INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team aviz

Analysis and Visualization

Saclay - Île-de-France

Theme : Interaction and Visualization

Activity Report

2010

Table of contents

1. Team

Research Scientists

Jean-Daniel Fekete [Team Leader, Senior Researcher, HdR]
Évelyne Lutton [Junior Researcher]
Pierre Dragicevic [Junior Researcher]
Petra Isenberg [Junior Researcher]

External Collaborators

Anastasia Bezerianos [École Centrale Paris, Assistant Professor]
Tobias Isenberg [University of Groningen, Digiteo Chair of Excellence for 2010–2012]

Technical Staff

Pierre-Luc Hémery [11/2009 to 11/2011, Engineer ADT]
Xiujun Li [11/2009 to 11/2010, Engineer on the ReActivity project]

PhD Students

Anissa Aroua [09/2010, Co-Advised by Évelyne Lutton and Anastasia Bezerianos (École Centrale Paris)]
Nicolas Heulot [09/2010, Co-Advised by Michael Aupetit (CEA LIST) and Jean-Daniel Fekete]
Yvonne Jansen [12/2010, Co-Advised by Pierre Dragicevic and Jean-Daniel Fekete]
Wael Khemiri [09/2008, Co-Advised by Jean-Daniel Fekete, Ioana Manolescu (INRIA, Gemo) and Véronique Benzaken (Paris-Sud, BD)]

Post-Doctoral Fellows

Nadia Boukhelifa [until 10/2010, Post-doctoral Researcher on the ReActivity Project]
Fanny Chevalier [until 02/2010 Post-doctoral Researcher]

Administrative Assistants

Hélène Milome [until Oct. 2010]
Alexandra Merlin [since Oct. 2010]

2. Overall Objectives

2.1. Objectives

All human activities are being transformed by our rapidly increasing abilities to collect, manage and understand vast amounts of data. A 2003 study estimated that the amount of data produced in the world was increasing by 50% each year[1]. According to SearchEngineWatch[2], the amount of information made available through Internet search engines has grown exponentially for the last decade, and major Web search engines currently index more than 2 billion documents. However, since our brains and sensory capacities have not evolved in the meantime, gaining competitive advantage from all this data depends increasingly on the effectiveness with which we support human abilities to perceive, understand, and act on the data.

With this increase of data, the traditional scientific method of applying model-based analysis to understand the data is no longer sufficient. We have access to data that we have never encountered before and have little or no idea of applicable models. Therefore, we need to explore them first to gain insights and eventually find models. This process has already been promoted by John Tukey in his 1977 book on *Exploratory Data Analysis*[3] which has become a branch of the domain of statistics. Whereas EDA is ultimately interested by finding models, data exploration can also reveal relevant facts that are, in themselves interesting and important.

[1] Peter Lyman and Hal R. Varian. How much information. Retrieved from http://www.sims.berkeley.edu/how-much-info-2003, 2003.
[2] http://www.searchenginewatch.com
[3] John W. Tukey. *Exploratory Data Analysis*. Addison-Wesley, 1977.

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. It focuses on four research themes:

- *Methods to visualize and smoothly navigate through large datasets;*
- *Efficient analysis methods to reduce huge datasets to visualizable size;*
- *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 four 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.

Evaluation methods to assess their effectiveness and usability: Evaluation of Visual Analytics tools is currently a challenge. Traditional HCI evaluation has focused on measuring performance (speed, error rate) for well-specified tasks. Visual Analytics is about developing insights from data. Measuring the number or quality of insights is difficult and not well understood. To address this problem, we have been actively working in three different directions: organizing workshops to gather experience and principles from researchers, co-organizing the Information Visualization Contest[5] to establish benchmarks for Information Visualization, and developing a framework to help evaluate Information Visualization applications built using the InfoVis Toolkit. To improve evaluation, we want to improve both theoretical and practical methods. We plan to add experiment modules into the InfoVis Toolkit to simplify the planning and realization of controlled experiments.

Engineering tools: for building visual analytic 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 four 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.

2.3. Highlights

Petra Isenberg Received the Best Paper Award at BELIV 2010 for her work on "work on Evaluating Information Visualization in Large Companies: Challenges, Experiences and Recommendations" [22].

Petra Isenberg Received an Honorable Mention at VAST 2010 for her work on "An Exploratory Study of Co-located Collaborative Visual Analytics around a Tabletop Display" [18].

Roadmap for Research in Visual Analytics: AVIZ contributed to the new book "Mastering The Information Age — Solving Problems with Visual Analytics"[28] written for describing what Visual Analytics is and why it needs basic research in Europe.

Strong collaboration on Database/Workflow/Visualization: AVIZ has continued its strong collaboration with the LEO INRIA project-team and the BD LRI group to tackle the problem of "Interactive data-intensive workflows for scientific applications".

We have continued to improve our workflow model for managing scientific data and will present it to a major conference in the field of databases [12].

3. Scientific Foundations

3.1. Scientific Foundations

The scientific foundations of Visual Analytics lie primarily in the domains of Information 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) [46], graphic designers such as Bertin [34] and Tufte [45], and HCI researchers in the field of Information Visualization [33].

EDA is complementary to classical statistical analysis. Classical statistics starts from a *problem*, gathers *data*, design 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 [39] and Triesman's "preattentive processing" theory [44]. 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 [37]. 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 [35]. 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 [5] [42], [40], [41], [38]. 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.

4. Application Domains

4.1. Introduction

AVIZ develops active collaboration with users from various application domains, making sure it can support their specific needs. By studying similar problems in different domains, we can begin to generalize our results and have confidence that our solutions will work for a variety of applications. Our current application domains include:

- Social Network Analysis, in cooperation with Microsoft Research and the University of Calgary;
- Biological research, in cooperation with Institut Pasteur;

- Digital Libraries, in cooperation with the French National Archives and the Wikipedia community;
- eScience, in collaboration with Microsoft Research (see 7.1) and with the INRIA LEO and LRI BD groups (see 7.3).

4.2. Social Network Analysis

In the social networks domain, we are working on exploratory visualization. Current studies in social networks presuppose that users know the nature of the networks they want to explore and the kinds of of transformations and layouts that will best suit their needs. This is often not true, and tools are very weak at helping users understand the nature of their networks and the transformations they could perform to get meaningful insights.

We have been focusing on the use of the matrix representation to explore large graphs. Matrices present challenging problems both interactively and mathematically. We are preparing a survey on methods to reorder matrices, whether from graphs from tabular data.

We are now expanding our research towards multivariate social networks and, more importantly, collaborative visualization and exploration of social networks using the wall-size display WILD recently installed at INRIA/LRI.

We have also designed and published about a novel hybrid system for visualizing genealogical graphs using a layout called "Quilts". The GeneaQuilt system[7] uses a diagonally organized layered graph to visualize a large number of generations in an interactive system, available at http://www.aviz.fr/geneaquilts.

4.3. Biological Visualization

Bioinformatics uses many complex data structures such as phylogenetic trees and genomes made of multi-scale parts (sequences of base pairs, genes, interaction pathways etc.) Biologists navigate through multitudes of these varied and complex structures daily in complex, changeable, data- and insight-driven paths. They also often need to edit these structures to annotate genes and add information about their functions. Visual Analytics is a powerful tool to help them, as we are currently pursuing in an exploratory work with Institut Pasteur on "New Generation Sequencing" and the exploration of huge biological datasets[32].

4.4. Digital Libraries

In the digital Library domain, we collaborate with Wikipedia contributors to improve Wikipedia, as well as with historians such as the French National Archives on the National Center of Renaissance on exploratory projects to visualize and analyze historical documents (see 7.1.)

4.5. eScience

Part of our research consists in supporting traditional sciences with high-level tools to help analyze and make sense of large datasets. We apply our tools and techniques to biology, social sciences and to Wikipedia which has become a major supporting tool for scientists (see 7.1). We also design software infrastructures to help scientists perform their analytical tasks with high-level tools instead of having to learn complex tools requiring computer science skills (see 7.3).

