

# Interaction for Visualization

Christian Tominski  
University of Rostock

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## ABSTRACT

Visualization has become a valuable means for data exploration and analysis. Interactive visualization combines expressive graphical representations and effective user interaction. Although interaction is an important component of visualization approaches, much of the visualization literature tends to pay more attention to the graphical representation than to interaction.

The goal of this work is to strengthen the interaction side of visualization. Based on a brief review of general aspects of interaction, we develop an interaction-oriented view on visualization. This view comprises five key aspects: the data, the tasks, the technology, the human, as well as the implementation. Picking up these aspects individually, we elaborate several interaction methods for visualization. We introduce a multi-threading architecture for efficient interactive exploration. We present interaction techniques for different types of data (e.g., multivariate data, spatio-temporal data, graphs) and different visualization tasks (e.g., exploratory navigation, visual comparison, visual editing). With respect to technology, we illustrate approaches that utilize modern interaction modalities (e.g., touch, tangibles, proxemics) as well as classic ones. While the human is important throughout this work, we also consider automatic methods to assist the interactive part.

In addition to solutions for individual problems, a major contribution of this work is the overarching view of interaction in visualization as a whole. This includes a critical discussion of interaction, the identification of links between the key aspects of interaction, and the formulation of research topics for future work with a focus on interaction.

## KEYWORDS

Visualization, interaction, zoomable user interfaces, interactive lenses, touch interaction, tangible interaction, proxemic interaction, selection, navigation, exploration, visual comparison, visual editing, large displays, automatic methods, navigation recommendations

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Christian Tominski  
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## CHAPTER 1

# Introduction

Nowadays, we live in a world full of data. Technological advances have led to a situation where we collect excessively far more data than we can make sense of—a problem known as *information overload* (Strother et al., 2012). *Visualization* has become an accepted means to address the information overload. The key idea behind visualization is to transform data into pictures that humans can interpret more easily than large quantities of numbers (Ware, 2012). *Interaction* between the human and the computer plays an integral role in the process of forming mental models of the data (Spence, 2007). This work emphasizes the role of interaction in visualization.

## 1.1 WHY FOCUS ON INTERACTION?

Bertin (1981) points out the importance of interaction for visual data exploration and analysis:

“A graphic is not ‘drawn’ once and for all; it is ‘constructed’ and reconstructed until it reveals all the relationships constituted by the interplay of the data. The best graphic operations are those carried out by the decision-maker himself.”

— Bertin (1981)

Bertin conveys two key messages. First, interaction is indispensable for constructive processes such as developing insight into complex data, and second, interaction enables the human to steer the data exploration and to make the final assessment of the data. Interestingly, Bertin expressed his thoughts on interaction years before visualization existed as a field. Still, the essence of his statement remains valid until today.

Computer-supported visualization has always included the notion of interactivity. Similar to what Bertin said, Pike et al. (2009) state the following:

“It is through the interactive manipulation of a visual interface—the analytic discourse—that knowledge is constructed, tested, refined and shared.”

— Pike et al. (2009)

Despite the importance of interaction in visualization, much of the literature on visualization focuses, in fact, on the visual part, not so much on the interaction part. Many visualization publications describe in detail aspects of the visual representation, but less is reported about the design and the implementation of interaction in visualization. Several other researchers have taken note of this deficiency:

## 2 1. INTRODUCTION

“Even though interaction is an important part of information visualization (Infovis), it has garnered a relatively low level of attention from the Infovis community.”

— Yi et al. (2007)

“Until recently, the focus of InfoVis has been more on the graphical representation and less on the interaction.”

— Fekete (2010)

“Also, although interaction isn’t yet a primary theme, the visualization research literature reflects an increasing focus on it.”

— Keefe (2010)

“Unfortunately, interaction is not discussed at all in graphic design, and even visualization textbooks tend to downplay this angle.”

— Elmqvist et al. (2011)

There are several explanations for why interactive aspects are not on equal terms with visual aspects. First, visualization has its roots in computer graphics. Second, reporting a result related to interaction (a process) is typically more difficult than reporting on a visual result (an image). Third, there is no standard notation one could rely on when describing interaction.

