



Interaction with Information for Visual Reasoning (Dagstuhl Seminar 13352)

David S. Ebert, Brian D. Fisher, Petra Isenberg

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Interaction with Information for Visual Reasoning

Edited by

David S. Ebert¹, Brian D. Fisher², and Petra Isenberg³

¹ Purdue University, US, ebertd@purdue.edu

² Simon Fraser University – Surrey, CA, bfisher@sfu.ca

³ INRIA Saclay – Île-de-France – Orsay, FR, petra.isenberg@inria.fr

Abstract

From August 26–August 30, 2013 Seminar 13352 was held at Dagstuhl on the topic of “Interaction with Information for Visual Reasoning.” The seminar brought together a group of cognitive scientists, psychologists, and computer scientists in the area of scientific visualization, information visualization, and visual analytics who were carefully selected for their theoretical and methodological capabilities and history of interdisciplinary collaboration. During the seminar seven discussion groups were formed during which the role of interaction for visualization was carefully reflected on. We discussed in particular the value, structure, and different types of interaction but also how to evaluate visualization and the idea of ‘narrative’ as applied to visual analytics. This report documents the program and short summaries of the discussion groups for the seminar.

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1 Executive Summary

David S. Ebert

Brian D. Fisher

Petra Isenberg

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Scientific and information visualization researchers routinely build and evaluate interactive visualization systems to aid human reasoning. However, this work is often disconnected from the methodological and theoretical tools developed by the cognitive and social sciences to address the complexities of human thought processes. Those tools and methods can help us to understand human perception and understanding of data visualization, but typically do not address how rich interaction with computational processes could be engineered to support better decision-making. Yet, an increasing number of researchers are turning to the question of how to best engineer interaction techniques for visualization and how to best study and understand their influence on cognition, insight formation, and also efficiency and effectiveness of work. The goal of this seminar was to bring together researchers in cognitive science and psychology with researchers in the field of visualization to discuss the value that interaction can bring to visualization, how best to study it, and how research on interaction in cognitive science can be best integrated into visualization tools and systems to the benefit of domain experts or casual users of these tools.



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3 About the Seminar

Participants

The seminar brought together a diverse group of international cognitive scientists, psychologists, and computer scientists in the area of scientific visualization, information visualization, visual analytics, and human computer interaction. All participants (see Figure 1) were carefully selected for their theoretical and methodological capabilities and history of interdisciplinary collaboration. Thirty participants joined the seminar, out of which seven had a background in psychology and the remainder were primarily computer scientists in training. Eleven participants were female and three in total came from industry. For about one third of participants this seminar was their first Dagstuhl event. Figure 2 shows gender balance and country statistics for all participants.

Format

The seminar followed a format largely based on breakout groups. The first day of the seminar involved short introduction slides for each participant with longer 15 minute invited talks from the domains of cognitive science and psychology. Tuesday the first four breakout groups discussed topics on mixed initiative interaction, crowd interaction, the value of interaction, and conceptual structures of interaction. Each breakout group was comprised of participants with mixed backgrounds in computer science and cognitive science/psychology and had the goal to work on a specific problem related to the title of the breakout group. Wednesday, each participant switched to a second breakout group on topics: evaluation of interaction, magical interaction, and visual narrative. Almost all participants then went together on a social event to visit the Völklinger Hütte (see Figure 3). Thursday morning we heard a presentation about DBLP, and continued with the second breakout group sessions. Thursday ended with discussion in the breakout groups about publishable results from the seminar and working towards establishing a publication plan of action. These were then presented in front of the whole group. Two invited talks started the day on Friday which ended with a discussion on publication venues that would be beneficial for both the computer scientists and cognitive scientists/psychologist. Table 1 gives an overview of the seminar schedule and the following list includes the titles of the individual breakout groups.