5. Software

5.1. GraphDice

Participants: Jean-Daniel Fekete [correspondant], Anastasia Bezerianos, Pierre Dragicevic, Niklas Elmqvist.

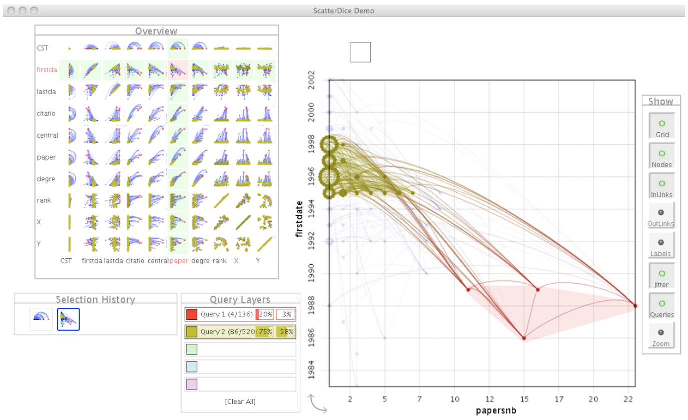


Figure 1. Screenshot of the GraphDice program.

GraphDice [6] is a visualization system for exploring multivariate networks (Fig. 1). GraphDice builds upon our previous system ScatterDice (best paper award at the IEEE InfoVis 2008 conference) [2]: it shows a scatter plot of 2 dimensions among the multiple ones available and provides a very simple paradigm of 3D rotation to change the visualized dimensions. The navigation is controlled by a scatter plot matrix that is used as a high-level overview of the dataset as well as a control panel to switch the dimensions.

While ScatterDice works on any tabular dataset (e.g. CSV file), the GraphDice system show networks using a node-link diagram representation as a scatter plot with links drawn between connected nodes. See http://www.aviz.fr/graphdice for more information and downloads.

5.2. The InfoVis Toolkit

Participant: Jean-Daniel Fekete [correspondant].

The InfoVis Toolkit [3] is an Interactive Graphics Toolkit written in Java to facilitate the development of Information Visualization applications and components.

The InfoVis Toolkit implements several visualization techniques (Fig. 2), as well as interaction techniques related. It is used for teaching the Information Visualization course (Masters level, Univ. of Paris-Sud) and is the basis for all AVIZ contracts. It is our main development platform for information visualization; most of our Information Visualization prototypes rely on it. It is available at http://ivtk.sourceforge.net.

In the forthcoming years, it will be superseded by extensions of the Obvious Toolkit (see 5.3).

5.3. The Obvious Toolkit

Participants: Pierre-Luc Hémery, Jean-Daniel Fekete [correspondant].

The Obvious Toolkit is a new Interactive Graphics Toolkit written in Java to facilitate the interoperability between Information Visualization toolkits and components (Fig. 3).

The Obvious Toolkit is an abstraction layer above visualization toolkits. Currently, it connect the most popular toolkits in Java: Prefuse, the InfoVis Toolkit, Improvise, as well as other libraries such as the Java Database Communication Toolkit (JDBC) and some others.

It is meant to provide an abstraction layer for information visualization application builders so that they can postpone their choice of a concrete toolkit to use. When the choice should be done, one of the toolkits or all of them can be connected dynamically to Obvious. It is available at http://code.google.com/p/obvious.

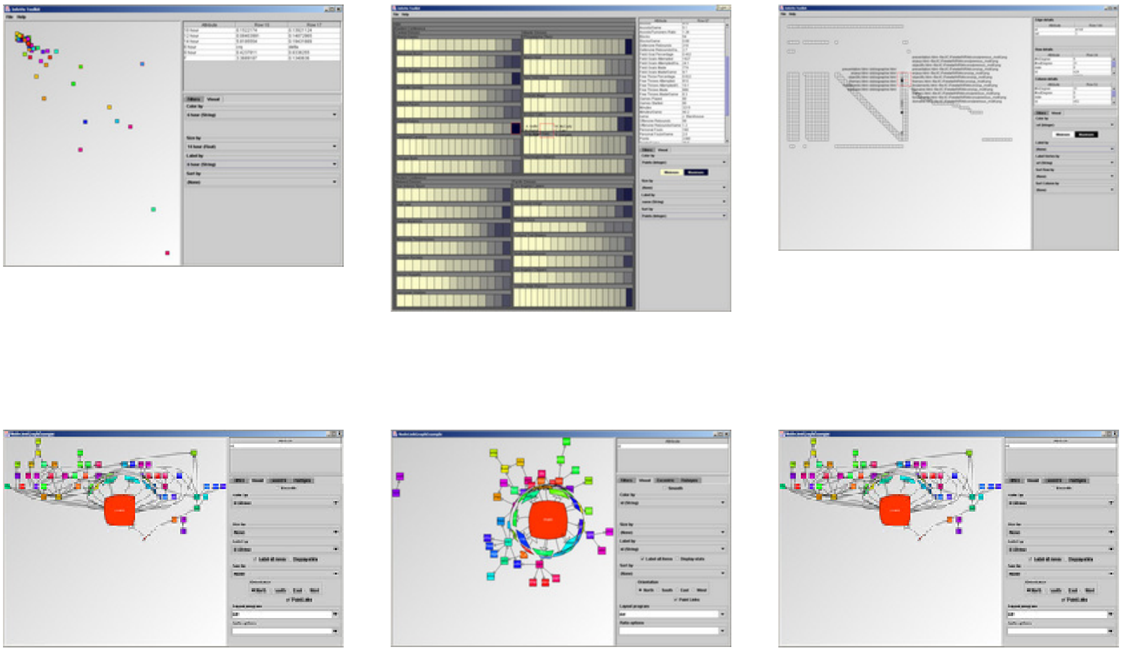


Figure 2. Several visualizations produced using the Infovis Toolkit

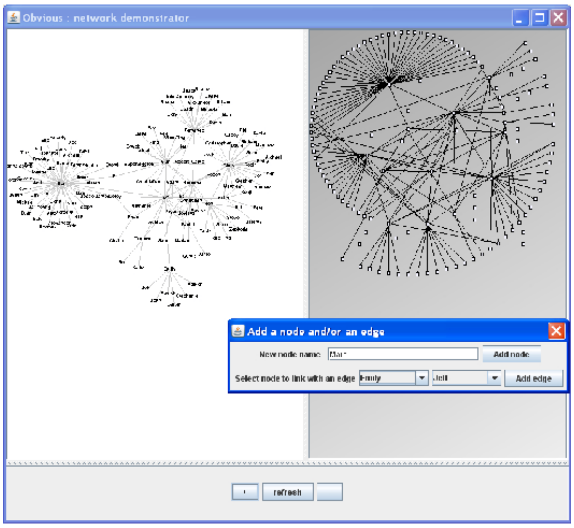


Figure 3. The Obvious toolkit showing the same graph with a Prefuse and an IVTK rendering.

5.4. GeneaQuilts

Participants: Jean-Daniel Fekete [correspondant], Pierre Dragicevic, Anastasia Bezerianos, Julie Bae, Ben Watson.

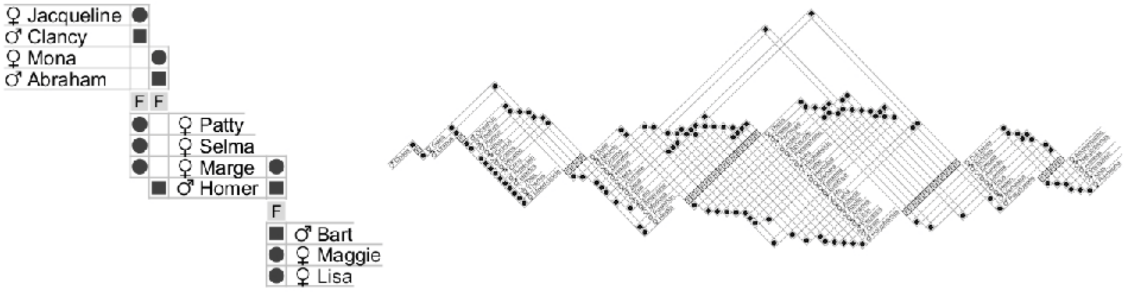


Figure 4. The genealogy of the Simpsons family (left) and of the Greek Pantheon (right), produced by the GeneaQuilts software.

