# Post-WIMP Interaction for Information Visualization

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# Contents

# Post-WIMP Interaction for Information Visualization

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ABSTRACT

Well-designed interactions for visualization systems hold great promise both for empowering people to effectively complete their tasks and for providing more natural and engaging user experiences. Leveraging advancements in hardware and software technology, the visualization research community has made considerable progress providing novel input and interaction experiences. These technologies continue to advance at a fast pace, and thus it seems timely to look back at what has been achieved so far and contemplate what might be possible in the future. In this monograph, we first present a condensed summary of research efforts investigating post-WIMP interaction techniques in visualization systems. We also include research from the broader HCI community and several product releases from industry that we believe to be relevant and have influenced visualization interfaces. Furthermore, we reflect on our own projects that investigated post-WIMP InfoVis interaction and systems. We discuss the main challenges we faced and lessons we learned, and we reflect on how our perspectives and viewpoints on post-WIMP for InfoVis have evolved over the

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course of these projects. Finally, we identify several open research directions that will help realize the full potential of post-WIMP interaction for and with InfoVis, expanding the boundaries of InfoVis and reaching a broader audience.

# 1

# Introduction

Interaction, a means for people to express their goals and intentions to systems, plays a critical role in information visualization (InfoVis). The importance of interaction grows as the size and complexity of data increases. Well-designed interactions empower people to effectively complete tasks with visualized data, which simply may not be possible with static visualizations. Furthermore, such interactions can provide a more fluid and engaging experience.

Over the past few decades, both industry and the broad human–computer interaction (HCI) research community have made significant advancements in hardware and software technologies that can be leveraged to support novel interaction techniques. We—InfoVis and HCI researchers—have been increasingly empowered to take a step closer to the post-WIMP user interfaces van Dam envisioned (van Dam, 1997), where the "interface disappears," enabling people to focus on their tasks rather than worrying about user interfaces consisting of icons, buttons, and menus. Touch-enabled devices are now affordable and prevalent, and they are also becoming increasingly compatible with complementary devices such as digital pens or styluses. Today, it is common to interact with touch input, and pinch and swipe gestures have become

de facto standards. Pen interaction allows people to draw, manipulate, and annotate digital artifacts, such as documents and charts in a more flexible and fluid way. Natural language understanding and generation has made astonishing progress, enabling people to talk to systems and helping them understand the visualized data.

Such advancements are particularly timely, encouraging, and important, presenting novel research opportunities across a wide range of application domains. The advancements also expand both the group of people who could use and benefit from InfoVis and the usage contexts and environments in which InfoVis will be used (Lee *et al.*, 2020). Unlike interaction with InfoVis systems so far, going forward, we cannot and should not assume that one person will be performing data analysis while sitting in front of a desktop computer, with access to a mouse and keyboard (Isenberg *et al.*, 2011). Multiple people with different roles and backgrounds may investigate data together on devices such as a wall-sized, multitouch-enabled display. Designers may create novel and engaging visual representations using a tiltable digital canvas equipped with a stylus. Lay people may consume visual data stories on their tablets while lying on a couch or their own data with their smartphones on a bus. Athletes may track how their speed and heart rate change while they are running.

The InfoVis research community has recognized the potential and importance of more natural, flexible, and fluid interactions, going beyond a traditional desktop environment (Lee *et al.*, 2012; Roberts *et al.*, 2014). The community has made slow but steady progress adapting and leveraging advancements in input and interaction technologies in novel ways. We assert that the InfoVis context serves as a great platform to demonstrate the benefits and potential of novel interaction technologies. It is time to take stock of what has been investigated so far and to look into the future.

In this monograph, we discuss recent explorations into post-WIMP interaction for InfoVis. Rather than conducting a comprehensive survey, we instead provide a more personal retrospective of our own projects and experiences. While our reflection is focused on our own research, we refer to other relevant research and commercial systems that have enabled and influenced our research and thinking both directly and indirectly.