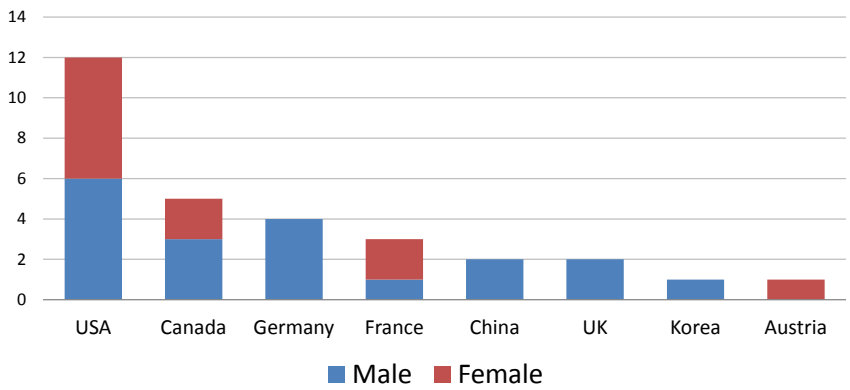
- Mixed Initiative Interaction
- Crowd Interaction in Visual Reasoning
- Magical Interaction
- Evaluating Interaction for Visual Reasoning
- Conceptual Structures of Interaction for Visual Reasoning
- Visual Narrative
- The Landscape of Explanations for the Value of Interaction for Visual Reasoning

Output

The organizers and participants planned to publish results from the breakout groups as a Morgan Claypool mini series on interaction for which David Ebert is the series editor. Working groups have been invited to publish their results there. Furthermore we are in contact with an international journal for an open-call special issue to further push the importance of interaction for visual reasoning as an emerging topic in the domain of visualization.



■ **Figure 1** Group picture of all participants taken in the sun outside the Dagstuhl chapel.



■ **Figure 2** Gender balance and country of participants' home institution.



■ **Figure 3** Excursion to Völklinger Hütte allowed for less structured research conversations and an interesting lesson about the ironworks (picture courtesy of Fanny Chevalier).

■ **Table 1** Schedule of the seminar. Details on talks and breakout groups follows further below.

<i>Monday</i>	<i>Tuesday</i>	<i>Wednesday</i>	<i>Thursday</i>	<i>Friday</i>
Introduction to the Seminar	Discussion: Breakout Groups	Discussion: Breakout Groups II	Presentation: DBLP	Invited Talks: Sketching
Introduction Participants I				
Introduction Participants II	Breakout Groups I	Breakout Groups II	Breakout Groups II	Discussion on Publication Venus & Closing
Introduction Participants III	Breakout Groups I	Social Event: Völklinger Hütte	Discussion Writing Groups I	
Invited Talks Psychology	Report from Breakout Groups I	Social Event: Völklinger Hütte	Discussion Writing Groups II	

The Dagstuhl team performed an evaluation at the end of the seminar. The responses were primarily positive with the overall quality of the seminar rated with a 10/11. All 16 respondents reported that they agreed or agreed completely that the seminar inspired new ideas for their own work, development or teaching. 15/16 respondents agreed that the seminar inspired joint work and all 16 respondents said that the seminar led to insights from neighboring fields. This is exciting as it shows that the seminar's goal of bridging the gap between two research communities was successfully met. In terms of improvements, several participants suggested to leave more room for (impromptu) talks and that it would have helped to prepare participants more prior to arriving at Dagstuhl. We take these as suggestions for the organization of possible future seminars.

Acknowledgments

We would like to acknowledge the valuable input of Dr. Shixia Liu (Microsoft Research Asia) in the application and preparation of this seminar.

4 Overview of Talks

4.1 Interacting with Information – Overview of Past & Current Work

Simon Attfield (Middlesex University, GB)

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Joint work of Attfield, Simon; Okoro, Efeosasere

In this talk I presented myself and my research interests. I discussed how an interest in information interaction focusing on domain areas such as journalism, e-discovery, intelligence analysis and healthcare has led to an interest in sensemaking and how it can be supported through digital design. Something I am currently interested in is information structuring during sensemaking, such as how it can be characterised and the comparative effects of different kinds of structuring, such as narrative and argumentation. For both of these questions I am working with Efeosasere Okoro to develop a relational language for capturing

the semantics of user generated information structures and looking at the comparative effects of different structuring conventions on task performance and user experience.