GeneaQuilts [7] is a new genealogy exploration software that allows genealogists and historians to visualize and navigate in large genealogies of up to several thousand individuals (Fig. 4). The visualization takes the form of a diagonally-filled matrix, where rows are individuals and columns are nuclear families. The GeneaQuilts system includes an overview, a timeline, search and filtering components, and a new interaction technique called Bring & Slide that allows fluid navigation in very large genealogies.

GeneaQuilts is available at http://www.aviz.fr/geneaquilts/. The last ten days, this Web page has been featured in several InfoVis and genealogy Websites and has been visited 3000 times.

5.5. Diffamation

Participants: Fanny Chevalier, Pierre Dragicevic [correspondant], Anastasia Bezerianos, Jean-Daniel Fekete.

The Diffamation system [14] allows rapid exploration of revision histories such as Wikipedia or subversion repositories by combining text animated transitions (Fig. 5) with simple navigation and visualization tools. Diffamation can be used for example to get a quick overview of the entire history of a Wikipedia article or to see what happened to one's contributions. This tools complements classical diff visualizations: once moments of interest have been identified, classical diff visualizations can come in useful to compare two given revisions in detail.

The Diffamation revision exploration system is available at http://www.aviz.fr/diffamation/. It has been presented at the plenary session of the Ubuntu Developer Summit, and Ubuntu developers are currently considering re-implementing it.

6. New Results

6.1. Evaluating the Benefits of Animated Text Transitions

Participants: Fanny Chevalier, Pierre Dragicevic [correspondant], Anastasia Bezerianos, Jean-Daniel Fekete.

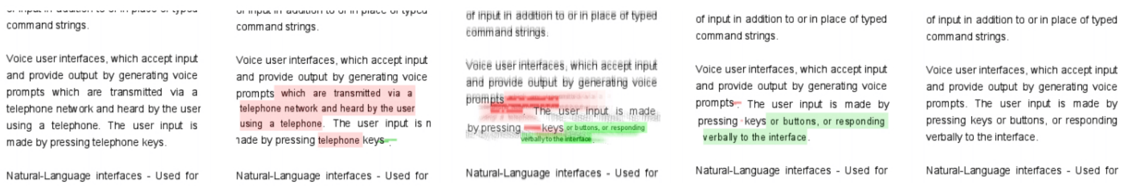
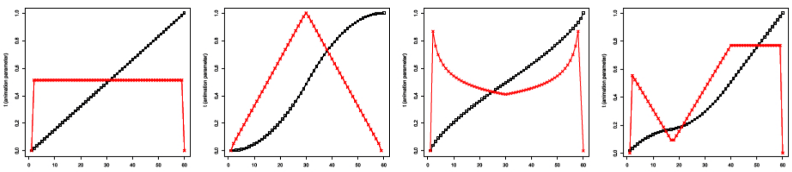


Figure 5. Detail of an animated transition between two revisions of the Wikipedia article User interfaces.

We examined the benefits of using text animated transitions for navigating in the revision history of textual documents [14]. We have designed an animation vocabulary for smoothly animating changes between text revisions (Fig. 5), and have shown this technique to be effective for tasks involving tracking changes in portions of text over time. Our controlled user study suggests that smooth text animation allows users to track changes in the evolution of textual documents more effectively than flipping pages. This technique has been implemented in a system that supports rapid exploration of revision histories (see 5.5).

6.2. Evaluating Temporal Distortion Schemes for Animated Transitions

Participants: Pierre Dragicevic [correspondant], Anastasia Bezerianos, Niklas Elmqvist, Wakas Javed.



(a) Constant rate. (b) Slow-in/Slow-out. (c) Fast-in/Fast-out. (d) Adaptive rate (frame 18).

Figure 6. Four different time distortion techniques for an animated transition.

Animated transitions are popular in many visual applications but they can be difficult to follow, especially when many objects move at the same time. One informal design guideline for creating effective animated transitions has long been the use of slow-in/slow-out pacing, but no empirical data exist to support this practice. We remedy this by studying object tracking performance under different conditions of temporal distortion, i.e., constant speed transitions, slow-in/slow-out, fast-in/fast-out, and an adaptive technique that slows down the visually complex parts of the animation (Fig. 6). Slow-in/slowout outperformed other techniques, but we saw technique differences depending on the type of visual transition.

These results provide solid empirical data on the use of animation for graphical user interfaces, an area that so far has largely been dominated by design principles from general animation that may not necessarily transfer to interaction design. Our results have just been conditionally accepted to the ACM CHI 2011 conference.

6.3. Evaluating Adaptive Color Scale Optimization for Visual Exploration

Participants: Niklas Elmqvist, Pierre Dragicevic [correspondant], Jean-Daniel Fekete.

Figure 7. A global Color Lens applied to an X-Ray image. The color scale dynamically adapts to the lens contents.

Visualization applications routinely map quantitative attributes to color using color scales. Although color is an effective visualization channel, it is limited by both display hardware and the human visual system. We proposed a new interaction technique that overcomes these limitations by dynamically optimizing color scales based on a set of sampling lenses. The technique inspects the lens contents in data space, optimizes the initial color scale, and then renders the contents of the lens to the screen using the modified color scale (Fig. 7). We presented two prototype implementations of this pipeline and validated our approach with two mutually linked and complementary user studies comparing the Color Lens with explicit contrast control for visual search. The Color Lens technique was significantly faster overall than the contrast slider for visual search tasks, and this better speed came at no extra cost in accuracy. Our results have been accepted this year to the TVCG journal [8].

6.4. Visualisation of Evolutionary Algorithms behaviour using GraphDice and GeneaQuilt

Participants: Évelyne Lutton [correspondant], Jean-Daniel Fekete.

An experimental analysis of evolutionary algorithms usually generates a huge amount of multidimensional data, including numeric and symbolic data. It is difficult to correctly navigate in such a set of data, in order for instance to be able to tune the parameters or evaluate the efficiency of some operators. Usual features of existing EA visualisation systems consist in visualising time- or generation-dependent curves (fitness, diversity, or other statistics). When dealing with genomic informations, the task becomes more difficult, as a convenient visualisation strongly depends on the considered fitness landscape. In this latter case the raw data are usually semi-structured sets of successive populations of points of a complex multidimensional space. We investigate the use of GraphDice and GeneaQuilt to navigate in such a complex set of data (Fig. 8). We consider here an off-line analysis, i.e. the data set as a static set, but the analysis we propose can be extended to on-line visualisation.

6.5. Evaluating Directed-Edge Representations for Graphs

Participants: Danny Holten, Petra Isenberg [correspondant], Jarke J. van Wijk, Jean-Daniel Fekete.

We provided novel design considerations for choosing directed-edge representations for node-link diagrams [17]. Node-link diagrams are probably the most popular type of graph representations ; nodes are depicted as dots and links as straight or curved lines connecting the nodes. We conducted a study comparing five directed-edge representations for use in node-link diagrams (Fig. 9): tapered (T), animated (A), animated compressed (A_c), glyph (G), and glyph compressed (G_c). We tested these representation on

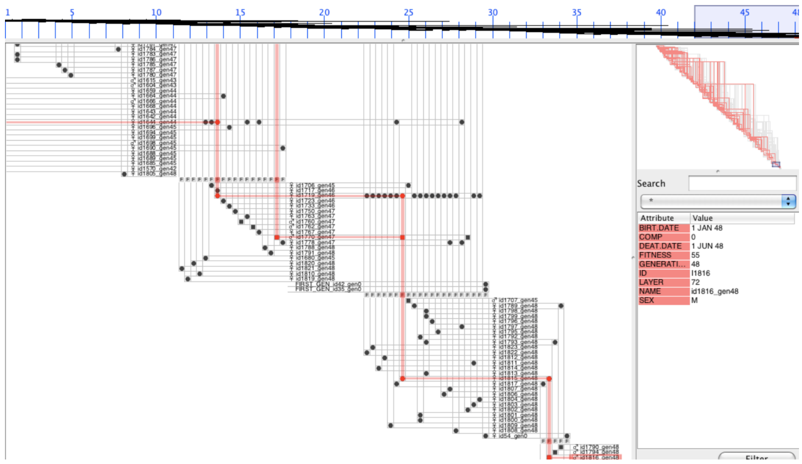


Figure 8. Visualisation of an evolutionary algorithm genealogy with GeneaQuilt. Optimisation of a Rosenbrock function in dimension 10 (50 individuals during 50 generations). Zoom on the last generations and track of the ancestor of a good individual (in red).