We begin this retrospective with a brief overview of research endeavors that have employed and adapted post-WIMP interaction techniques in InfoVis systems. We include and highlight major milestones we believe to be worth mentioning, for example, being the first attempt/application or having a major impact, sparking a thread of research projects. To provide a better context, we also include not only research and activities from the broader HCI community but also product releases from industry (e.g., the Perceptive Pixel, iPhone/iPad, and various Surface devices) that we found relevant and influential to novel interactions within InfoVis. We first collected a purposive sample of 110 publications each author found worth mentioning and categorized them by interaction modality, target device, publication year, and venues. From this sample we selected a representative subset to cover in this monograph. (Throughout the writing process, we incorporated additional papers including the ones suggested by reviewers.) We chose not to cover an in-depth analysis of a wide variety of visualization-related research areas, for example, looking into general HCI research on post-WIMP interaction or including post-WIMP interaction for Scientific Visualization, as we wanted our retrospective to stay close to our personal experiences in the InfoVis area. We acknowledge that what we cover here is by no means exhaustive or comprehensive and that a systematic review on post-WIMP interaction for InfoVis or visualization more broadly would be a good complement to this monograph.

In the scope of this monograph, we generally follow van Dam's notion of post-WIMP (van Dam, 1997), focusing on interaction techniques that do not require a mouse and keyboard. One exception to this is the inclusion of natural language interaction that uses a keyboard because it obviates the need to fully rely on menus and toolbars, and segues into speech-based interaction. Conversely, we exclude interactions purely based on mouse-driven direct manipulation: while they are widely adopted and highly valuable, they inherently rely on a mouse and widgets. Similarly, we do not discuss augmented reality (AR) and virtual reality (VR) applications if their interaction relies solely on a WIMP metaphor (e.g., interacting with menus and buttons in AR/VR through a controller).

We also discuss key insights and knowledge collectively gained and synthesized from our own projects that employed and adapted post-WIMP interaction techniques in InfoVis systems. We aim to reflect on the challenges we faced, lessons we learned along with the misconceptions we initially had, and how our perspectives and viewpoints of post-WIMP for InfoVis have evolved over the course of different projects. The key reflections and viewpoints that are explored in-depth are:

1. As we explore the benefits and strengths of multimodal interactions, we must strive to maximize the synergies between different modalities while identifying the most suitable operation-to-modality mappings and logical (i.e., semantically meaningful) combinations of modalities.

2. Post-WIMP and WIMP interfaces have their own strengths and weaknesses, and they can complement each other. We thus can and should create synergy between post-WIMP and WIMP to improve and enhance overall user experiences.

3. While it is important to design natural and novel interactions, to increase the resulting systems' practical viability (beyond research settings), we need to consider consistency in interactions across different visualizations, especially within one system. Going beyond a single system, it may not be possible (or even desirable) to design a universal interaction set. However, it may be beneficial to consider an interaction model that can characterize and describe interactions that can be commonly used across different visualizations and systems.

4. Although the two styles of natural language input—typing and speech—share several characteristics, speech has unique challenges from a system design and development aspect. We discuss three key challenges—triggering of speech input, lack of assistive features like autocomplete, and transcription errors—with potential workarounds to guide future work exploring InfoVis systems with speech-based interactions.

5. As acknowledged by several researchers for other contexts (Olsen Jr., 2007; Ren *et al.*, 2018; Stasko, 2014; Thudt *et al.*, 2017), the traditional comparative studies emphasizing performance metrics (i.e., time and accuracy) are often not appropriate for evaluating post-WIMP visualization systems. We share their viewpoints and suggestions regarding the use of more appropriate evaluation methods and metrics by properly adapting existing methods or devising new ones.

6. Problem-oriented research is a well-established approach with great values (Shneiderman, 2016). However, to spark creative innovations that post-WIMP offers, we need to embrace technology inspired research as well. This will help us take a step closer to our overarching goal, enabling people to stay in the flow of their visual exploration instead of worrying about how to manipulate user interfaces.

Beyond these discussions, to pave the way for future research, we also highlight six open research directions: further leveraging the extensive HCI research on interaction and interfaces, the development of post-WIMP interaction prototyping toolkits for InfoVis, context-aware visualization interfaces, post-WIMP interfaces for data manipulation, interacting with data physicalization, and developing mobile and accessible visualization systems that cater to broader audiences.

Although this monograph describes a personal perspective, we hope it will help readers gain an initial understanding of how post-WIMP interaction techniques have evolved in the context of InfoVis, where we currently stand, and more importantly where we can go in the future. Ultimately, we hope to inspire researchers and practitioners in both the InfoVis and the broader HCI communities. InfoVis-oriented readers will get an overview of the applications and unrealized potential of post-WIMP interactions, while HCI researchers and practitioners may see untapped opportunities where their novel and innovative technologies and interaction techniques might flourish.

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