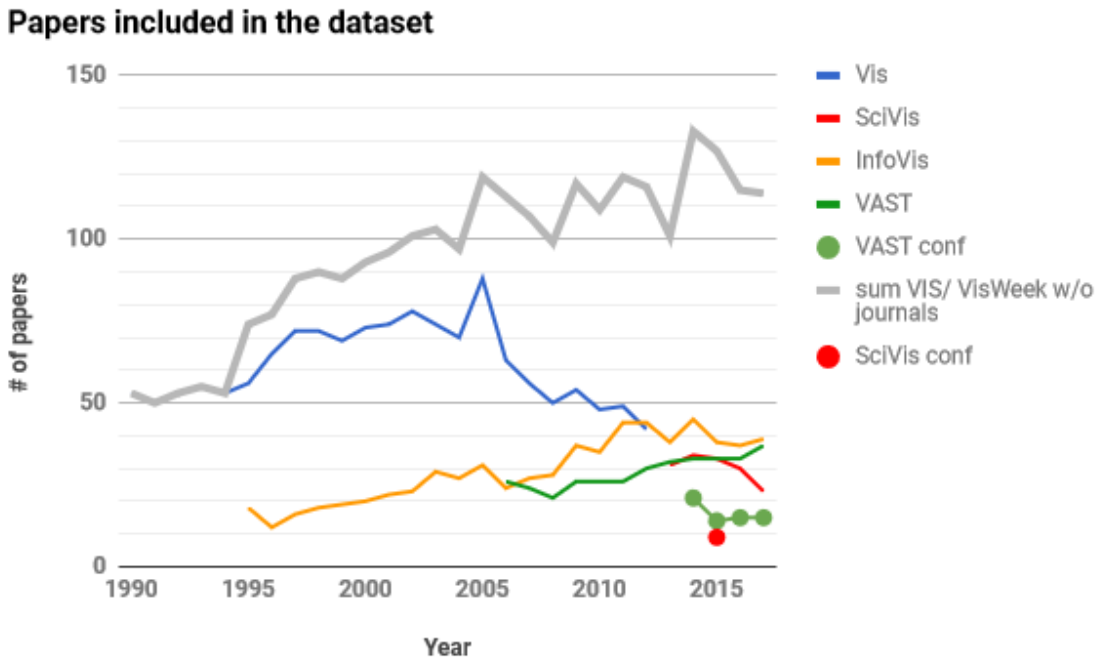

Figure 6. Overview of the files included in the dataset.

We have created and keep maintaining a dataset with information about every paper that has appeared at the IEEE Visualization (VIS) set of conferences: InfoVis, SciVis, VAST, and Vis. The information about each paper includes its title, abstract, authors, and citations to other papers in the conference series, among many other attributes. This data is meant to be useful to the broad data visualization community to help understand the evolution of the field and as an example document collection for text data visualization research.

6.5. An Exploratory Study of Word-Scale Graphics in Data-Rich Text Documents

Participants: Pascal Goffin, Jeremy Boy, Wesley Willett, Petra Isenberg [correspondant].