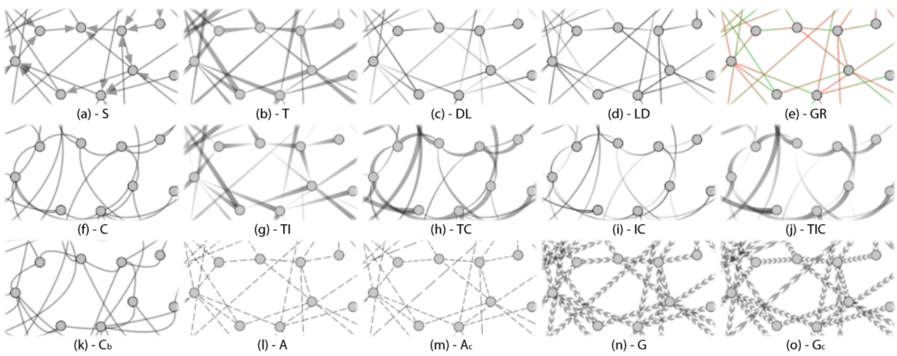


Figure 9. 15 possible representations for directed edges, of which 5 were tested in our final study: b, l, m, n, and o.

graphs with varying parameters of three densities and edges of two different lengths. We tested one low-level connectivity task: showing two nodes, asking if the first node was connected to the second. We collected the time to complete and the number of errors, as well as a user questionnaire eliciting subjective feedback from participants.

The study showed that T and A_c were the best techniques overall and that both Glyph representations are not to be recommended. T was the fastest technique and participants were significantly more correct using A_c. This study is the first that tested whether the ability to infer edge length from the edge representation would be important. Indeed, we conclude that both A_c and G_c techniques fared better on average than their non-compressed counterparts. Also, all three techniques which encoded edge length (including T) were the most preferred by our participants.

From this study and previous work, we can conclude that the best directed-edge representation for the readability tasks are T and A_c. We provide advice and recommendations in the discussion section for choosing a representation according to various constraints and tradeoffs.

6.6. Evaluating Collaborative Visual Analytics on Tabletops

Participants: Petra Isenberg [correspondant], Danyel Fisher, Ringel Morris Meredith, Kori Inkpen, Mary Czerwinski.

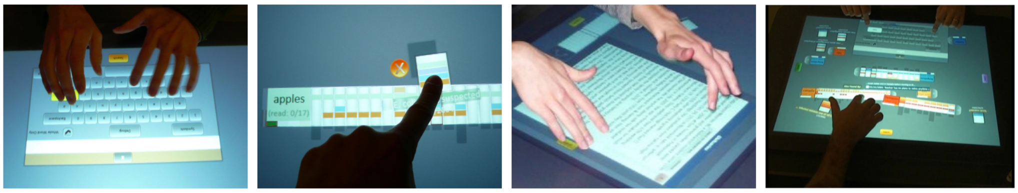


Figure 10. Several different aspects of the Cambiera system in use during a document analysis task. (a) Analysts begin by searching for data. (b) A document is pulled out of a search result list. (c) A document is zoomed to be read and analyzed. (d) The workspace can be ?exibly arranged and shared.

Co-located collaboration can be extremely valuable during complex visual analytics tasks. We conducted a detailed exploratory study of a complex collaborative problem solving activity around a digital tabletop display [18]. We studied Cambiera, a tool for collaborative analysis work with text document collections (Fig. 10). The contributions of this study were a set of findings on our digital tabletop setting as a context for co-located problem solving. We explored its suitability, identified eight collaboration styles which pairs adopted while solving the problem collaboratively, and described how collaboration impacted their success in the task. In particular, our study showed that Cambiera—in the digital tabletop setting—was a successful work context for complex problem solving. Our task required teams to constantly react to new information, to re-interpret what they had found, and to re-assess their strategies. Hence, participants worked together in a variety of work styles, supported by Cambiera's flexible collaborative search, organization, and sharing mechanisms. We found that teams that connected most often about their individual findings, and worked closely together throughout, were more successful at the task and required fewest assists. Based on these observations, we offered recommendations for features that could be used to improve co-located problem-solving tools more generally. In particular, support for teams to make ad-hoc changes to all aspects of their current work strategies as well as features that encourage them to share information and connect with each other frequently, are worth considering.

6.7. Evaluating Touch Interaction for 3-D Information Spaces

Participants: Lingyun Yu, Pjotr Svetachov, Petra Isenberg, Maarten Everts, Tobias Isenberg [correspondant].

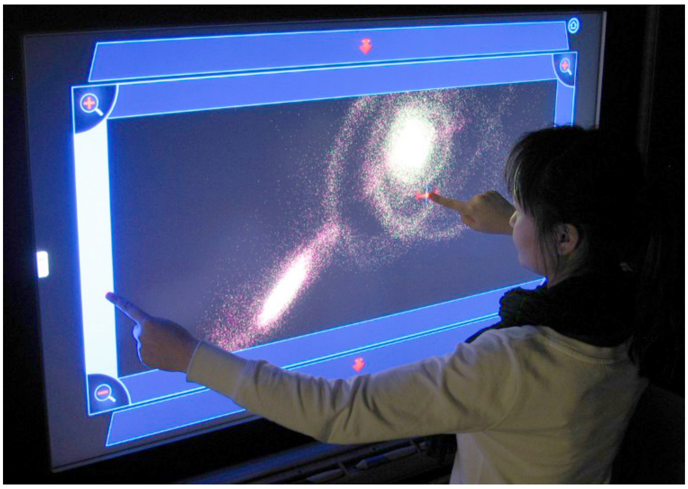


Figure 11. The FI3D system.

We designed and evaluated FI3D, a novel direct-touch data exploration technique for 3D visualization spaces [11] (Fig. 11). The exploration of three-dimensional data is core to many tasks and domains involving scientific visualizations. Thus, effective data navigation techniques are essential to enable comprehension, understanding, and analysis of the information space. While evidence exists that touch can provide higher-bandwidth input, somesthetic information that is valuable when interacting with virtual worlds, and awareness when working in collaboration, scientific data exploration in 3D poses unique challenges to the development of effective data manipulations. FI3D provides touch interaction with 3D scientific data spaces in 7 DOF. This interaction does not require the presence of dedicated objects to constrain the mapping, a design decision important for many scientific datasets such as particle simulations in astronomy or physics. We conducted an evaluation that compared the technique to conventional mouse-based interaction. Our results show that touch interaction is competitive in interaction speed for translation and integrated interaction, is easy to learn and use, and is preferred for exploration and wayfinding tasks. To further explore the applicability of our basic technique for other types of scientific visualizations we presented a second case study, adjusting the interaction to the illustrative visualization of fiber tracts of the brain and the manipulation of cutting planes in this context.

7. Contracts and Grants with Industry

7.1. ReActivity

Participants: Nadia Boukhelifa, Fanny Chevalier, Pierre Dragicevic, Jean-Daniel Fekete [correspondant], Xiujun Li.