4.2 Cognitive Science of Representational Systems

Peter C.-H. Cheng (University of Sussex – Brighton, GB)

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In addition to giving a brief overview of Peter Cheng's main areas of research the talk focused on how cognitive science can inform the design of representational systems to support complex problem solving and learning in conceptually rich domains. It seems necessary to combine our understanding of higher cognition, forms of external representations and the nature of knowledge within a Representational Epistemic approach in order to successfully design graphical displays that can fully accommodate the many diverse tasks that are typically found in complex domains. Novel notations and visualisation were briefly presented for event scheduling, personnel rostering, production planning and scheduling, high school algebra, electricity, particle mechanics, probability theory, propositional logic and syllogisms.

4.3 Flexible Perception of Structure in Viz & Education

Steve Franconeri (Northwestern University – Evanston, US)

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Selective attention allows us to filter visual information, amplifying what is relevant and suppressing what competes. But recent work in our lab suggests another role – flexibly extracting and manipulating visual structure. Selective attention allows us to group objects with similar features, extract spatial relationships between objects, and imagine manipulations of objects. An understanding of these mechanisms has concrete implications for the design of visualizations across science and education.

4.4 A Sample of Sketching Research in Cognitive Science

Steve Franconeri (Northwestern University – Evanston, US)

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Sketching is a tool for visual thinking. It helps people explore information sets that are too large to hold (or process) in working memory. It helps people re-organize information, allowing it to be seen from a new perspective. I presented two case studies of the power of sketching – in the first, sketching reveals how people understand a problem within an image, and in the second, sketching facilitates insight by promoting foraging through visual relationships.

4.5 Human Interactions in Abstract Visual Spaces

Wayne D. Gray (*Rensselaer Polytechnic Institute, US*)

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Human behavior is interactive behavior. Behavior emerges from the interaction of bounded cognition with the natural or designed task environment and task goals. Topics covered included: (a) Interactive routines, (b) The eye-hand span, (c) Analogies for memory, (d) Local, not global optimization, (e) Modeling the whole human (not just the convenient bits!), (f) Modeling pre-attentive and attentive visual processes, (g) Tools for the statistical analysis of visual saliency and similarity, (h) Tools for analyzing eye data, and (i) Possibilities for more indepth talks including *The Cognitive Science of Natural Interaction* and *Elements of Extreme Expertise*.

4.6 Interacting with Visual Representatives

David Kirsh (*University of California – San Diego, US*)

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Topics covered were: a) what is the difference between epistemic and pragmatic actions – and why they matter for visualization theory; b) explain a core(epistemic) interactive strategy used in reasoning with visualizations. This involves mentally projecting a structure onto an external structure, for instance, an illustration, a geometric figure, a manipulable visualization, then physically realizing that mentally projected structure by altering the external structure or visualization, then start this a) perceive mental project structure; b) create structure process over again by mentally projecting onto this newly altered structure; c) explain the importance of the difference between explicit and implicit encoding of information: when does representation A encode information more explicitly than representation B – good visualizations encode the right information more explicitly; d) what does interaction do for us that we could not do as well in our heads?

4.7 Sketching and Embodied Cognition

David Kirsh (*University of California – San Diego, US*)

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I explore two topics that highlight the power of embodied cognition: using the process of making a sketch to help decide whether a stone is a genuine tool shaped by prehistoric humans as opposed to a visually similar stone that occurs naturally. This shows how the process of physically working with a sketch or illustration teaches us more than just looking at the same illustration or sketch. The second topic introduces another instance of ‘modeling or simulation to drive cognition.’ In dance there is a process called marking that has many of the same virtues of sketching but this time using the body instead of paper and pencil. Marking is a process in dance practice where a dances sketches a phrase, using less energy

and working on aspects of that phrase rather than performing the whole phrase in all its complexity and with all the effort and speed required for full out performance. Our study of marking showed that marking can help a person explore aspects of a movement, one by one; it also allows a person to bring certain elements or dimensions of the phrase into focus. This idea that modeling or imperfectly simulating a complex process can lead to insight that is hard or impossible to obtain by studying the full process is found in practices other than dance and lithic sketching. In painting artists make practice sketches in order to explore elements they want to highlight or get just right. By making simplified models they bring aspects or elements or dimensions of the complex thing they want to paint into better focus, ensuring they capture features they might otherwise have missed. Attached is a paper published on marking and other issues related to interactivity “Embodied Cognition and the Magical Future of Interaction design.”