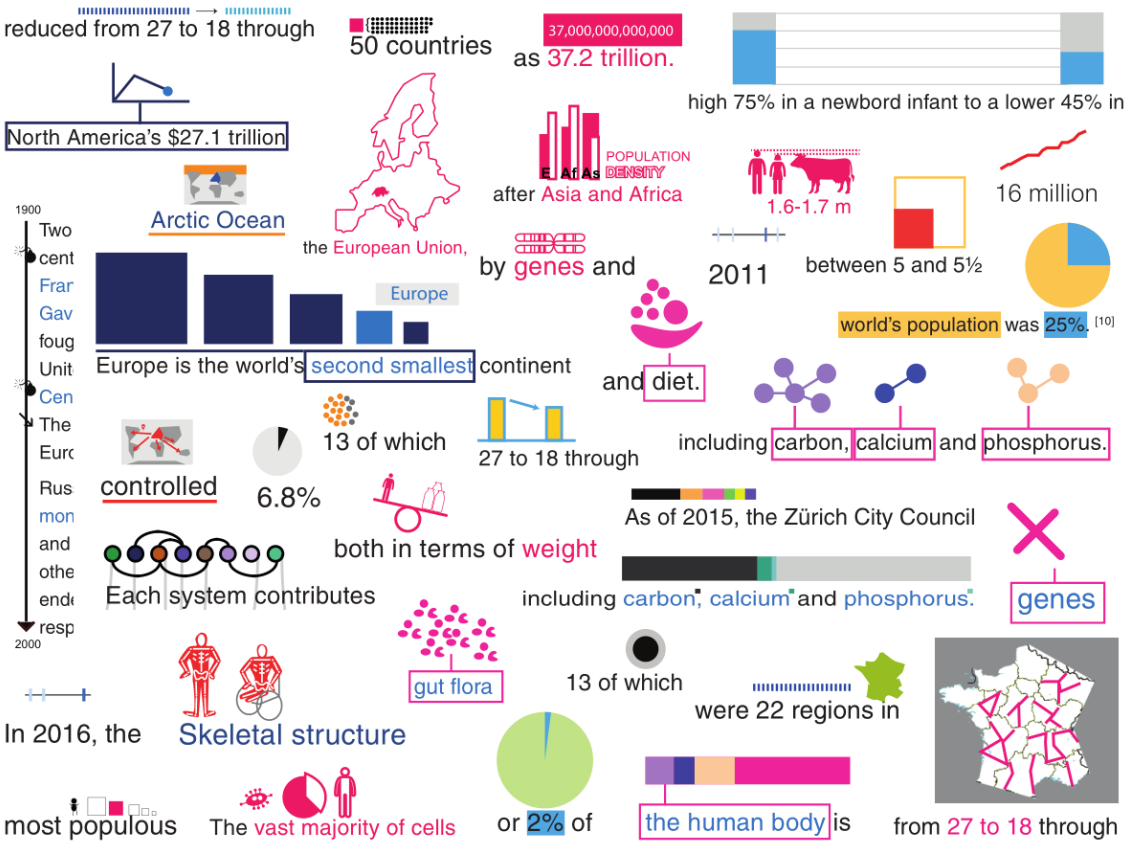

Figure 7. Overview of the word-scale visualizations created in our study.

We contribute an investigation of the design and function of word-scale graphics and visualizations embedded in text documents. Word-scale graphics include both data-driven representations such as word-scale visualizations and sparklines, and non-data-driven visual marks. Their design, function, and use has so far received little research attention. We conducted an open ended exploratory study with 9 graphic designers. The study resulted in a rich collection of different types of graphics, data provenance, and relationships between text, graphics, and data. Based on this corpus, we derived a systematic overview of word-scale graphic designs, and examine how designers used them. We also discussed the designers' goals in creating their graphics, and

characterized how they used word-scale graphics to visualize data, add emphasis, and create alternative narratives. Building on these examples, we discuss implications for the design of authoring tools for word-scale graphics and visualizations, and explore how new authoring environments could make it easier for designers to integrate them into documents.

6.6. Hybrid Tactile/Tangible Interaction for 3D Data Exploration

Participants: Lonni Besançon [correspondant], Paul Issartel, Mehdi Ammi, Tobias Isenberg.

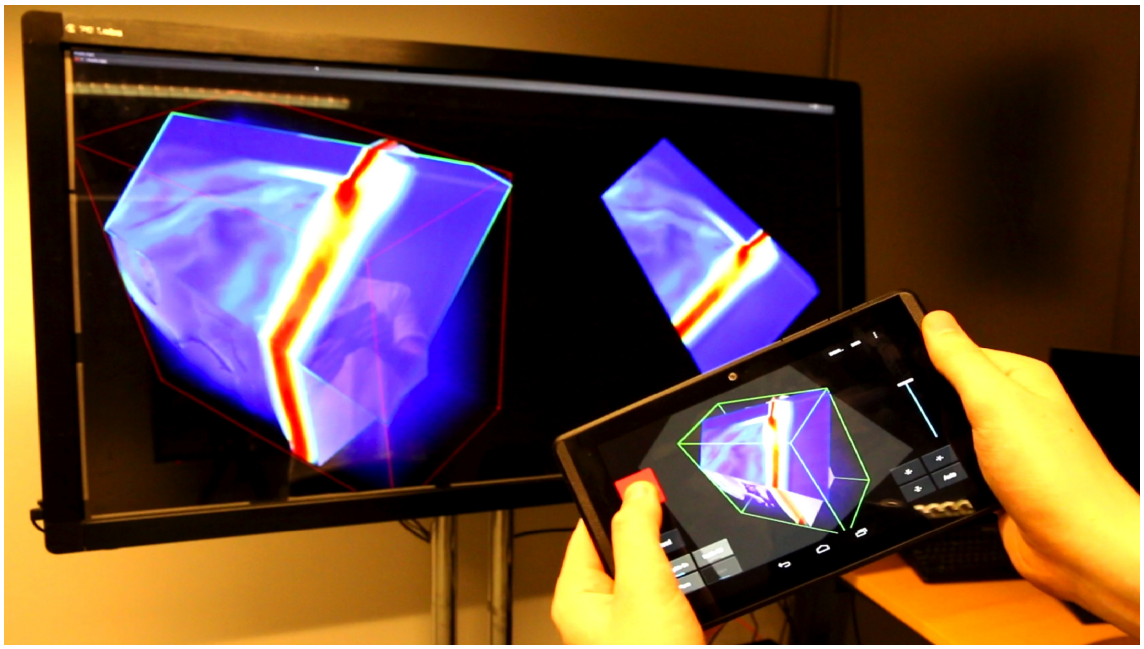

Figure 8. Picture of the hybrid interaction system.

We present the design and evaluation of an interface that combines tactile and tangible paradigms for 3D visualization. While studies have demonstrated that both tactile and tangible input can be efficient for a subset of 3D manipulation tasks, we reflect here on the possibility to combine the two complementary input types. Based on a field study and follow-up interviews, we present a conceptual framework of the use of these different interaction modalities for visualization both separately and combined—focusing on free exploration as well as precise control. We present a prototypical application of a subset of these combined mappings for fluid dynamics data visualization using a portable, position-aware device which offers both tactile input and tangible sensing. We evaluate our approach with domain experts and report on their qualitative feedback.