This project belongs to the joint INRIA-Microsoft Research Laboratory and is a collaboration of the VIBE Group at Microsoft Research in Redmond, the in|situ| and AVIZ INRIA groups. It is a three-year project started in 2007, focused on analyzing researchers' activities to help them reflect on these activities, analyze them or communicate them more effectively. The project has to deal with logging, storing, summarizing, visualizing and interacting with activity data to solve interesting problems in science.

Both VIBE and INRIA are faced with difficult problems in term of data capture, management, retrieval, effective visualization of stored data, effective aggregation, higher-level summarization (inferring the high-level user activity from the captured low-level user activity) and reflective presentation of that information. The teams are collaborating in designing Information Visualization infrastructures capable of managing large amounts of information and interacting with it. The ReActivity project involves logging, visualizing and interacting with logged data. It is split into three phases: collecting the logs in a consistent, extensible and robust way, mining the logs to extract higher-level information and visualizing the information for understanding, interaction and sharing. It addresses these issues for simple desktop-based information initially and then increase the scope of the project by aggregating information from outside sources.

We have started to work on providing group awareness mechanisms to Wikipedia contributors. We have organized participatory design workshop with important contributors of the French Wikipedia and gathered a set of requirements and processes. From that, we have designed a set of interactive components and visualizations that seem important to improve the collective writing of Wikipedians. Some of the information required to these components and visualizations is not provided by the standard Wikipedia tables accessible on the web; it has to be computed. We are working on mechanisms to compute this information effectively to be able to test the components with real users doing real tasks. Important information include the amount of changes made by each users on each page, the ratio between the number of characters entered by a contributor and finaly remaining on wikipedia pages etc. This information is important to quickly assess the profile of contributors to quickly monitor changes and raise the overall quality of Wikipedia [15], [27].

We have worked on the software infrastructure needed to support high-level awareness for Wikipedia and this had been much harder than expected due to the amount of data to manage and summarize. Our summarization server is available for the partners since June 2010 [13].

We are now working on assessing the benefits of the information served by our WikiReactive infrastructure at http://www.aviz.fr/wikireactive.

7.2. VisMaster: Visual Analytics - Mastering the Information Age

Participants: Jean-Daniel Fekete [correspondant], Fanny Chevalier, Pierre-Luc Hémery.

VisMaster was a European Coordination Action Project focused on the research discipline of Visual Analytics: One of the most important challenges of the emerging Information Age is to effectively utilise the immense wealth of information and data acquired, computed and stored by modern information systems. On the one hand, the appropriate use of available information volumes offers large potential to realize technological progress and business success. On the other hand, there exists the severe danger that users and analysts easily get lost in irrelevant, or inappropriately processed or presented information, a problem which is generally called the information overload problem. Visual Analytics is an emerging research discipline developing technology to make the best possible use of huge information loads in a wide variety of applications. The basic idea is to appropriately combine the strengths of intelligent automatic data analysis with the visual perception and analysis capabilities of the human user.

With VisMaster, we wanted to push the limits of today's Visual Analytics. To achieve this goal, we formed a Coordination Action to join European academic and industrial R&D excellence from several individual disciplines, forming a strong Visual Analytics research community. The project is divided into an array of thematic working groups that focus on advancing the state of the art in Visual Analytics. Specifically, the working groups will join excellence in the fields of data management, data analysis, spatial-temporal data, and human visual perceptionresearch with the wider visualisation research community.

The VisMaster Project main goals were to:

- form and shape a strong European Visual Analytics community
- define the European Visual Analytics Research Roadmap
- expose public and private stakeholders to Visual Analytics technology
- set the stage for larger follow-up Visual Analytics research initiatives in Europe.

In the VisMaster project, AVIZ is in charge of the Work Package 4: Infrastructure for Visual Analytics. This work-package is responsible for providing and maintaining the communication infrastructure for the collection of resources in other work-packages and the dissemination of the project results to the public. The scientific management board, consisting of all work-package leaders and chaired by the scientific manager also works in the domain of this work-package and is responsible for the coordination of workshops and the invitation of new community partners.

After having conducted one workshop on software infrastructure for visual analytics, we have started a google code project called "Obvious" to validate a unified infrastructure for Visual Analytics. Since October, Pierre-Luc Hémery has joined AVIZ as an engineer for 2 years to implement the specifications and organize a software community around it, see http://code.google.com/p/obvious. The code is available and will be announced soon.

We have also delivered a video, with the help of the multimedia team of INRIA Rocquencourt, for promoting the domain of Visual Analytics in the European Community, explaining what it was and why more research is required to fulfill its goal. The video is available on the web site of INRIA (http://videotheque.inria.fr/videotheque/doc/635) and on YouTube at http://www.youtube.com/watch?v=5i3xbitEVfs where is has been viewed more the 2,500 times as of Dec. 2010.

Finally, we have written a chapter of the new book "Mastering The Information Age - Solving Problems with Visual Analytics" [28] aimed at defining a research roadmap for visual analytics in Europe.

The project VisMaster CA acknowledges the financial support of the Future and Emerging Technologies (FET) programme within the Seventh Framwork Programme (FP7) for research of the European Commission (EC) under FET-Open grant number 225429. For more information, see http://www.vismaster.eu.

7.3. Interactive data-intensive workflows for scientific applications

Participants: Jean-Daniel Fekete [correspondant], Ioana Manolescu [INRIA LEO Project Team], Véronique Benzaken [LRI BD group], Wael Khemiri, Pierre-Luc Hémery.

Today's scientific data management applications involve huge and increasing data volumes. Data can be numeric, e.g. output of measure instruments, textual, e.g. corpora studied by social scientists which may consist of news archives over several years, structured as is the case of astronomy or physics data, or highly unstructured as is the case of medical patient files. Data, in all forms, is increasingly large in volume, as a result of computers capturing more and more of the work scientists used to do based on paper, and also as a result of better and more powerful automatic data gathering tools, e.g. space telescopes, focused crawlers, archived experimental data (mandatory in some types of government-funded research programs) and so on.

The availability of such large data volumes is a gold mine for scientists which may carry research based on this data. Today's scientists, however, more often than not rely on proprietary, ad-hoc information systems, consisting perhaps of a directory structure organized by hand by the scientist, a few specialized data processing applications, perhaps a few scripts etc.

For example, social scientists are interested in analyzing online social networks such as Wikipedia where new forms of group organization emerge. Visualizing the hypertext network that connects articles together requires accessing the hypertext data, computing some "shape" to visualize the network and using visualization tools to navigate the representation effectively. We have designed the Zoomable Adjacency Matrix Explorer (ZAME [36]) that allows the exploration by computing a linear ordering of the articles contained in Wikipedia using a fast and complex dimension reduction algorithm (see figure 1). However, all the required steps to access the data, compute the ordering, store it for reuse, visualize it and navigate on the representation is done using ad-hoc methods, very tedious to implement and out of reach of the sociologists who are interested by the study.

Off-the-shelf databases are not well adapted for scientific data management for several reasons.

First, database systems are not very flexible: changing the schema in a relational database management system (RDBMS) is very difficult, whereas exploratory usage of data routinely requires adding it new dimensions e.g., building summary categories to help the user tame the data complexity and volume. More flexible formats, such as XML or RDF, bring their own problems, which for the time being are mostly performance ones!

Second, database systems are tuned towards specific declarative search operations, typically expressed using a query language. In contrast, exploring scientific data involves operations such as clustering and finding interesting data orders, which cannot be specified based on stored attributes, but have to be discovered by complex, possibly iterative computations.

Finally, databases support query-based interactions, but lack more friendly interfaces, allowing the user to inspect a large data set, with varying level of detail for different, dynamically specified subsets [43].

The purpose of the project is *to investigate models, algorithms, and propose an architecture* of a system helping scientists to organize and make the most out of their data. The research work spans over three related, yet distinct areas, among which we expect it to build bridges: workflow modeling; database execution and optimization; and information visualization.

We have designed an architecture model for a Visual Analytics relying on a workflow execution model that takes into account the dynamicity of data. We have implemented a proof of concept called “EdiFlow”: a Scientific Workflow relying on standard databases that provides a clean semantics for dynamic data management. The work on EdiFlow has been accepted for publication at the very selective ICDE conference [12], which demonstrates that the Database and the Visual Analytics communities have common issues to address.