4.8 Toward Systematic Design of Different Interactive Visualization Components

Kamran Sedig (University of Western Ontario, CA)

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Visualization tools can support and enhance the performance of cognitive activities such as sense making, problem solving, and analytical reasoning. To do so effectively, however, a human-centered approach to their design and evaluation is required. This presentation highlights a number of different issues that we have been investigating in order to identify some of the main components of interactive visualizations in order to develop a systematic approach for their design and analysis. A few of the issues that are discussed include: Interaction, interactivity, cognitive activities (i. e., reasoning), and visual representations. A recent paper dealing with interaction design for visual representations is also uploaded.

5 Working Groups

5.1 Visual Narratives

Simon Attfield (Middlesex University, GB), Jörn Kohlhammer (Fraunhofer IGD – Darmstadt, DE), Catherine Plaisant (University of Maryland – College Park, US), Margit Pohl (TU Wien, AT), Huamin Qu (The Hong Kong University of Science & Technology, HK), Michelle X. Zhou (IBM Almaden Center – San José, US)

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As a group we explored the application of the notion of ‘narrative’ to visual analytics. We defined narrative as, ‘A sequence of events connected in a meaningful structure where the connecting principles are time, causation, logic, rationale and/or entity relationships.’ We considered that a ‘visual narrative’ is the visual rendering of this, and that an ‘Interactive visual narrative’ is a visual narrative where interaction occurs during construction and/or presentation. For the construction phase some key considerations are element selection and

editing and annotating the narrative. For presentation some key considerations are pace, branching, overview and detail, and annotation.

We agreed that narrative can bring structure to information and that this can support comprehension, recall, personal and public audit of an analysis, and also help support analytic systematicity and influence decisions.

We agreed on at least four kinds of narrative as applied to visual analytics. These are:

Stories in the data – Stories which recount temporal and/or causal sequences within data.

This is relevant where the data has a temporal dimension or when time is used to 'unfold' data. It is a selective and possibly interpreted account of what the data 'says' structured around temporal associations. It may provide a 'natural' way of thinking about data when it comes to identifying particular kinds of pattern, generating causal explanations, making predictions of the future and for supporting higher-level categorisation (e.g. determining intent of actors during legal cases for crime classification).

The stories of analysis – Stories which communicate the provenance of an analytic outcome by way of a history of the analytic process. It depicts the process through which an analysis was conducted and conclusions reached. Visibility of this story can offer support to the analyst and to others either during or after an analysis for reflecting what was done, auditing and interpreting outcomes. To support construct of this story, data might be gathered during the analysis by automated logging and/or manual annotation. Considerations in abstracting a meaningful narrative include: What are the meaningful agents and objects? What are the meaningful units of activity? How do you detect and represent analytic branching? How do you make a narrative engaging and build in 'Dramaturgie' (crisis/outcome, tension/release)? How do you map from low-level events (as captured by logging) to a meaningful story of progressive sensemaking?

The 'logic' of the conclusion – This is a story which recounts the (probably informal) logic of an analytic outcome. It links elements in terms of premises (both observed and assumed) and conclusions into a coherent argument. It is different from a 'story in the data' and a 'story of the analysis' in that it specifically links elements in terms of the way that one proposition supports another, rather than how one event led to another. It is a sequence of ideas akin to a logical or mathematical proof in which the relations between ideas are determined by relations of implication and not the chronology in which they occurred. An advantage of this kind of story is that its form can make explicit assumptions which might otherwise remain implicit.