More on the project Web page: http://lonni.besancon.pagesperso-orange.fr/Projects/HybridInteraction/HybridInteraction.html.

6.7. Pressure-Based Gain Factor Control for Mobile 3D Interaction using Locally-Coupled Devices

Participants: Lonni Besançon [correspondant], Mehdi Ammi, Tobias Isenberg.

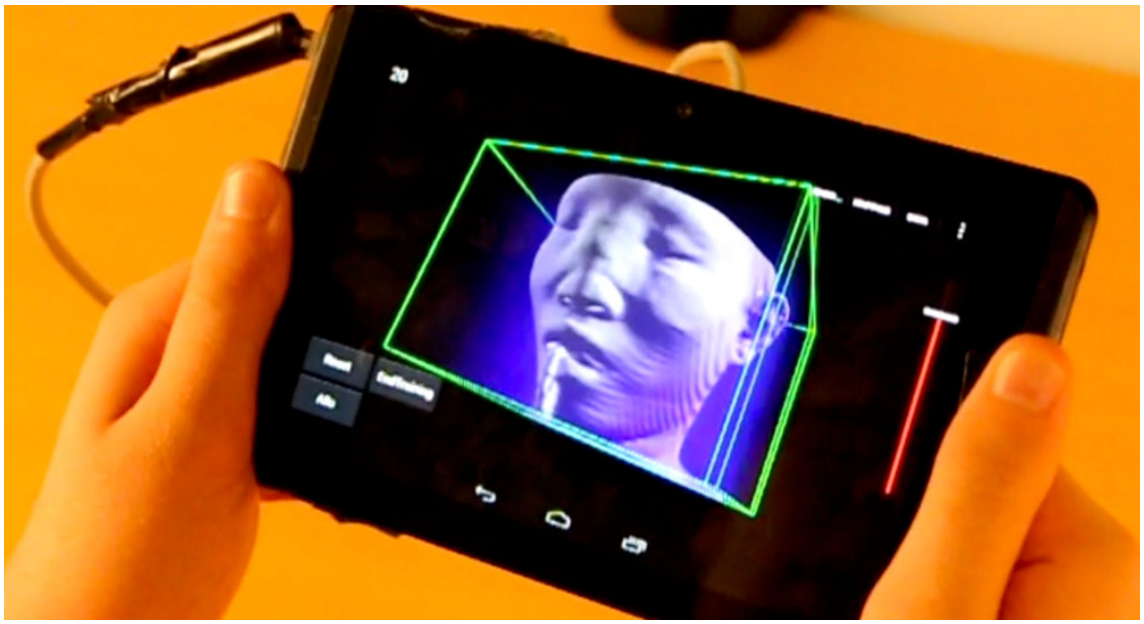

Figure 9. Picture of the pressure-based gain factor control prototype.

We present the design and evaluation of pressure-based interactive control of 3D navigation precision. Specifically, we examine the control of gain factors in tangible 3D interactions using locally-coupled mobile devices. By focusing on pressure as a separate input channel we can adjust gain factors independently from other input modalities used in 3D navigation, in particular for the exploration of 3D visualizations. We present two experiments. First, we determined that people strongly preferred higher pressures to be mapped to higher gain factors. Using this mapping, we compared pressure with rate control, velocity control, and slider-based control in a second study. Our results show that pressure-based gain control allows people to be more precise in the same amount of time compared to established input modalities. Pressure-based control was also clearly preferred by our participants. In summary, we demonstrate that pressure facilitates effective and efficient precision control for mobile 3D navigation.

More on the project Web page: http://lonni.besancon.pagesperso-orange.fr/Projects/Pressure/Pressure.html.

6.8. Pressure-Based Gain Factor Control for Mobile 3D Interaction using Locally-Coupled Devices

Participants: Lonni Besançon [correspondant], Mehdi Ammi, Tobias Isenberg.

We present the design and evaluation of pressure-based interactive control of 3D navigation precision. Specifically, we examine the control of gain factors in tangible 3D interactions using locally-coupled mobile devices. By focusing on pressure as a separate input channel we can adjust gain factors independently from other input modalities used in 3D navigation, in particular for the exploration of 3D visualizations. We present two experiments. First, we determined that people strongly preferred higher pressures to be mapped to higher gain factors. Using this mapping, we compared pressure with rate control, velocity control, and slider-based control in a second study. Our results show that pressure-based gain control allows people to be more precise in the same amount of time compared to established input modalities. Pressure-based control was also clearly preferred by our participants. In summary, we demonstrate that pressure facilitates effective and efficient precision control for mobile 3D navigation.

6.9. The Attraction Effect in Information Visualization

Participants: Evanthia Dimara [correspondant], Pierre Dragicevic, Anastasia Bezerianos.