We are now extending EdiFlow to use its dynamic capabilities to describe and manage the user interaction. We model interaction as table changes and interactive operations as data updates. We expect to demonstrate that large-scale interactive systems can be modeled using distributed database technologies, probably with the addition of the novel mechanisms to manage long transactions and distributed computations.

7.4. Advanced Visual Exploration with Non-photorealisitic and Interactive Rendering

Participants: Tobias Isenberg, Jean-Daniel Fekete [correspondant], Pierre Dragicevic.

AVIZ and CNRS/LIMSI have invited Tobias Isenberg on a Digiteo Chair of Excellence, a very prestigious and competitive position offered by the Digiteo Consortium on the Saclay area. Tobias will be collaborating with both teams on a project call AVENIR: “Advanced Visual Exploration with Non-photorealisitic and Interactive Rendering”.

This project will take a unique research approach to visualization that is situated at the intersection of several related directions: scientific and information visualization, non-photorealistic and illustrative rendering, and interaction on large displays. It aims to establish this area as a new research direction within the scope of the newly emerging domain of illustrative visualization which takes inspiration both from traditional illustration and computer-driven visualization. For this purpose we will investigate how to integrate both direct-touch interaction and non-photorealistic rendering into traditional scientific and information visualization applications.

On the one side, we will use techniques from non-photorealistic and illustrative rendering to provide abstraction and emphasis as well as make use of its ability to provide clear and understandable depictions. In addition, we will investigate the possibility for data reduction. Some non-photorealistic techniques can provide faster rendering than their photorealistic counterparts and can, thus, inspired the transfer of these techniques to visualization applications. This will greatly improve the visualization of large amounts of data.

On the other side, we will use direct-touch interaction on large displays to provide an intuitive and easily approachable platform for integrated visualization applications that allow the exploration of the large amounts of data we want to visualize. This specific setting not only allows a person to interact with a visualization in a very direct way but also affords collaborative visualization for small groups of scientists. This will create synergies from discussions between colleagues or in the context of small research teams which otherwise would not be possible for a single person.

This integration of visualization with non-photorealistic rendering and large-display interaction will not only integrate well with existing research directions of the two participating Digiteo teams, but also provide them with exciting new application domains: it will use concepts from both scientific visualization (VENISE) and information visualization (AVIZ) and will apply large display concepts (VENISE). Through this collaboration this grant will lead the way toward a new way of presenting and exploring scientific data.

7.5. CSDL

Participants: Évelyne Lutton [correspondant], Jean-Daniel Fekete, Anastasia Bezerianos, Anissa Aroua.

CSDL, Complex Systems Design Lab (2009–2012) is a project of the System@tic pole whose main contractor is Dassault Aviation, together with 27 academic and industrial partners. The aim of CSDL is to settle a complete collorative environment for decision making in the framework of complex systems design [4]. CSDL funds have been used to hire a PhD student (Anissa Aroua) in september 2010 on using visualization of multidimensional data to steer interactive evolutionary algorithms.

8. Other Grants and Activities

8.1. Regional Initiatives

AVIZ is participating to two local projects:

- The AVENIR Chair of Excellence for Digiteo
- The CSDL project with System@tic Pole

8.2. European Initiatives

- AVIZ has participated to the European project VisMaster and led the work-package 4 on Software Infrastructures for Visual Analytics (see 7.2).
- Jean-Daniel Fekete is a member of the reviewing committee for the German DFG “Scalable Visual Analytics” program.

8.3. International Initiatives

AVIZ members are now Collaborating Researchers of the SurfNet Research Alliance (http://www.nsercsurfnet.org/). This Canadian research network is focused on collaboration on new surfaces, a topic that directly concerns AVIZ with its WILD large and tabetop displays.

9. Dissemination

9.1. Animation of the scientific community

AVIZ members are active in the Information Visualization domain worldwide.

- Jean-Daniel Fekete was keynote speaker for the PacificVis 2010 Symposium in Taiwan;
- Jean-Daniel Fekete was the President of the French-Speaking HCI Association (AFIHM)
- Jean-Daniel Fekete was paper co-chair of the IEEE InfoVis 2010 Conference;
- Jean-Daniel Fekete was Associate Editor of the International Journal of Human-Computer Studies (IJHCS) (2003-2010), published by Elsevier

[4] http://www.teratec.eu/activites/projetsR_D_systematic.html

- Jean-Daniel Fekete was co-Editor in Chief for the Journal d'Interaciton Personne-System (JIPS), published by AFIHM
- Jean-Daniel Fekete was member of the Program Committee of IEEE VAST 2010
- Jean-Daniel Fekete was member of the program committee of EG EuroVis 2010;
- Jean-Daniel Fekete was member of the program committee of IEEE PacificVis 2010;
- Pierre Dragicevic was member of the program committee of IEEE InfoVis 2010;
- Pierre Dragicevic was demo chair at ACM UIST 2010;
- Petra Isenberg was co-chair of the Discover Exhibition at IEEE InfoVis 2010;
- Petra Isenberg was member of the program committee of IEEE InfoVis 2010;
- Petra Isenberg was member of the program committee of EG EuroVis 2010;
- Petra Isenberg was member of the program committee of ACM ITS 2010;
- Petra Isenberg was publicity chair of ACM ITS 2010;
- Evelyne Lutton was Associate editor of the Journal of Artificial Evolution and Applications (2007-2010) Hindawi
- Evelyne Lutton was member of the program committee of EuroGP 2010;
- Evelyne Lutton was member of the program committee of EvoIASP 2010;
- Evelyne Lutton was member of the program committee of PPSN 2010;
- Evelyne Lutton was member of the program committee of CEC 2010;
- Evelyne Lutton was member of the program committee of GECCO 2010;
- Pierre Dragicevic and Jean-Daniel Fekete co-organized the HCI-InfoVis Open House 2010 with the In Situ team.

9.2. Teaching

- Jean-Daniel Fekete presented a 12h Master Course on Information Visualization at the École des Mines de Nantes;
- Pierre Dragicevic and Jean-Daniel Fekete presented a 60h Master Course on Information Visualization at Polytech' Paris-Sud;
- Petra Isenberg presented a course on "Collaborative Visualization" for the "GK summer school" organized by the University of Konstanz in Klausen, Italy;
- Tobias Isenberg presented a course on "Non-photorealistic Rendering / Illustrative Visualisation" for the "GK summer school" organized by the University of Konstanz in Klausen, Italy.

10. Bibliography

Major publications by the team in recent years

[1] F. CHEVALIER, P. DRAGICEVIC, A. BEZERIANOS, J.-D. FEKETE. *Using Text Animated Transitions to Support Navigation in Document Histories*, in "CHI '10: Proceedings of the 28th international conference on Human factors in computing systems", New York, NY, USA, ACM, 2010, p. 683–692 [*DOI :* 10.1145/1753326.1753427], http://www.aviz.fr/diffamation/diffamation-CHI2010.pdf.

[2] N. ELMQVIST, P. DRAGICEVIC, J.-D. FEKETE. *Rolling the Dice: Multidimensional Visual Exploration using Scatterplot Matrix Navigation*, in "IEEE Transactions on Visualization and Computer Graphics", 2008, vol. 14, n^{o} 6, p. 1141-1148, (Best Paper Award), http://doi.ieeecomputersociety.org/10.1109/TVCG.2008.153.

[3] J.-D. FEKETE. *The InfoVis Toolkit*, in "Proceedings of the 10th IEEE Symposium on Information Visualization (InfoVis 04)", Austin, TX, IEEE Press, October 2004, p. 167-174, http://www.lri.fr/~fekete/ps/ivtk-04.pdf.

[4] N. HENRY-RICHE, J.-D. FEKETE, M. J. MCGUFFIN. *NodeTrix: a Hybrid Visualization of Social Networks*, in "IEEE Transactions on Visualization and Computer Graphics", 2007, vol. 13, n° 6, p. 1302-1309, http://doi.ieeecomputersociety.org/10.1109/TVCG.2007.70582.

