Human Aspects of Visualization

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1 Introduction

This book is intended to give an overview of important issues concerning Human-Computer Interaction and information visualization. It is based on an IFIP [4] workshop that took place during the Interact'09 conference in Uppsala [3]. This workshop, co-organized by IFIP WG TC13.7 on "HCI and Visualization" [2] and the European VisMaster Coordinated Action [5], surveyed and expanded our understanding of the cognitive and perceptual issues of interactive visualization and visual analytics and brought together researchers interested in these issues. It outlined the research required to understand what aspects of analysis match human capabilities most closely, and how interactive visual support should be designed and adapted to make optimal use of human capabilities in terms of information perception and processing.

This is a challenging agenda that has to take into account many factors including user roles, tasks, collaborations, interests and previous knowledge as well as understanding the capabilities of display devices and computation methods for dealing with often very large data sets. The workshop goals required the cooperation of scientists from different disciplines addressing aspects of visualization and analysis. This enabled a mapping between foundational theories in the different research areas to support collaboration among researchers in these fields. This included researchers and developers already working at the intersection of HCI, visualization, visual analytics, and related areas such as data mining, data management, perception and cognition.

2 Goals and Issues

Displays affect the visual interaction of human with computer devices more than any other hardware component. The display determines, for example, the physical size of the viewport, the range of effective field-of-view and resolution that is possible, and the types of feasible interaction modalities. All other interactions

must be placed in the context of the display. Thus in recent years, two trends have been emerging.

First, visualization on large displays has become an increasingly important research topic. This is manifested in many applications in the use of wall-sized display devices. For example, large public screens enable a bigger audience to view the contents. Large displays for collaborative work provide the necessary screen real estate to allow the display of different points of view of the different users. The use of large display areas enables a more thorough immersion in virtual reality applications. And finally, large high-resolution displays enable visualization of large and complex datasets by facilitating both overview and detail views at the same time.

On the other hand, the proliferation of mobile devices requires visual applications on very small screens. With these smaller-scale displays, assumptions of the normal desktop metaphor no longer apply and mice and keyboards, designed for desktop interaction, become unsatisfactory. This calls for novel interaction devices and techniques designed for small screens of mobile devices.

Regardless of the device in use, interactive visualization methods are needed to augment cognitive resources by providing an additional, external visual resource to the human memory. They may reduce the amount of searching and make it easier to recognize patterns as well as enhance the understanding of relationships especially in large amounts of data and information. In addition, interactive visualization methods provide a medium that enables the user to have a representation of information that he or she can quickly and easily modify, restructure or consider from a different perspective. This ability to manipulate the data is of extreme importance especially for analytical reasoning and sensemaking.

Research in HCI and visualization has produced numerous forms of visualization and methods for interacting with visualizations of large data sets. However, systematic understanding of the interaction issues with visualization and the human cognitive and perceptual processes involved is perhaps less well developed. Therefore, the workshop at Interact 2009 tackled the human aspects of visualization and built an inspiring platform for presentations and intensive and controversial discussions. The articles in this book capture the exciting presentations and discussions about these issues.

3 The Articles in this Book

The following section is a short overview of the papers in this book. All but the paper of Bob Spence – the keynote speaker at the workshop – are listed in alphabetical order (name of the first author).

3.1 The Broker

Bob Spence (Keynote)

There is a considerable amount of existing perceptual and cognitive knowledge that is highly relevant to information visualization. Nevertheless, it is difficult to directly apply it to the design of information visualization. Much of the research is very abstract in nature. Some results might be context-dependent and could not be easily generalized to information visualization applications. In his keynote lecture, Bob Spence, therefore, advocated that "Brokers" should mediate between cognitive scientists and information visualization designers. "The task of a Broker is to interpret relevant knowledge acquired by cognitive and perceptual psychologists and bring it suitably to the notice of interaction designers, thereby avoiding the need for that designer to have knowledge of cognition and perception."

A suitable method to do this brokerage is to develop Design Actions. Design Actions are structured forms that provide design guidance at a useful level of detail. In a way, they translate knowledge from cognitive psychology into a "language" that can be understood by designers. Basically, they are guidelines, but they also contain information about the empirical evidence supporting them, and advantages and disadvantages of following the guideline.