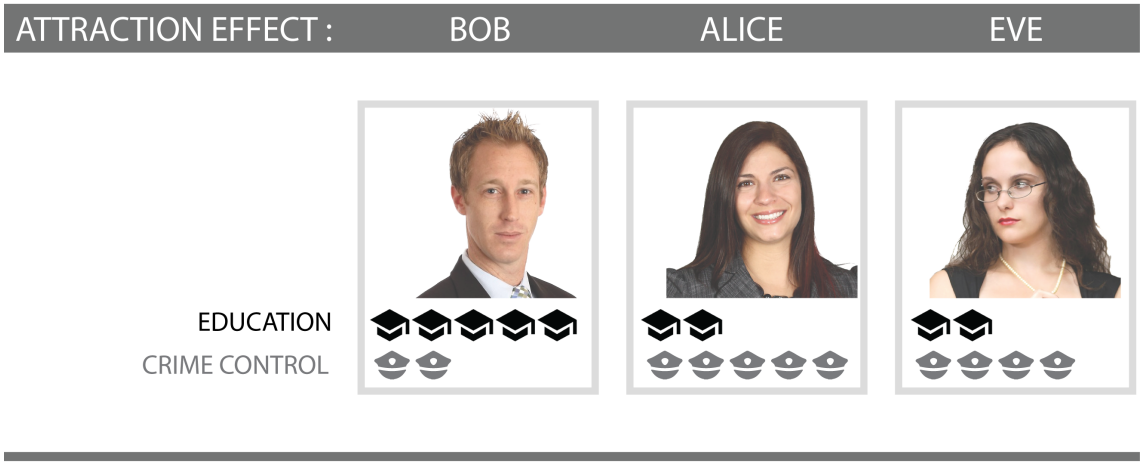

Figure 10. Example of an attraction effect in elections: Bob has an excellent education plan, while Alice is very strong in crime control. The addition of Eve, a candidate similar but slightly inferior to Alice, raises Alice's attractiveness as a candidate. This irrelevant option is called a decoy.

The attraction effect is a well-studied cognitive bias in decision making research, where one's choice between two alternatives is influenced by the presence of an irrelevant (dominated) third alternative. We examine whether this cognitive bias, so far only tested with three alternatives and simple presentation formats such as numerical tables, text and pictures, also appears in visualiza-tions. Since visualizations can be used to support decision making — e.g., when choosing a house to buy or an employee to hire — a systematic bias could have important implications. In a first crowdsource experiment, we indeed partially replicated the attraction effect with three alternatives presented as a numerical table, and observed similar effects when they were presented as a scatterplot. In a second experiment, we investigated if the effect extends to larger sets of alternatives, where the number of alternatives is too large for numerical tables to be practical. Our findings indicate that the bias persists for larger sets of alternatives presented as scatterplots. We discuss implications for future research on how to further study and possibly alleviate the attraction effect.

More on the project Web page: http://www.aviz.fr/decoy.

6.10. Narratives in Crowdsourced Evaluation of Visualizations: A Double-Edged Sword?

Participants: Evanthia Dimara [correspondant], Pierre Dragicevic, Anastasia Bezerianos.

We explore the effects of providing task context when evaluating visualization tools using crowdsourcing. We gave crowdworkers i) abstract information visualization tasks without any context, ii) tasks where we added semantics to the dataset, and iii) tasks with two types of backstory narratives: an analytic narrative and a decision-making narrative. Contrary to our expectations, we did not find evidence that adding data semantics increases accuracy, and further found that our backstory narratives can even decrease accuracy. Adding dataset semantics can however increase attention and provide subjective benefits in terms of confidence, perceived easiness, task enjoyability and perceived usefulness of the visualization. Nevertheless, our backstory narratives

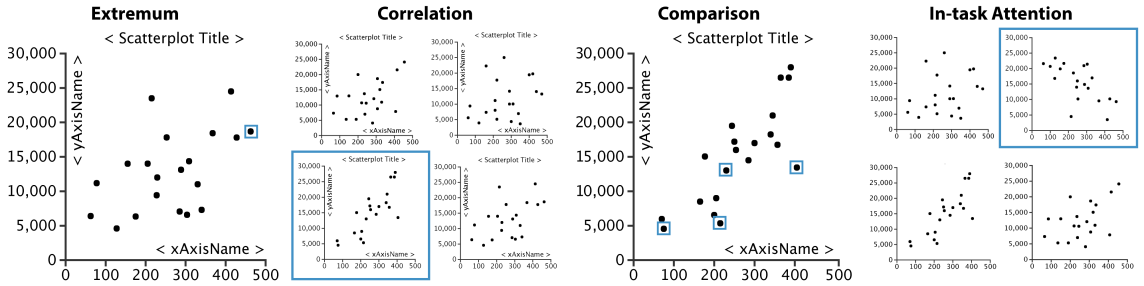

Figure 11. Stimuli used in each task (Ext, Cor and Com), and in the in-task attention test. Correct answers are annotated in blue. Axes were labeled (X,Y) for ABS, and (size m2, price ($)) in all other context conditions. The title was Diagram Z : Datapoints in ABS, and was Diagram Z : Houses in SEM (all tasks) and DM-NAR (Ext, Cor tasks). In all other conditions the title was Agency Z : Houses. Z was an integer (1, 2, 3, or 4) identifying the scatterplot.

did not appear to provide additional subjective benefits. These preliminary findings suggest that narratives may have complex and unanticipated effects, calling for more studies in this area.

More on the project Web page: http://www.aviz.fr/narratives.