Educational narratives – A story generated for pedagogical motives intended for teaching others how to perform or interpret an analysis or how to use complex analytic tools. A key role of story in this case is to lead the student through a series of ideas which may progressively build in a way that is engaging, accessible and memorable. Where the learning supports informed decision making, for example in the case of educating patients, there may be considerations of how presentational elements, such as order, might affect bias.

Finally, we discussed interaction issues as these relate to narrative in visual analytics. We identified three phases of user involvement which deserve consideration. They are: **Data gathering**, raising questions of how this is done; **Narrative construction**, raising questions of how this is done and when; and **Presentation**, raising questions about the provision of overviews for the sake of coherent user mental models, the level of user involvement in interaction (lean forward vs lean back), the pace of presentation, granularity and abstraction of the narrative, and the tension between telling an engaging and representative story.

5.2 Evaluating Interaction for Visual Reasoning

Anastasia Bezerianos (University Paris South, FR), Mary Czerwinski (Microsoft Research – Redmond, US), Brian D. Fisher (Simon Fraser University – Surrey, CA), Steve Franconeri (Northwestern University – Evanston, US), Wayne Gray (Rensselaer Polytechnic Institute, US), Petra Isenberg (INRIA – Saclay, FR), Bongshin Lee (Microsoft Research – Redmond, US), Jinwook Seo (Seoul National University, KR)

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One of the main challenges in designing interactive visual analytics systems is to measure the effectiveness of their interaction designs. Traditional performance measures such as task completion time and error rate often fail to demonstrate the value of interacting with visual representations and the effect of interaction on the analysts' reasoning process. Measuring insights is also limited in that it is hard to replicate and quantify, and it does not capture the role of the interactive system in the process that leads to the insightful moments. The role of interaction is thus difficult to tease out with an insight based evaluation. The goal of this paper is to present to the visual analytics community alternative measures related to interaction, human reasoning and analysis processes, borrowed and adapted from the field of cognitive psychology. The article that will be written based on the discussion at Dagstuhl will be structured around the design of a study to evaluate different interaction modalities for visual reasoning. It will discuss both high level questions, such as the formation and evolution of a research question, and low level aspects including the choice of evaluation tasks and methodologies. This article will serve both as an introduction to alternative evaluation measures and methodologies adapted from cognitive psychology, as well as a walkthrough example for researchers on how to formalize research hypotheses and structure evaluations around them.

5.3 The Landscape of Explanations for the Value of Interaction for Visual Reasoning

Sheelagh Carpendale (University of Calgary, CA), Anastasia Bezerianos (University Paris South, FR), Peter Cheng (University of Sussex – Brighton, GB), Brian D. Fisher (Simon Fraser University – Surrey, CA), Steve Franconeri (Northwestern University – Evanston, US), Daniel Keefe (University of Minnesota – Twin Cities, US), Bongshin Lee (Microsoft Research – Redmond, US), Chris North (Virginia Polytechnic Institute – Blacksburg, US)

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Our intuition tells us that interaction is a really important factor for visual reasoning. As a community we have generated a wealth of examples of interaction techniques. However, there is little consensus about how to explain how interactions actually create these benefits. By examining a series of diverse interaction techniques in light of visual reasoning we will begin mapping the landscape of explanations of how these interactions add value in terms of visual reasoning. We will use a semi-structure knowledge acquisition process to gather a series of interaction examples that each have three parts: a short stop motion storyboard, an accompanying verbal explanation of the task and system; and, in particular, the creators

explanations of the perceived benefits in terms of visual reasoning. By intentionally both sampling for diversity and analyzing from the perspectives of multiple research disciplines we hope to add richness to this discussion. The contribution of this paper is an exploration the space of alternative explanations to expand our understanding of the value of interaction for visual reasoning.