[5] C. PLAISANT, J.-D. FEKETE, G. GRINSTEIN. *Promoting Insight-Based Evaluation of Visualizations: From Contest to Benchmark Repository*, in "IEEE Transactions on Visualization and Computer Graphics", 2008, vol. 14, n° 1, p. 120–134, http://doi.ieeecomputersociety.org/10.1109/TVCG.2007.70412.

Publications of the year

Articles in International Peer-Reviewed Journal

[6] A. BEZERIANOS, F. CHEVALIER, P. DRAGICEVIC, N. ELMQVIST, J.-D. FEKETE. *GraphDice: A System for Exploring Multivariate Social Networks*, in "Computer Graphics Forum - Eurographics/IEEE-VGTC Symposium on Visualization 2010 (EuroVis 2010)", June 2010, vol. 10, n° 3, p. 863-872 [*DOI :* 10.1111/J.1467-8659.2009.01687.X], http://www.aviz.fr/graphdice/graphdice.pdf.

[7] A. BEZERIANOS, P. DRAGICEVIC, J.-D. FEKETE, J. BAE, B. WATSON. *GeneaQuilts: A System for Exploring Large Genealogies*, in "IEEE Transactions on Visualization and Computer Graphics", Nov-Dec 2010, vol. 16, n° 6, p. 1073–1081, http://doi.ieeecomputersociety.org/10.1109/TVCG.2010.159.

[8] N. ELMQVIST, P. DRAGICEVIC, J.-D. FEKETE. *Color Lens: Adaptive Color Scale Optimization for Visual Exploration*, in "IEEE Transactions on Visualization and Computer Graphics", 2010, to appear, http://doi.ieeecomputersociety.org/10.1109/TVCG.2010.94.

[9] N. ELMQVIST, J.-D. FEKETE. *Hierarchical Aggregation for Information Visualization: Overview, Techniques, and Design Guidelines*, in "IEEE Transactions on Visualization and Computer Graphics", 2010, vol. 16, n° 3, p. 439–454, http://doi.ieeecomputersociety.org/10.1109/TVCG.2009.84.

[10] N. ELMQVIST, Y. RICHE, N. HENRY-RICHE, J.-D. FEKETE. *Mélange: Space Folding for Visual Exploration*, in "IEEE Transactions on Visualization and Computer Graphics", 2010, vol. 16, n° 3, p. 468–483, http://doi.ieeecomputersociety.org/10.1109/TVCG.2009.86.

[11] L. YU, P. SVETACHOV, P. ISENBERG, M. H. EVERTS, T. ISENBERG. *FI3D: Direct-Touch Interaction for the Exploration of 3D Scientific Visualization Spaces*, in "IEEE Transactions on Visualization and Computer Graphics", Nov-Dec 2010, vol. 16, n° 6, p. 1613–1622, http://dx.doi.org/10.1109/TVCG.2010.157.

International Peer-Reviewed Conference/Proceedings

[12] V. BENZAKEN, J.-D. FEKETE, P.-L. HÉMERY, W. KHEMIRI, I. MANOLESCU. *EdiFlow: data-intensive interactive workflows for visual analytics*, in "International conference on Data Engineering (ICDE 2011)", Hannover, Germany, IEEE, 04 2011, to appear, http://hal.inria.fr/inria-00532552/en/.

[13] N. BOUKHELIFA, F. CHEVALIER, J.-D. FEKETE. *Real-time Aggregation of Wikipedia Data for Visual Analytics*, in "Proceedings of Visual Analytics Science and Technology (VAST 2010)", Los Alamitos, CA, USA, IEEE Computer Society, 2010, p. 147–154, http://www.aviz.fr/wikireactive/wikireactivity.pdf.

[14] F. CHEVALIER, P. DRAGICEVIC, A. BEZERIANOS, J.-D. FEKETE. *Using Text Animated Transitions to Support Navigation in Document Histories*, in "CHI '10: Proceedings of the 28th international conference on Human factors in computing systems", New York, NY, USA, ACM, 2010, p. 683–692 [*DOI :* 10.1145/1753326.1753427], http://www.aviz.fr/diffamation/diffamation-CHI2010.pdf.

[15] F. CHEVALIER, S. HUOT, J.-D. FEKETE. *WikipediaViz: Conveying Article Quality for Casual Wikipedia Readers*, in "Pacific Visualization Symposium (PacificVis), 2010 IEEE", IEEE Press, March 2010, p. 49-56, http://dx.doi.org/10.1109/PACIFICVIS.2010.5429611.

[16] N. HENRY-RICHE, B. LEE, F. CHEVALIER. *iChase: Supporting Exploration and Awareness of Editing Activities on Wikipedia*, in "Proceedings of AVI 2010", ACM Press, May 2010, p. 59-66, http://doi.acm.org/10.1145/1842993.1843004.

[17] D. HOLTEN, P. ISENBERG, J. J. VAN WIJK, J.-D. FEKETE. *An Extended Evaluation of the Readability of Tapered, Animated, and Textured Directed-Edge Representations in Node-Link Graphs*, in "Pacific Visualization Symposium (PacificVis), 2011 IEEE", IEEE Press, March 2011, conditionally accepted.

[18] P. ISENBERG, D. FISHER, M. RINGEL MORRIS, K. INKPEN, M. CZERWINSKI. *An Exploratory Study of Co-located Collaborative Visual Analytics around a Tabletop Display*, in "Proceedings of Visual Analytics Science and Technology (VAST 2010)", Los Alamitos, CA, USA, IEEE Computer Society, 2010, p. 179–186, Honorable Mention, http://research.microsoft.com/pubs/135532/CambieraStudy.pdf.

[19] A. KATSIFODIMOS, J.-D. FEKETE, A. CADY, C. GERMAIN-RENAUD. *Visualizing the dynamics of e-science social networks*, in "EGEE User Forum", Uppsala Sweden, 04 2010, http://hal.inria.fr/inria-00544452/en/.

[20] B. KAUFMANN, J. LOUCHET, É. LUTTON. *Hand Posture Recognition Using Real-Time Artificial Evolution*, in "Applications of Evolutionary Computation, EvoApplicatons 2010: EvoCOMPLEX, EvoGAMES, EvoIASP, EvoINTELLIGENCE, EvoNUM, and EvoSTOC, Proceedings, Part I", Istanbul, Turkey, C. D. CHIO, S. CAGNONI, C. COTTA, M. EBNER, A. EKÁRT, A. ESPARCIA-ALCÁZAR, C. K. GOH, J. J. M. GUERVÓS, F. NERI, M. PREUSS, J. TOGELIUS, G. N. YANNAKAKIS (editors), Lecture Notes in Computer Science, Springer, April 7-9 2010, vol. 6024, p. 251-260, http://evelyne.lutton.free.fr/Papers/KaufmannEvoIASP2010.pdf.

[21] S. MESMOUDI, N. PERROT, R. REUILLON, P. BOURGINE, É. LUTTON. *Optimal viable path search for a cheese ripening process using a multi-objective EA*, in "ICEC 2010, International Conference on Evolutionary Computation", October 2010, 24-26 oct, Valencia, Spain, http://evelyne.lutton.free.fr/Papers/MesmoudiICEC2010.pdf.

[22] M. SEDLMAIR, P. ISENBERG, D. BAUR, A. BUTZ. *Evaluating Information Visualization in Large Companies: Challenges, Experiences and Recommendations*, in "Proceedings of the CHI Workshop Beyond Time and Errors: Novel Evaluation Methods for Information Visualization (BELIV)", New York, NY, USA, ACM Press, 2010, p. 79–86, Best Paper Award, http://www.beliv.org/papers/beliv2010/Research%20Papers/17-Sedlmair_2009_EIV.pdf.

[23] F. P. VIDAL, J. LOUCHET, J.-M. ROCCHISANI, É. LUTTON. *Artificial Evolution for PET and SPECT reconstruction*, in "AAPM Annual Meeting", Philadelphia, PA, July 2010.