6.11. Conceptual and Methodological Issues in Evaluating Multidimensional Visualizations for Decision Support.

Participants: Evanthia Dimara [correspondant], Pierre Dragicevic, Anastasia Bezerianos.

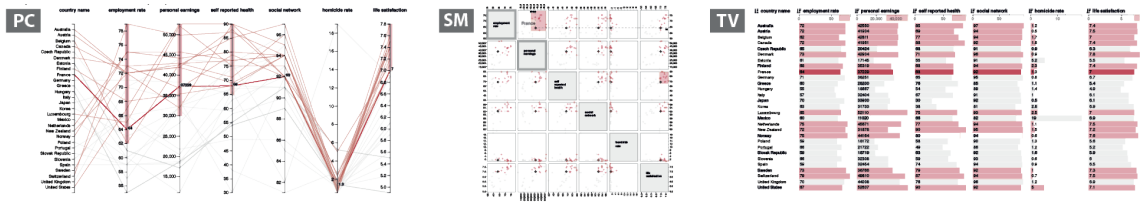

Figure 12. The visualizations we evaluated: Parallel Coordinates (PC), Scatterplot Matrix (SM) and Tabular Visualization (TV).

We explore how to rigorously evaluate multidimensional visualizations for their ability to support decision making. We first define multi-attribute choice tasks, a type of decision task commonly performed with such visualizations. We then identify which of the existing multidimensional visualizations are compatible with such tasks, and set out to evaluate three elementary visualizations: parallel coordinates, scatterplot matrices and tabular visualizations. Our method consists in first giving participants low-level analytic tasks, in order to ensure that they properly understood the visualizations and their interactions. Participants are then given multi-attribute choice tasks consisting of choosing holiday packages. We assess decision support through multiple objective and subjective metrics, including a decision accuracy metric based on the consistency between the choice made and self-reported preferences for attributes. We found the three visualizations to be comparable

on most metrics, with a slight advantage for tabular visualizations. In particular, tabular visualizations allow participants to reach decisions faster. Thus, although decision time is typically not central in assessing decision support, it can be used as a tie-breaker when visualizations achieve similar decision accuracy. Our results also suggest that indirect methods for assessing choice confidence may allow to better distinguish between visualizations than direct ones. We finally discuss the limitations of our methods and directions for future work, such as the need for more sensitive metrics of decision support.

More on the project Web page: http://www.aviz.fr/dm.

7. Partnerships and Cooperations

7.1. European Initiatives

7.1.1. FP7 & H2020 Projects

7.1.1.1. CENDARI

Title: Collaborative EuropeaN Digital/Archival Infrastructure

Programm: FP7

Duration: February 2012 - January 2016

Coordinator: Trinity College - Dublin

Partners:

Consortium of European Research Libraries (United Kingdom)

Koninklijke Bibliotheek (Netherlands)

Fondazione Ezio Franceschini Onlus (Italy)

Freie Universitaet Berlin (Germany)

King's College London (United Kingdom)

"matematicki Institutnu, Beograd" (Serbia)

Narodni Knihovna Ceske Republiky (Czech Republic)

Societa Internazionale Per Lo Studio Del Medioevo Latino-S.I.S.M.E.L.Associazione (Italy)

The Provost, Fellows, Foundation Scholars & The Other Members of Board of The College of The Holy & Undivided Trinity of Queen Elizabeth Near Dublin (Ireland)

Georg-August-Universitaet Goettingen Stiftung Oeffentlichen Rechts (Germany)

The University of Birmingham (United Kingdom)

Universitaet Stuttgart (Germany)

Universita Degli Studi di Cassino E Del Lazio Meridionale (Italy)

Inria contact: L. Romary

'The Collaborative EuropeaN Digital Archive Infrastructure (CENDARI) will provide and facilitate access to existing archives and resources in Europe for the study of medieval and modern European history through the development of an 'enquiry environment'. This environment will increase access to records of historic importance across the European Research Area, creating a powerful new platform for accessing and investigating historical data in a transnational fashion overcoming the national and institutional data silos that now exist. It will leverage the power of the European infrastructure for Digital Humanities (DARIAH) bringing these technical experts together with leading historians and existing research infrastructures (archives, libraries and individual digital projects) within a programme of technical research informed by cutting edge reflection on the impact of the digital age on scholarly practice. The enquiry environment that is at the heart of

this proposal will create new ways to discover meaning, a methodology not just of scale but of kind. It will create tools and workspaces that allow researchers to engage with large data sets via federated multilingual searches across heterogeneous resources while defining workflows enabling the creation of personalized research environments, shared research and teaching spaces, and annotation trails, amongst other features. This will be facilitated by multilingual authority lists of named entities (people, places, events) that will harness user involvement to add intelligence to the system. Moreover, it will develop new visual paradigms for the exploration of patterns generated by the system, from knowledge transfer and dissemination, to language usage and shifts, to the advancement and diffusion of ideas.'

7.2. International Initiatives

7.2.1. Informal International Partners

- University of Calgary. Pierre Dragicevic and Petra Isenberg collaborate with Wesley Willett on situated data visualization.
- University of Washington, Chicago University and University of Zurich. Pierre Dragicevic collaborates with Matthew Kay, Steve Haroz and Chat Wacharamanotham on transparent statistical reporting and efficient statistical communication
- Stanford University. Pierre Dragicevic and Jean-Daniel Fekete collaborate with Sean Follmer on swarm user interfaces.
- Chicago University and University of Maryland, Evanthia Dimara and Pierre Dragicevic collaborate with Steven Franconeri and Catherine Plaisant on a taxonomy of cognitive biases.