5.4 Mixed Initiative Interaction

Christopher Collins (University of Ontario, CA), Simon Attfield (Middlesex University, GB), Fanny Chevalier (University of Toronto, CA), Mary Czerwinski (Microsoft Research – Redmond, US), Heidi Lam (Google Inc. – Mountain View, US), Catherine Plaisant (University of Maryland – College Park, US), Christian Tominski (Universität Rostock, DE), Michelle X. Zhou (IBM Almaden Center – San José, US)

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The group defined mixed initiative interaction as a type of interaction for visual reasoning in which the human analyst and the visualization system both are active participants in the interaction. In a traditional interaction scenario, the visualization software is reactive, responding to inputs from the analyst. In MI interaction, the system would play a more active role, for example, making suggestions about appropriate views or next steps in the analysis process. There are then two directions of interaction: human to system, e.g. applying filters, making selections, loading new data; system to human, e.g. suggesting views, suggesting next steps, automatic highlighting of potentially interesting part of a view.

Mixed initiative interaction has been studied for several years, but remains on the periphery of mainstream visualization research. Systems in this area are often called ‘smart visualization’ or ‘intelligent user interfaces’. However, it seems the community is skeptical due to the cost of error: if a smart visualization system suggests a particular representation type, or an analysis process which is inappropriate to the data or current task requirements, then an analyst could become frustrated, or, worse, may come to incorrect conclusions, biased by the underlying interaction model. Other challenges in this research include being able to gather appropriate and sufficient user data to create a model of the user, such as understanding their level of experience, preferences, prior domain knowledge, etc. As this sort of data is difficult to gather and often inconclusive, we focussed our discussion on MI interaction possibilities in scenarios where we do not have prior knowledge about the analyst. Our discussions lead to a list of factors which can be used to evaluate the success of system-initiated interaction prompts:

- Are they timely? Are suggestions provided at the right time or do they interrupt the analyst’s flow?
- Does the system take initiative sparingly? If the system takes the initiative too often, the analyst may become fatigued and ignore suggestions.
- Are system suggestions appropriate? Is the system suggesting views, prompts, or other cues which enhance the analysis experience and potential for insight? Or do they lead to incorrect conclusions about the data?
- Is the provenance of system suggestions transparent? Can the human analyst understand why the system makes any given suggestion?

Scenarios where MI interaction may be useful include a new analyst using a system for the first time and requiring tutorial-style guidance. In this scenario, the system may not know much about the characteristics, prior knowledge, interaction styles and preferences of the analyst and has to provide assistance based on characteristics of the data and the current interaction session, and perhaps a crowd-driven model of the way other analysts have used the system.

Human to System Interaction (Human Initiative)

We called the types of traditional interactions, such as selecting data items, panning and zooming a view, “*explicit* interactions”. Newer forms of interaction, such as ‘model steering’ by repositioning items in a visualization to indicate prior knowledge about their relatedness, are also important inputs to a mixed initiative system.

Where we focused our discussion was on new forms of cues which may be gathered by the system in a mixed initiative interaction model to improve the quality and timeliness of prompts and suggestions. We called these inputs ‘implicit interactions’. We enumerated the following list of potential ‘implicit interactions’ which could be tracked by a visualization system and used to decide when and how to take initiative:

- Dwell time (eye gaze, touch, or mouse cursor)
- Facial gestures
- Highlighting / copying behaviour
- Repeated actions
- Body position / gestures (proxemics)
- Thrashing—changing actions / direction
- Emotional indicators
- Physiological indicators
- Mouse signatures
- Keyboard signatures
- Repositioning items on the screen
- The history of what they have explored already (the analysis process)

These implicit interactions could provide a wealth of data to a mixed initiative system, but would also have drawbacks which need to be investigated, including privacy concerns, potential for reinforcing actions (encouraging ‘tunnel vision’), or ambiguity of the meaning of the indicators. For example, physiological and behavioural indicators of excitement and annoyance may be quite similar. Which implicit interactions would be most important and how they could work together to create a profile of the analyst state are areas of future research inspired by our discussions.