[24] F. P. VIDAL, J. LOUCHET, J.-M. ROCCHISANI, É. LUTTON. *New Genetic Operators in the Fly Algorithm: Application to Medical PET Image Reconstruction*, in "Applications of Evolutionary Computation, EvoAp-

plicatons 2010: EvoCOMPLEX, EvoGAMES, EvoIASP, EvoINTELLIGENCE, EvoNUM, and EvoSTOC, Proceedings, Part I", Istanbul, Turkey, C. D. CHIO, S. CAGNONI, C. COTTA, M. EBNER, A. EKÁRT, A. ESPARCIA-ALCÁZAR, C. K. GOH, J. J. M. GUERVÓS, F. NERI, M. PREUSS, J. TOGELIUS, G. N. YANNAKAKIS (editors), Lecture Notes in Computer Science, Springer, April 7-9 2010, vol. 6024, p. 292-301, http://evelyne.lutton.free.fr/Papers/Vidal2010EvoIASP.pdf.

[25] F. P. VIDAL, É. LUTTON, J. LOUCHET, J.-M. ROCCHISANI. *Threshold selection, mitosis and dual mutation in cooperative co-evolution: application to medical 3D tomography*, in "PPSN 2010, 11th International Conference on Parallel Problem Solving From Nature", Springer-Verlag, September 2010, Krakow, Poland, http://evelyne.lutton.free.fr/Papers/Vidal2010PPSN.pdf.

[26] T. VON LANDESBERGER, A. KUIJPER, T. SCHRECK, J. KOHLHAMMER, J. J. VAN WIJK, J.-D. FEKETE, D. W. FELLNER. *Visual Analysis of Large Graphs*, in "Eurographics 2010 State of the Art Reports", H. HAUSER, E. REINHARD (editors), Eurographics Association, April 2010, to appear, http://www.gris.informatik.tu-darmstadt.de/~tschreck/papers/egstar10.pdf.

National Peer-Reviewed Conference/Proceedings

[27] F. CHEVALIER, S. HUOT, J.-D. FEKETE. *Visualisation de mesures agrégées pour l'estimation de la qualité des articles Wikipedia*, in "Extraction et gestion des connaissances (EGC'2010), Actes", Hammamet, Tunisie, Revue des Nouvelles Technologies de l'Information, Cépaduès-Éditions, 26 au 29 janvier 2010, p. 351–362, http://www.aviz.fr/wikipediaviz/wikipediaviz_EGC-2010.pdf.

Scientific Books (or Scientific Book chapters)

[28] J.-D. FEKETE. *Infrastructure*, in "Mastering The Information Age - Solving Problems with Visual Analytics", D. KEIM, J. KOHLHAMMER, G. ELLIS, F. MANSMANN (editors), Eurographics Assoc., 2010, chap. 6, p. 87–108, http://www.vismaster.eu/wp-content/uploads/2010/11/chapter-6.pdf.

[29] J.-D. FEKETE. *Visualiser l'information pour la comprendre vite et bien*, in "L'usager numérique", ADBS éditions, 25, rue Claude-Tillier, 75012 Paris, September 2010, p. 161–194.

Research Reports

[30] D. HOLTEN, P. ISENBERG, J.-D. FEKETE, J. J. VAN WIJK. *Performance Evaluation of Tapered, Curved, and Animated Directed-Edge Representations in Node-Link Graphs*, Laboratory for Quality Software (LaQuSo), Eindhoven University of Technology, 2010, n^{o} LaQuSo DH/PI/JDF/JvW/415, http://www.win.tue.nl/~dholten/papers/directed_edges_tr.pdf.

[31] P. ISENBERG, M. SEDLMAIR, D. BAUR, T. ISENBERG, A. BUTZ. *Collaborative Visualization on Interactive Surfaces—CoVIS '09*, Ludwig Maximilias University Munich, Munich, April 2010, n^{o} LMU-MI-2010-2, ISSN 1862-5207, http://www.medien.ifi.lmu.de/pubdb/publications/pub/isenberg2010covis/isenberg2010covis.pdf.

Other Publications

[32] M. EID. *ContigViz: Visualization to assist DNA Sequence Assembly for Next Generation Sequencing*, Département Informatique, Université Paris-Sud, September 2010.

References in notes

[33] S. K. CARD, J. D. MACKINLAY, B. SHNEIDERMAN (editors). *Readings in information visualization: using vision to think*, Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 1999.

[34] J. BERTIN. *Sémiologie graphique : Les diagrammes - Les réseaux - Les cartes*, Les réimpressions, Editions de l'Ecole des Hautes Etudes en Sciences, Paris, France, 1967.

[35] A. BEZERIANOS, P. DRAGICEVIC, R. BALAKRISHNAN. *Mnemonic rendering: an image-based approach for exposing hidden changes in dynamic displays*, in "UIST '06: Proceedings of the 19th annual ACM symposium on User interface software and technology", New York, NY, USA, ACM, 2006, p. 159–168, http://doi.acm.org/10.1145/1166253.1166279.

[36] N. ELMQVIST, T.-N. DO, H. GOODELL, N. HENRY-RICHE, J.-D. FEKETE. *ZAME: Interactive Large-Scale Graph Visualization*, in "Proceedings of the IEEE Pacific Visualization Symposium 2008", IEEE Press, March 2008, p. 215–222, http://www.aviz.fr/~fekete/ps/zame.pdf.

[37] J.-D. FEKETE, C. PLAISANT. *Interactive Information Visualization of a Million Items*, in "Proc. IEEE Symposium on Information Visualization 2002 (InfoVis 2002)", Boston, USA, IEEE Press, October 2002, p. 117-124.

[38] J.-D. FEKETE, C. PLAISANT. *Les leçons tirées des deux compétitions de visualisation d'information*, in "Proceedings of IHM 2004", Namur, Belgium, International Conference Proceedings Series, ACM Press, September 2004, p. 7-12.

[39] J. J. GIBSON. *The Ecological Approach to Visual Perception*, Lawrence Erlbaum Associates, New Jersey, USA, 1979.

[40] Y. GUIARD, Y. DU, J.-D. FEKETE, M. BEAUDOUIN-LAFON, C. APPERT, O. CHAPUIS. *Shakespeare's Complete Works as a Benchmark for Evaluating Multiscale Document-Navigation Techniques*, in "Proceedings of BEyond time and errors: novel evaLuation methods for Information Visualization (BELIV'06)", Venice, Italy, ACM Press, May 2006, p. 65-70.

[41] N. HENRY-RICHE, J.-D. FEKETE. *Evaluating Visual Table Data Understanding*, in "Proceedings of BEyond time and errors: novel evaLuation methods for Information Visualization (BELIV'06)", Venice, Italy, ACM Press, May 2006, 6 pages, to be publised.

[42] B. LEE, C. PLAISANT, C. SIMS PARR, J.-D. FEKETE, N. HENRY-RICHE. *Task taxonomy for graph visualization*, in "BELIV '06: Proceedings of the 2006 AVI workshop on BEyond time and errors", New York, NY, USA, ACM, 2006, p. 1–5, http://doi.acm.org/10.1145/1168149.1168168.

[43] T. MUNZNER, C. JOHNSON, R. MOORHEAD, H. PFISTER, P. RHEINGANS, T. S. YOO. *NIH-NSF Visualization Research Challenges Report Summary*, in "IEEE Computer Graphics and Applications", 2006, vol. 26, n^{o} 2, p. 20-24, http://doi.ieeecomputersociety.org/10.1109/MCG.2006.44.

[44] A. TRIESMAN. *Preattentive Processing in Vision*, in "Computer Vision, Graphics, and Image Processing", August 1985, vol. 31, n^{o} 2, p. 156-177.

[45] E. TUFTE. *The Visual Display of Quantitative Information*, Graphics Press, 1983.

[46] J. W. TUKEY. *Exploratory Data Analysis*, Addison-Wesley, 1977.