7.3. International Research Visitors

7.3.1. Visits of International Scientists

- Catherine Plaisant (June–July): Invited professor from 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 University of Bari, Italy. 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.

7.3.1.1. Internships

- Jaemin Jo (March–April): intern from Seoul National University, Korea. Worked on converting a KNN algorithm into a progressive form.
- Nicola Pezzotti (April–May): intern from University of Delft, The Netherlands. Worked on data structures and algorithms for managing very large (out of core) datasets in the context of progressive algorithms.

8. Dissemination

8.1. Promoting Scientific Activities

8.1.1. Scientific Events Organisation

8.1.1.1. Member of the Organizing Committees

- Jean-Daniel Fekete organized the Doctoral Colloquium (Doctoriales) for the Journées Visu 2017
- Tobias Isenberg was Posters co-chair for EuroVis 2017
- Pierre Dragicevic co-organized the CHI 2017 workshop on Moving Transparent Statistics Forward @CHI 2017.
- Petra Isenberg was Posters co-chair for VIS 2017
- Evanthia Dimara organized the workshop "DECISIVe 2017: Dealing with Cognitive Biases in Visualisations" at IEEE VIS'2017 (http://decisive-workshop.dbvis.de/).

8.1.2. Scientific Events Selection

8.1.2.1. Member of the Conference Program Committees

- Jean-Daniel Fekete was a member of the program committee for IEEE VIS 2017.
- Jean-Daniel Fekete was a member of the test of time award committee for IEEE InfoVis 2017.
- Jean-Daniel Fekete was a member of the program committee for EuroVis 2017.
- Tobias Isenberg was a member of the program committee for ACM/Eurographics Expressive 2017.
- Tobias Isenberg was a member of the program committee for ACM SUI 2017.
- Tobias Isenberg was a member of the program committee for IEEE VISAP 2017.
- Tobias Isenberg was a member of the program committee for IEEE InfoVis 2017.
- Tobias Isenberg was a member of the program committee for EuroVis 2017, full & short papers.
- Tobias Isenberg was a member of the program committee for Eurographics 2017.
- Tobias Isenberg was a member of the program committee for SCCG 2017.
- Tobias Isenberg was a member of the program committee for IEEE 3DUI 2017.
- Pierre Dragicevic was a member of the program committee for IEEE VIS 2017.
- Pierre Dragicevic was a member of the program committee for IHM 2017.
- Pierre Dragicevic was a member of the program committee for the DECISIVE 2017 workshop.
- Petra Isenberg was a member of the program committee for IEEE InfoVis 2017.
- Petra Isenberg was a member of the program committee for EuroVA 2017.
- Petra Isenberg was a member of the short paper committee for EuroVis 2017.
- Petra Isenberg was a member of the program committee for IEEE PacificVis 2017.
- Tanja Blascheck was a member of the Program Committee – NIER and Tool Tracks for VISSOFT 2017.

8.1.2.2. Reviewer

- Jean-Daniel Fekete reviewed for CHI, EuroVis, InfoVis.
- Tobias Isenberg reviewed for InfoVis, SciVis, EuroVis, SIGGRAPH, Eurographics, CHI, VR, SCCG, 3DUI, ISS, Graphics Interface, PacificVis, Expressive, SUI, VISAP.
- Pierre Dragicevic reviewed for CHI, VIS, UIST, Interact, IHM.
- Petra Isenberg reviewed for EuroVA, EuroVis, Interact, PacificVis, InfoVis.
- Christoph Kinkeldey reviewed for ACM INWUT.
- Tanja Blascheck reviewed for EuroVis, PacificVis, VISSOFT (IEEE Working Conference on Software Visualization), VRST (ACM Symposium on Virtual Reality Software and Technology).
- Lonni Besançon reviewed for 3DUI, CHI, ICMI, IHM, ISS, OzCHI, VR, VRST.

8.1.3. Journal

8.1.3.1. Member of the Editorial Boards

- Tobias Isenberg is member of the editorial board of Elsevier's Computers & Graphics journal.

- Pierre Dragicevic is member of the editorial board of the Human-centric Computing and Information Sciences (HCIS) journal.

8.1.3.2. Reviewer - Reviewing Activities

- Jean-Daniel Fekete reviewed for TVCG.
- Tobias Isenberg reviewed for TVCG.
- Pierre Dragicevic reviewed for TVCG.
- Petra Isenberg reviewed for TVCG, InfoVis Journal.
- Christoph Kinkeldey reviewed for TVCG, IEEE CG&A, IJGIS, ISPRS IJGI.
- Tanja Blascheck reviewed for JEMR (Journal of Eye Movement Research), Pattern Recognition Journal, TVCG.
- Lonni Besançon reviewed for IEEE Consumer Electronic.