System to Human Interaction (System Initiative)

Others have researched system-initiated interaction driven by user profiles and data characteristics, so we targeted our discussions on the types of feedback a system could provide based on analysis of implicit interaction data. The timing of system-initiated interaction is crucial: ideally it is timely, does not interrupt the flow of analysis and human-initiated interaction, and is appropriate to the data and task. Design decisions to consider in future work include: (a) how to present interaction and analysis suggestions, (b) how to reveal the provenance of guidance (why a suggestion is made by the system), (c) how to encode the confidence level the system has in a suggestion, etc. We recommended that system feedback

could also be subtle or implicit. For example, if the system senses the analyst is “lost” or “stressed”, rather than asking “are you stressed?” it could simply provide additional on screen help, adjust or simplify the interface, and suggest alternative views.

We explored a variety of system responses which may be appropriate if the indicators strongly point to the need for system-initiated interaction. Specifically, we looked at possible responses to various detected emotional states, such as frustration, confusion, boredom, interest, and engagement. System responses may include: show more views like the current view, show views different from the current view, show what other people (all people / people like me / experts) did in similar situations, offer help, or simplify the view (remove a data dimension or perform aggregation). MI interaction should be flexible and perhaps system-initiation should be turned off automatically after the analyst does not acknowledge or use system suggestions over a long period of time.

To conclude our meetings, the group brainstormed about a paper outline reporting on our mixed initiative interaction for visual reasoning ideas, and assigned next steps to the participants.

5.5 Conceptual Structures of Interaction for Visual Reasoning

Kelly Gaither (University of Texas – Austin, US), David S. Ebert (Purdue University, US), Thomas Ertl (Universität Stuttgart, DE), Hans Hagen (TU Kaiserslautern, DE), Petra Isenberg (INRIA Saclay, FR), Tobias Isenberg (INRIA Saclay, FR), Jörn Kohlhammer (Fraunhofer IGD – Darmstadt, DE), Margit Pohl (TU Wien, AT), Kamran Sedig (University of Western Ontario, CA)

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Interaction is a fundamental element of successful visualization methods and tools. In visualization, interaction can support many low-level and high-level tasks and goals, can support different representation and interaction intends, and can be realized by different techniques. The specific incarnations of the interaction design, however, are driven by the specific application domain, by the tasks being supported, by the type of data being analyzed, by the specific representations being chosen, by potential limitations of computability, and by the needs and requirements of the users. The question that we aimed to analyze is if we can identify general principles of interactions that bridge different domains and are common among tasks, data types, and representations. Can we formulate or propose a language or schema of interaction that is common for most if not all visualization tools and methods, potentially with different dialects?

5.6 Magic Interactions with Information for Visual Reasoning

Daniel Keefe (University of Minnesota – Twin Cities, US), Sheelagh Carpendale (University of Calgary, CA), Peter Cheng (University of Sussex – Brighton, GB), Fanny Chevalier (University of Toronto, CA), Christopher Collins (University of Ontario, CA), Tobias Isenberg (INRIA Saclay, FR), David Kirsh (University of California – San Diego, US), Heidi Lam (Google Inc. – Mountain View, US), Chris North (Virginia Polytechnic Institute – Blacksburg, US), Kamran Sedig (University of Western Ontario, CA), Christian Tominski (Universität Rostock, DE), Xiaoru Yuan (Peking University, CN)


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Today, there is much excitement around the concept of “natural user interfaces.” The interest is sparked in part by the widespread availability of multi-touch devices, including smart phones and tablets. However, the trend is not limited to these new commercial devices; a variety of recently developed user interface techniques that enable seemingly more direct ways of interfacing with computers have been dubbed “natural.” Will these natural interactions define the future of computing? As user interface designers, and in particular as designers and researchers interested in supporting users as they reason about super-complex information, we have to ask, is “natural” actually the right target? Do we really want to design natural interactions or do we want something else? How about “supernatural” or even “magical” interactions? Our Dagstuhl working group found that the more we thought about the systems and human-computer interfaces that have most influenced us or impacted our work, the more we recognized that (at least the first few times we used these systems) they all felt magical. Some examples include: (1) clicking and dragging a drawing of a cartoon character who then responds “intelligently” by changing his pose in direct response to the user’s input, understanding how to move as if by magic; (2) Browsing video data by clicking directly on characters in the video rather than using a slider; (3) Bumping mobile devices to transfer files; and (4) Selecting 3D point clouds just by drawing a 2D lasso. All of these interactions have “the power of apparently influencing the course of events by using mysterious or supernatural forces” and “a quality that makes something seem removed from everyday life, esp. in a way that gives delight” – two properties taken directly from the definition of the word magic. Grounded in findings from the cognitive science research community, we developed several explanations for when and why “magical interactions” seem to work well, including the notions of a different cognitive cost structure for natural vs. magical interactions, superpower and amplification, context/temporal appropriateness, and working with underspecified and imprecise data or applications. Based on these insights, we call for a new research focus that moves beyond “natural user interfaces” and instead targets magic interactions with information.