Bob Spence's article provides a valuable foundation for the following papers, many of which try to connect psychological research with design issues of information visualization.

3.2 Comparing Different Layouts of Tag Clouds: Findings on Visual Perception

Stephanie Deutsch, Johann Schrammel, Manfred Tscheligi

Tag clouds are an example of casual information visualization as described in the article of Andreas Kerren (see below). They can support users who want to get a comprehensive overview of the annotations that are often chaotically made by communities on the web. Clustering can produce meaningful units within tag clouds, but these units have to be presented in a way that can be easily perceived and understood.

The authors argue that, while tag clouds are intuitively comprehensible and attractive for users, they have certain limitations, e.g. the amount of redundant annotations or the problem that concepts are understood differently by various users. In addition, more possibilities for interaction would be advantageous. They also emphasize the importance of developing a solid foundation in perceptual psychology, especially with regard to visual perception and eye movement. Their empirical study indicates that semantic clustering (in contrast to traditional methods of tag-cloud-generation) might be useful for classifying annotations. However, they point out that there are still open questions regarding the design of such visualizations.

3.3 The Personal Equation of Complex Individual Cognition during Visual Interface Interaction

Tera Marie Green, Brian Fisher

Green and Fisher discuss approaches from cognitive psychology that might guide the design of interactive visual interfaces. They point out that the interaction with visual interfaces consists of complex cognitive behavior. So far, evaluation studies have focused on low-level cognitive processes (e.g. pre-attentive processing). This turns out to be interesting but not sufficient. In this context, they discuss theories of reasoning, especially the so-called sense-making loop. They point out that human reasoning processes can vary widely and therefore it is not easy to develop comprehensive theories of human reasoning. Models like the sense-making loop may form a general framework, but cannot guide concrete design decisions.

The authors also argue that human cognition is fundamentally influenced by individual differences (e.g. how humans categorize information, how they perceive visually or which problem-solving behaviors they adopt). Based on this assumption, they developed the Human Cognition Model, an operational framework to guide the design of collaborative interactive systems.

3.4 Faceted Visual Exploration of Semantic Data

Philipp Heim, Jürgen Ziegler

Heim and Ziegler address the problem of searching and exploring semantic data, in particular whether faceted search might be a possible way to support such search processes in Semantic Web data. In faceted search, the search space is divided based on independent search dimensions that serve as filters. To support users in their exploration of semantic data they developed a graphical tool representing facets and search results as nodes in a visualization that exploits the graph-based structure of linked semantic data. This graphical representation can help users to develop a coherent cognitive model of the target domain.

Heim and Ziegler argue that searching semantic data differs from using relational databases and conventional information retrieval. The tool they developed is specifically targeted at searching and exploring semantic data and especially supports exploration and hypotheses refinement processes.

3.5 Fisheye Interfaces – Research Problems and Practical Challenges

Mikkel Rønne Jakobsen, Kasper Hornbæk

One of the major problems in information visualization is the representation of large amounts of data and information. Cognitive overload resulting from the display of large amounts of data has to be avoided by an appropriate and effective design. There are several possibilities to reach this goal, one of which is focus+context interfaces (e.g. fisheye interfaces). Although using fisheye interfaces is a well-known technique dating back many years, Jakobsen and Hornbæk

argue in their article that many problems concerning this technique are still not solved. They point out that, for example, the notion of focus is not very well defined in the literature. Consequently, different systems are developed with a large variety of interaction strategies. This makes it difficult to give an overall assessment of such systems. In addition, fisheye interfaces are seldom integrated into practical applications where they could probably be most useful.

Jakobsen and Hornbæk address some of the open questions they describe in their empirical research. Their work indicates that even for well-known techniques, many usability issues are still not solved. Apart from that, their discussion also deals with more general questions of the representation of large datasets on the screen and raises issues relevant for the information visualization community as a whole.