This work is an attempt to balance the visualization plus interaction equation. To this end, we deliberately look at visualization from an interaction perspective.

### 1.2 AN INTERACTION-ORIENTED VIEW

We develop and discuss an interaction-oriented view of visualization, bringing together the relevant concerns under a common hood. *Data* and *tasks* are key factors of visualization and likewise they are primary concerns to be considered for interaction. Further, we consider the *technology* providing the means for display, interaction, and computation, as well as the *human* user as the recipient of visual information and active participant in the interactive data exploration and analysis process.

That said, the primary topic of interest of this work is to investigate interaction in visualization along the key factors: data, tasks, technology, and human. Studying these factors individually with a focus on interactive approaches, we provide a broader picture on interaction in visualization as a whole. Addressing the *data*, we discuss solutions taking into account both the structure of data as well as the spatial and temporal frame of reference in which data are usually given. With regard to *tasks*, we present interaction techniques for visual comparison and data editing, both of which being highly relevant in data-intensive work places. We introduce techniques that utilize different interaction *technologies*, including classic mouse and keyboard interaction, but also modern touch interfaces and physical interaction in front of large high-resolution displays. Focusing on the *human* user, we look at techniques for reducing interaction costs by drawing inspiration from natural interaction, by following real-world workflows, and by integrating automatic methods.

The interaction side of visualization is also studied from an *implementation* perspective. We present an efficient multi-threading architecture that can serve as a general basis for developing interactive visualization systems. We further illustrate several solutions that incorporate modern display technology and interaction modalities to implement novel ways of interacting with visual representations of data.

With our interaction-oriented view organized according to data, tasks, technology, human, and implementation, we hope to contribute to lifting interaction in visualization to a level that corresponds to its widely acknowledged importance.

## 1.3 OUTLINE

Chapter 2 starts with an introduction to the fundamental concepts of visualization and interaction. The introduction collects various definitions, explains basic interaction techniques, studies the visualization-interaction gap, and discusses the advantages and disadvantages of interaction in visualization. Basics of implementing interactive visualization solutions complement this chapter.

Chapter 3 takes a closer look at the aspects of interaction in visualization and develops a structured interaction-oriented view on the topic. As indicated, we will cover five key aspects: the data, the tasks, the technology, the human, and the implementation.

In Chapter 4, we present methods and techniques that illustrate key questions and corresponding solutions with respect to our interaction-oriented view. In Section 4.1, we address interaction implementation on a fundamental level by discussing a multi-threading architecture for interactive visualization applications. Section 4.2 sets the focus on the data aspect by introducing effective ways of interacting with graph structures and movement trajectories in space and time. The task aspect is taken up in Section 4.3, where we illustrate interaction techniques for visual data comparison and data editing tasks. In Section 4.4, we present tangible views and explain physical navigation in front of large displays as novel ways of interaction that take advantage of technological progress. Addressing the human user, we discuss the use of automatic event-based methods and navigation recommendations as means to reduce interaction costs in Section 4.5. All approaches are described in a compact way, presenting the key messages with a focus on interaction in visualization.

Chapter 5 provides an overall summary and conclusion. Key concerns are to derive and discuss insights about the greater picture of interaction in visualization as drawn in this work and to identify research topics for future work.



# Author's Biography

## CHRISTIAN TOMINSKI

**Christian Tominski** received a diploma and doctoral degree from the University of Rostock, Germany, in 2002 and 2006, respectively. He is a senior researcher and lecturer at the Institute for Computer Science at the University of Rostock. His research interests are in visualization and visual analytics. He is particularly interested in the role of interaction for visual data exploration and analysis. He worked on utilizing novel display and interaction devices for interactive visualization and on integrating automatic methods to assist the visualization. Christian has authored and co-authored more than 50 academic publications on new visualization approaches and interaction methods. He also developed a number of visualization tools for time-oriented data, spatio-temporal data, movement data, and graph data. More about Christian's research and demos of visualization prototypes can be found on his website at: <http://www.informatik.uni-rostock.de/~ct>.