5.7 Crowd Interaction in Visual Reasoning

David Kirsh (University of California – San Diego, US), Huamin Qu (The Hong Kong University of Science & Technology, HK), Jinwook Seo (Seoul National University, KR), Xiaoru Yuan (Peking University, CN)

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How can we harness the intelligent capacity of crowds to reason visually about a topic? In recent years real-time posting of images, video and tweets by citizens in the midst of a natural disaster has provided better information to first responders than information from helicopters and their own officials on the ground. That new source of local information is just starting. It presents a great opportunity for data mining but also for visual reasoning. There are major challenges. How should we enable *intelligent aggregation* of visual and other qualitative data? How should we make *visual and textual summaries* to communicate ideas? How might we use groups to *preprocess data* to support interactive visualizations?

The basic methods of crowd sourcing in use to date are far removed from our goal of using crowds to create meaningful visualizations. Currently, crowds are used for judging the plausibility of statements, for making value judgments, for giving aggregate views, but as yet not for creating visual narratives, intelligent visualizations, or preprocessing qualitative data.

In our group we identified problems that need to be solved to harness crowd power for visual reasoning and qualitative argumentation. Beside aggregation and intelligent summarizing we considered questions of coordination: how should the identification and disbursement of tasks be intelligently managed? Can this be done automatically or can we use Turkers to make themselves into a self-organizing system? How can Turkers be unleashed on a problem and generate requests that when answered in the right way are amenable to visualizing complex problems?

Participants

- Simon Attfield
Middlesex University, GB
- Anastasia Bezerianos
University Paris South, FR
- Sheelagh Carpendale
University of Calgary, CA
- Peter C.-H. Cheng
Univ. of Sussex – Brighton, GB
- Fanny Chevalier
University of Toronto, CA
- Christopher Collins
University of Ontario, CA
- Mary Czerwinski
Microsoft Res. – Redmond, US
- David S. Ebert
Purdue University, US
- Thomas Ertl
Universität Stuttgart, DE
- Brian D. Fisher
Simon Fraser Univ. – Surrey, CA
- Steve Franconeri
Northwestern University –
Evanston, US
- Kelly Gaither
University of Texas – Austin, US
- Wayne D. Gray
Rensselaer Polytechnic, US
- Hans Hagen
TU Kaiserslautern, DE
- Petra Isenberg
INRIA Saclay – Île-de-France –
Orsay, FR
- Tobias Isenberg
INRIA Saclay – Île-de-France –
Orsay, FR
- Daniel Keefe
University of Minnesota –
Duluth, US
- David Kirsh
University of California – San
Diego, US
- Jörn Kohlhammer
Fraunhofer IGD –
Darmstadt, DE
- Heidi Lam
Google Inc. –
Mountain View, US
- Bongshin Lee
Microsoft Res. – Redmond, US
- Chris North
Virginia Polytechnic Institute –
Blacksburg, US
- Catherine Plaisant
University of Maryland – College
Park, US
- Margit Pohl
TU Wien, AT
- Huamin Qu
The Hong Kong University of
Science & Technology, HK
- Kamran Sedig
Univ. of Western Ontario, CA
- Jinwook Seo
Seoul Nat. University, KR
- Christian Tominski
Universität Rostock, DE
- Xiaoru Yuan
Peking University, CN
- Michelle X. Zhou
IBM Almaden Center –
San José, US