8.1.4. Invited Talks

- Jean-Daniel Fekete: Seminar Dataviz : idée, méthode et perception Visualisation d'information : des principes au passage à l'échelle, INED, Paris, December 4, 2017
- Jean-Daniel Fekete: Keynote EA Artificial Evolution 2017, Progressive Data Analysis: a new computation paradigm for scalability in exploratory data analysis. October 25, 2017
- Jean-Daniel Fekete: Keynote ChinaVis 2017, Qingdao, China, Progressive Data Analysis: a new computation paradigm for scalability in exploratory data analysis , July 17, 2017
- Jean-Daniel Fekete: Invited Talk China-Germany Workshop, Qingdao, China, Visualization for the People, July 16, 2017
- Jean-Daniel Fekete: Keynote WSOM+ 2017, LORIA, Nancy, France, Visualization of Complex Networks, June 28th, 2017
- Jean-Daniel Fekete: Keynote VISIGRAPP 2017, Porto, Portugal, Understanding Complex Networks, Feb. 27, 2017
- Jean-Daniel Fekete: Invited Talk, Univ. of Konstanz and Univ. of Stuttgart, ProgressiVis: A New Language Paradigm for Scalability in Exploratory Analytics, Feb. 9, 2017
- Jean-Daniel Fekete: Keynote Speech, Univ. of Grenoble, Visualizing [Dense, Dynamic, Complex] Networks, Feb. 2, 2017
- Jean-Daniel Fekete: Open Data Conference, La Rochelle, Panel on Open Data and Visualization, Jan. 17, 2017
- Tobias Isenberg: Invited talk at TU Wien, Austria, December 22: "Interactive Navigation and Selection using Tactile and Tangible Inputs for 3D Data Exploration"
- Tobias Isenberg: Invited talk at Visualization research group, University of Bergen, Norway, April 7: "Abstraction in Non-Photorealistic Rendering and Illustrative Visualizations."
- Tobias Isenberg: Invited talk at Dept. of Computer Science, University of Bergen, Norway, April 6: "Tactile Navigation and Selection for 3D Data Exploration."
- Tobias Isenberg: Invited talk at Connecting The Dots/Intelligent Trackers (CTD/WIT 2017), Orsay, France, March 7: "Abstraction in Scientific Data Visualization: Application to Brain Connectivity and Structural Biology."
- Pierre Dragicevic: "Statistical Dances: Why No Statistical Analysis is Reliable and What To Do About It". Séminaires Recherche Reproductible, LIG, Grenoble. 22 June 2017.
- Petra Isenberg: "Evaluation in Visualization: A closer look at current practices, issues, and perspectives". University of Stuttgart, Visualization Seminar Series
- Petra Isenberg: "Evaluation in Visualization: A closer look at current practices, issues, and perspectives". Technical University of Vienna, Visualization Seminar Series

- Tanja Blascheck: “Evaluating Interactive Visualizations using Eye Tracking, Interaction Logs, and Think-Aloud Protocols”. Inria, Aviz, Saclay, France, 3 March 2017.
- Kuno Kurzhals and Tanja Blascheck: “Visual Analysis of Eye Tracking Data”. Popakademie, Mannheim, Germany, 3 July 2017.
- Tanja Blascheck: “ Understanding Interactive Visualizations: Leveraging Eye Movements and Visual Analytics”. Hochschule Karlsruhe, Karlsruhe, Germany, 31 August 2017.
- Evanthia Dimara: “The Attraction Effect in Information Visualization”. Invited talk at University of Athens, 28 September 2017.
- Evanthia Dimara: “Biais cognitifs dans la visualisation d’information: implications pour l’évaluation”. Talk at Visu 2017.

8.1.5. Leadership within the Scientific Community

- Jean-Daniel Fekete is a member of the Steering Committee of EuroVis (Eurographics WG on Data Visualization).
- Jean-Daniel Fekete is a member of the Steering Committee of the IEEE Information Visualization Conference.
- Jean-Daniel Fekete is a member of the Eurographics Publication Board.
- Tobias Isenberg is a member of the Executive Committee of the Visualization and Computer Graphics Technical Committee of the IEEE Computer Society and serves as Publications Chair
- Tobias Isenberg is a member of the Steering Committee of Expressive (Joined Symposium on Computational Aesthetics, Sketch-Based Interfaces & Modeling, and Non-Photorealistic Animation & Rendering)

8.1.6. Scientific Expertise

- Tobias Isenberg reviewed for NSERC.
- Pierre Dragicevic reviewed for NSERC.

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

- “Information Visualization” taught by Jean-Daniel Fekete at Polytechnique, Data Science, Saclay, France, Dec. 2017
- “Big Data Visual Analytics” seminar taught by Jean-Daniel Fekete at Centrale Supelec, Decision Support and Business of Intelligence, Nov. 28th, Saclay, France, 2017
- “Information Visualization and Visual Analytics” taught by Jean-Daniel Fekete at ISCD Summer School, Roscoff, France, August 2017
- “Photorealistic Rendering” taught by Tobias Isenberg at Polytech Paris-Sud and Université Paris-Saclay, France
- “Introduction to Computer Graphics” taught by Tobias Isenberg at Polytech Paris-Sud, France
- “Non-Photorealistic Rendering” taught by Tobias Isenberg at the University of Granada, Spain
- “Introduction to Statistics” guest lecture by Pierre Dragicevic for the Visual Analytics Master Course at École Centrale, Paris.
- “Interactive Information Visualization” taught by Petra Isenberg at Université Paris Sud
- “Visual Analytics” taught by Petra Isenberg at CentraleSupelec

8.2.2. Supervision

- PhD: Evanthia Dimara, Information Visualization for Decision Making, Université Paris-Sud, 2014, Pierre Dragicevic and Anastasia Bezerianos. Defended on Nov 30.

