Empirical evaluation of information visualizations: an introduction

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Throughout the 1990s, we have witnessed the burgeoning interest and rapidly advancing technologies in the field of information visualization (Card, Mackinlay & Shneiderman, 1999; Chen, 1999; Ware, 2000). This field has captured the imagination of researchers and practitioners from a wide range of disciplines all over the world. Increasingly powerful and visually appealing information visualization techniques are finding their way into everyday life in our information society. The widespread proliferation of information visualization techniques has also highlighted the need for principles and methodologies for empirical evaluation of these techniques. Urgently needed are improved methods in areas such as task analysis, usability evaluation and usage analysis, especially those with special emphasis on visualization–intrinsic user interfaces.

Until recently, research in information visualization has largely focused on the development of innovative computing techniques. George Robertson, the inventor of well-known information visualization techniques such as Cone Trees (Robertson, Mackinlay & Card, 1991), was among the first to draw our attention to the importance of empirical evaluation with his keynote speech in 1998 at the IEEE Information Visualization Symposium. We are finally beginning to see evaluations of advanced visualization techniques, but progress has been slow and isolated (e.g. Pirolli, Card & Van Der Wege, 2000; Graham, Kennedy & Hand, 2000).

This special issue aims to provide a timely and unifying forum for researchers and practitioners to tackle some of the fundamental and practical issues concerning empirical evaluation of information visualizations. We have solicited nine original articles on topics related to this theme. Two thematic aspects become apparent in this special issue, namely, evaluating well-known information visualization techniques and analysing the use of information visualization techniques in a practical context. A detailed introduction will be given below to guide the reader of the special issue.

1. Evaluating information visualization techniques

The first four articles focus on the empirical evaluation of well-known information visualization techniques and systems, such as VIBE, Treemap and Hyperbolic 3D.

Authors of these articles not only report the results of in-depth analysis of some of the best-known information visualization techniques, but also demonstrate methodologies that could be adapted and applied to the evaluation of other information visualization techniques. This sub-theme also includes an article addressing a more basic comparison between two- and three-dimensional visualizations.

VIBE is a classic information visualization designed by researchers at the University of Pittsburgh (Olsen *et al.*, 1993). In VIBE the degree of match between a document and query term is represented spatially. Documents relevant to a query term are expected to be located nearer to that query term. This special issue includes an article by Morse, Lewis and Olsen (2000), in which they developed a method to match task and visualization features of a retrieval system based on a visual taxonomy. As a result, the effects of specific visualization features can be singled out and inspected in isolation from the rest of the system. They called this a *de-featuring* method, i.e. by eliminating features and functions until only the visualization remains. By starting with the simplest instances, it becomes possible to test increasingly more complex situations and compare results within a level of difficulty as well as across levels.

Treemap displays (Johnson & Shneiderman, 1991; Shneiderman, 1992) are another example of information visualization techniques that have little in-depth empirical evaluations. Stasko, Catrambone, Guzdial and McDonald (2000) present two empirical studies of visualizations of hierarchies, in particular, computer file and directory structures. The Treemap and Sunburst space-filling visualizations were evaluated with targeted end users. Different search strategies were adopted with each tool, which also appeared to influence performance. Overall, users preferred Sunburst over the alternative Treemap visualization for the tasks examined.

Hierarchies have been one of the most commonly used data structures in information visualization, notably in Cone Trees (Robertson *et al.*, 1991), Cat-a-Cone (Hearst & Karadi, 1997) and Hyperbolic 3D (Munzner, 1998). Empirical evaluations of information visualization concerning hierarchical structures are clearly significant to the development of information visualization. In this special issue, Risden, Czerwinski, Munzner and Cook (2000) examine the strengths and weaknesses of two conventional 2D browsers and that of the third design, in which an interactive three-dimensional hyperbolic view is integrated with a traditional two-dimensional list view. The authors have demonstrated that integrating the ability to view the overall structure of the information space with the ability to easily assess local and global relationships is key to successful search performance. The contribution of this article is that it demonstrates where novel focus + context views might become particularly useful for experienced users. It appears that novel, 3D interactive techniques might best be introduced alongside more familiar 2D visualizations, allowing the user to mix interaction strategies as necessary. The article by North and Shneiderman (2000) in this issue echoes this latter finding.