3.6 Visualization of Workaday Data Clarified by Means of Wine Fingerprints

Andreas Kerren

In his contribution, Kerren discusses the topic of information visualization for the masses, also called casual information visualization. Originally, information visualization was predominantly developed for expert users who needed sophisticated applications for complex problems. Nowadays, an increasing number of non-specialist users are interested in such tools, but may only occasionally need them or encounter them. Such systems have to be more intuitive and easier to learn than the ones geared for professional users. Potential visualizations for such systems are simple node-link diagrams, tag clouds or treemaps.

Kerren points out that intuitive and easy to learn interfaces are not always obvious. In his research, he initially assumed that treemaps would be easier to understand for casual users than bubble diagrams; however, this assumption was found to be incorrect. It is anticipated that simple visualizations will become even more important because of the increasing utilization of social software to support, for example, the perception of relationships between members of communities in Facebook.

3.7 Staying Focused: Highlighting-on-Demand as Situational Awareness Support for Groups in Multi-display Environments

Olga Kulyk, Tijs de Kler, Wim de Leeuw, Gerrit van der Veer, Betsy van Dijk

In recent years, there has been an increase in research on cooperative problem solving using information visualization techniques. It is hoped that multi-display environments may support group decision-making capabilities, as the displays can act both as communication tools and information devices. The authors point out that group decision processes are often flawed, for example, because of the dominance of single group members or because group members ignore alternative solutions.

Cooperative information visualization tools might overcome such problems by giving a comprehensive overview of existing possibilities and enabling group members to draw attention to various solutions by highlighting them. Technologies like tabletop computers or large tablets might be especially valuable in this context if they are appropriately designed and well integrated into the decision process.

3.8 Using Gaze Data in Evaluating Interactive Visualizations

Harri Siirtola, Kari-Jouko Räihä

Siirtola and Räihä discuss the difficulties in carrying out effective evaluations of interactive visualizations. Because of these difficulties, evaluations of such systems have often been missing. Thus, it is difficult to assess whether interactive visualizations are really useful. One of the reasons for this lack of evaluation studies might be that carrying out effective evaluations is both time-consuming and costly. They propose a simpler methodology for evaluation by using eye tracking.

In recent years, eye tracking has become more attractive for evaluation studies because the systems have become cheaper and easier to use. Nevertheless, the authors point out that the volume of data and the lack of methodologies to generalize these data is still a problem. This is especially difficult for animations when it is difficult to measure fixations on moving objects. In addition, there are still many open questions as far as interpretation of the data is concerned.

3.9 Giga-Scale Multi-resolution Volume Rendering on Distributed Display Clusters

Sebastian Thelen, Jörg Meyer, Achim Ebert, Hans Hagen

Large high-resolution displays have proven to be beneficial in various kinds of collaborative scenarios. They allow users to physically navigate the space in front of the screen and interact with applications in a highly dynamic way. Due to their extended screen space, large high-resolution displays are often employed by user groups to explore data sets that, because of their size, could not be perceived entirely on a regular small desktop display. However, visualizing such data sets is challenging since their size can exceed the computational resources of render nodes by several orders of magnitude, thus making data exploration more complicated.

Thelen et al. describe a technique to visualize and explore gigabyte-sized volumetric data sets on distributed display clusters, such as tiled monitor walls or tiled projector walls. Their method uses a wavelet-based multi-resolution approach in combination with octree-based space subdivision to significantly increase the level-of-detail that each render node in the cluster is able to display. The paper describes the underlying visualization approach and analyzes the results obtained with various data sets. The implementation was successfully tested on a tiled display comprised of 25 compute nodes driving 50 LCD panels. The system was able to produce renderings of volumetric data sets larger than the

texture buffer size of a single graphics card at significantly higher levels of detail than on a single desktop display.

3.10 Teaching Visual Design as a Holistic Enterprise

Gerrit C. van der Veer, Corné Verbruggen

Van der Veer and Verbruggen argue that approaches in Visual Design education are often limited because of a focus on the design of the computer screen. Such an approach does not take into consideration that the interpretation of visual representations is often influenced by a specific context and by the experiences and attitudes of the observers. Designers of the visualization tools usually cannot anticipate users' reactions and therefore develop tools that are not adaptable to users' needs. This gap between designers' and users' mental models has often been described in Human-Computer Interaction textbooks and it is the main reason for recommending user studies. But, the argumentation of the authors goes beyond this; they point out, for example, that visualization tools do not merely produce representations on the screen but also introduce physical artifacts that are part of the display device – each device has specific characteristics like portability, opportunity for dialogue, visibility in daylight or in a building.