- PhD: Lonni Besançon, An Interaction Continuum for Scientific Visualization, Université Paris-Sud, 2014, Tobias Isenberg. Defended on December 14.
- PhD: Paola Llerena Valdivia, Wavelet-based analysis of time-varying data on graphs, University of São Paulo - USP, 2017, Jean-Daniel Fekete, Luis Gustavo Nonato.
- PhD: Marc Barnabé, Multiscale reconstruction of microbial ecosystems using semi-supervised machine learning, Université Paris-Sud, 2017, Jean-Daniel Fekete, Evelyne Lutton, INRA.
- PhD in progress: Xiyao Wang, Augmented Reality Environments for the Interactive Exploration of 3D Data, Univ. Paris-Sud; 2017, Tobias Isenberg
- PhD in progress: Sarkis Halladjian, Spatially Integrated Abstraction of Genetic Molecules, Univ. Paris-Sud; 2017, Tobias Isenberg
- PhD in progress: Haichao Miao, Visual Abstraction and Modeling for DNA Nanotechnology, TU Wien, Austria, 2016, Tobias Isenberg

8.2.3. Juries

- Jean-Daniel Fekete: Member of the PhD committee of Dr. Arnaud Prouzeau.
- Jean-Daniel Fekete: Member of the PhD committee of Dr. Antoine Lhuillier.
- Jean-Daniel Fekete: Member of the PhD committee of Dr. Alexandre Perrot.
- Jean-Daniel Fekete: Member of the PhD committee of Dr. Nicolas Médoc.
- Jean-Daniel Fekete: Member of the HdR committee of Dr. Jean-Philippe Cointet.
- Jean-Daniel Fekete: Member of the HdR committee of Dr. Gilles Bailly.
- Tobias Isenberg: Member of the PhD committee of Dr. Paul Issartel.
- Pierre Dragicevic: Hiring committee for tenure-track assistant Professor of Information Visualization, University of Copenhagen.
- Pierre Dragicevic: Member of the Commission Consultative de Spécialistes de l'Université Paris-Sud (CCSU).
- Pierre Dragicevic: Mid-term PhD evaluation committee of Michael Wessely.
- Pierre Dragicevic: Mid-term PhD evaluation committee of Abby Liu.
- Pierre Dragicevic: Reviewer for Ruoqi He's M2 internship.
- Petra Isenberg: Jury Inria Starting Research Positions

8.3. Popularization

- Jean-Daniel Fekete contributed to the DataVis section of the Terra Data exhibition at La Cité des Sciences, April 4th 2017 to January 7th 2018
- Jean-Daniel Fekete contributed to the exhibition on Jacques Bertin at EHESS Paris, November 14th to December 15th 2017
- Jean-Daniel Fekete and Charles Perin organized a workshop on data visualization for the "retrospective Jacques Bertin" at EHESS Paris on November 23-24 2017
- Pierre Dragicevic and Yvonne Jansen: the Curated List of Physical Visualizations is continuously being updated.
- Pierre Dragicevic and Jean-Daniel Fekete: Demo of Zooids at Inria's 50th anniversary. 7 Nov 2017.
- Jean-Daniel Fekete and Pierre Dragicevic interviewed by France Culture (la méthode scientifique) on Zooids. 21 Dec 2017.
- The Zooids video has been watched 12 million times, shared 65,000 times and liked 86,000 times on Facebook.

9. Bibliography

Publications of the year

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[2] M. BEHRISCH, B. BACH, M. HUND, M. DELZ, L. VON RÜDEN, J.-D. FEKETE, T. SCHRECK. *Magnostics: Image-based Search of Interesting Matrix Views for Guided Network Exploration*, in "IEEE Transactions on Visualization and Computer Graphics", 2017, 1 p. [*DOI :* 10.1109/TVCG.2016.2598467], https://hal.inria.fr/hal-01377861

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[6] *Best Paper*
E. DIMARA, A. BEZERIANOS, P. DRAGICEVIC. *The Attraction Effect in Information Visualization*, in "IEEE Transactions on Visualization and Computer Graphics", 2017, vol. 23, n° 1 [*DOI :* 10.1109/TVCG.2016.2598594], https://hal.inria.fr/hal-01355750.

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[20] *Best Paper*
J. ZHAO, M. GLUECK, P. ISENBERG, F. CHEVALIER, A. KHAN. *Supporting Handoff in Asynchronous Collaborative Sensemaking Using Knowledge-Transfer Graphs*, in "IEEE Transactions on Visualization and Computer Graphics", 2018, vol. 24, n° 1, pp. 340-350 [*DOI :* 10.1109/TVCG.2017.2745279], https://hal.inria.fr/hal-01565560.

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