Multiple coordinated visualizations enable users to rapidly explore complex information. However, users often need unforeseen combinations of coordinated visualizations. North and Shneiderman (2000) introduce their snap-together visualization tool, which enables users to configure their own user interfaces to visualizations. Their article describes two studies of users operating this tool. Operating an overview-and-detail coordination reliably improved user performance over detail-only and uncoordinated interfaces for most tasks.

The domain of information retrieval has profound connections to information visualization, primarily due to the need for improved visualizations of search results. Sutcliffe, Ennis and Hu (2000) describe their empirical evaluation of an information-retrieval system incorporating a bullseye view and a hierarchical thesaurus for the display of retrieved documents. Their study is based on two information-retrieval tasks. The usability metrics of user behaviour, performance and attitude were all collected to evaluate this novel system. While more experienced search users used the bullseye visualization effectively and spent longer on the search tasks, less experienced searchers were confused by the concept of similarity searching expressed as visual clusters. The conclusion from the study is that while a visual user interface for information searching might appear useful, careful evaluation is necessary to determine whether or not the design actually improves performance across all users and under what circumstances.

Two- and three-dimensional visualizations have always been some of the most popular design options when it comes to the layout of a semantic structure. It has been long debated whether a three-dimensional visualization would indeed offer the user with richer semantics, more informative and intuitive controls of the underlying information (e.g. Sutcliffe & Patel, 1996). In this special issue, Westerman and Cribbin (2000) address this question through two empirical studies in which visualizations based on two- and three-dimensional multidimensional scaling solutions are compared and analysed. They are particularly interested in the extent to which two- and three-dimensional solutions differ in terms of semantic richness and cognitive demands. Their conclusion is that, for the purpose of information search, the amount of additional semantic information that can be conveyed by a three-dimensional solution is outweighed by an associated increase in cognitive demands.

2. Information visualization in context

Despite the proliferation of information visualization techniques, user-centred design of information visualization is rare in the literature. The following three articles share their emphasis on in-depth analysis of the development of information visualization in a practical context. Valuable insights are drawn from their experiences.

Graham, Kennedy and Benyon (2000) present a case study of visualizing and exploring multiple hierarchical structures as in botanical taxonomies. In this article, the authors describe the use of a variety of practical user-centred design methods as integral parts of their visualization development and evaluation process. Here, the visualization becomes a means to an end. Practitioners of information visualization should find many useful insights from this article.

The defining feature of hypertext is the provision of mechanisms that enable users of a hypertext system to explore the interconnectivity of information. Throughout the history of research in hypertext systems, visualizing information structure has been one of the few enduring topics. Among others, graphical overview maps have emerged as a popular design feature of hypertext systems. While the majority of empirical evaluation studies have concentrated on the effects of a graphical overview map on the reader of a hypertext system, Pohl and Purgathofer (2000) in this special issue turn their attention to writers or authors, of such hypertext systems. Their in-depth study focuses on how graphical overview maps change the authoring process. Their article demonstrates in

detail a number of interesting aspects of evaluating information visualization in a wider, task-oriented context.

The article written by Trafton, Kirschenbaum, Tsui, Miyamoto, Ballers & Raymond (2000) presents yet another good example of a methodology for user-centred information visualization. In this case, the domain experts are meteorologists. Their article describes how the authors used a protocol analysis methodology to examine the types of visualizations used by experts in their own domain, with promising results.

Finally, the meta-analysis conducted by Chen and Yu (2000) presents an initial synthesis of empirical findings across individual studies found in the contemporary literature of information visualization.

The articles included in this special issue represent the rapidly growing interest in empirical evaluation of information visualizations. This also indicates that information visualization, as a multidisciplinary field of study, has began to reach a mature stage of its evolution. The insights and inspirations that one can draw from these studies will no doubt provide valuable forces to stimulate the further development of innovative information visualization techniques and a better understanding of the value of various information visualization techniques.

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