Design education has to take all of these aspects into consideration. In this sense, it should be holistic and address more than screen design. Consequently, usability is just one aspect of the story. Other factors to be considered are, for example, that the audience is often heterogeneous and comes from different backgrounds and that one needs to take into account the rules of human perception that could be analyzed by Cognitive Psychology.

4 Summary

Throughout the discussions during the "Human Aspects of Visualization" workshop, several common topics among the participants emerged and these common topics are reflected in the papers.

A common theme that is probably essential for this area is the relationship between research from cognitive psychology and design of interactive visualization systems. This problem was mentioned by Bob Spence in his keynote address, but can also be found in other articles in this book. Green and Fisher, for example, describe theories of reasoning and problem-solving and point out that there is no single theory in this area that might effectively explain the design of information visualizations, and therefore, one needs to make use of a number of different theories. This makes it difficult to formulate guidelines for explaining effective designs of information visualizations. Deutsch et al. also discuss psychological theories as foundation for research in information visualization. Kulyk at al. extensively discuss research from social psychology and sociology to substantiate their results. Related issues are also elaborated in van der Veer and Verbruggen's discussion of a holistic approach in design education; they point out that many different disciplines are necessary to develop successful visual

designs, not only psychology but also, for example, media theory or sociology because the functioning of visual design depends on the social context and on the characteristics of the media being used.

Another common topic was information visualization for non-experts. As information visualization systems are increasingly adopted by non-expert users, their design will have to be adapted to this population. Kerren explicitly discusses this problem and tries to give an outline of possible solutions. This is also mentioned in the paper by Deutsch et al.

Methodological issues also played an important role in the workshop discussions. One open question is whether traditional methods of cognitive psychology or HCI are appropriate for the investigation of perceptual and cognitive aspects of information visualization. Methodologies such as eye-tracking (discussed by Siirtola and Räihä as well as by Deutsch et al.) offer the potential for radically different ways of approaching evaluation. However, these are themselves areas of substantial complexity. One problem is the appropriate interpretation of the data gained from eye-tracking studies and the definition of the variables that could be measured by this technology.

Another important issue that should play an important role in the future of visualization and HCI is the design of visualization systems supporting cooperative activities (see the contribution of Kulyk et al.). Technologies like tabletop computers might be the medium of choice in group situations. The papers indicate that there are still many open research questions even when one considers topics that have been studied for a considerable time like fisheye interfaces. The book can only outline some of the most prominent problems and some potential solutions to the effective application of human-computer interaction in information visualization.

As already mentioned above, the workshop at the Interact conference was co-organized by IFIP WG TC13.7 on "HCI and Visualization" (HCIV) and the European VisMaster Coordinated Action.

HCIV is a major program in Human Computer Interaction and Visualization that started in 2006. The aim of this initiative is to establish a study and research program that will combine the knowledge of both the science and the practice in the fields of HCI and Visualization. One of the main steps in organizing this program is a workshop series with world-renowned experts in the fields of Human Computer Interaction and Visualization. Since 2009, HCIV is an official working group of IFIP Technical Committee on Human-Computer Interaction (TC.13). In addition, all HCIV workshops since 2009 have been approved as an official IFIP event (including the Interact 2009 workshop on human aspects of visualization).

VisMaster is a European Coordination Action Project focused on the research discipline of Visual Analytics. The main strategic goal of this action is the shaping of a new research community for the field of Visual Analytics. It explicitly addresses issues of human cognition, perception and decision-making. To support the human visual and reasoning abilities efficiently, tools for visual analysis

tasks have to be designed appropriately. The workshop helped in shaping the Visual Analytics community and hereby provided valuable input to the VisMaster project; in particular creating a foundation for the discussion of perceptual and cognitive issues in the European Visual Analytics roadmap "Mastering the Information Age" [1].

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