Beyond Guidelines: What Can We Learn from the Visual Information Seeking Mantra?

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Abstract

The field of information visualization offers little methodological guidance to practitioners who seek to design novel systems. Though many sources describe the foundations of the domain, few discuss practical methods for solving visualization problems. One frequently cited guideline to design is the "Visual Information-Seeking Mantra", proposed by Shneiderman in 1996. Although often used to inform the design of information visualization systems, it is unclear what use this has been for visualization designers. We reviewed the current literature that references the Mantra, noting what authors have found useful about it and why they cite it. The results indicate a need for empirical validation of the Mantra and for a method, such as design patterns, to inform a holistic approach to visualisation design.

Keywords *– Guidelines, Patterns, Visual Information Seeking Mantra, Visualization Methodology.*

1. Introduction

In the field of information visualization, one notable theoretical development is the "visual information seeking mantra" described by Shneiderman in his seminal paper at the 1996 IEEE Visual Languages conference [20]. It offers two contributions for understanding information visualization methodology, namely, the "Visual Information Seeking Mantra" and the "task-by-data-type taxonomy". While the task-by-data-type taxonomy (TTT) offers useful categorization of data types in the context of information visualization, it is not unprecedented in the literature, as there are efforts by many other authors [23, 29, 11] to describe data taxonomies for the purpose of visualization design. More interestingly, the Visual Information Seeking Mantra (hereafter, simply the "Mantra") offers guidance to practitioners based upon Shneiderman's extensive experience designing information visualization software. The Mantra, "Overview first, zoom and filter, then details-on-demand", describes how data should be presented on screen so that it is most effective for users.

Shneiderman has described the ideas in this paper as "descriptive and explanatory" rather than prescriptive [9]. This caveat notwithstanding, the Mantra has been widely cited by researchers developing novel information visualization tools as a justification for their methodological approaches. In effect, the Mantra has become a prescriptive principle for many information visualization designers, either implicitly or explicitly. Furthermore, although numerous authors cite the Mantra, there are no reasonably obvious studies that have validated Shneiderman's recommendations. While the methodological suggestions are generally accepted as valid, they have not been subjected to adequate and rigorous assessment. The Mantra appears to act as an inspiration and guideline for practitioners rather than a scientifically studied methodological approach.

That interesting and useful information visualizations are developed in spite of this attests to the effectiveness of his techniques. For most designers, the Mantra works. However, we believe it is important to validate the recommendations in a more rigorous manner and to situate them in a design context that is more useful for practitioners than guidelines alone. For example, the visualization design patterns proposed by Wilkins [27] attempt to overcome such limitations of guidelines. Formal research would yield clearer understanding of the Mantra's strengths and weaknesses and suggest the most appropriate contexts for its use. This would support a design framework that would account for and prevent conflicting recommendations that are common to guidelines. Thus, we believe such study would provide a reliable foundation for future visualization designers to begin their work. Card and Mackinlay call for just this sort of analysis in their notable methodological discussion

of information visualization design, "As for any technology area, [it] is necessary to develop abstractions that rise above particular point designs in order to allow...codification of art into technology to occur."[9]

Increasing the urgency for such validation is that practitioners both within and outside the domain of information visualization have few methodologies to choose from. The Mantra is one of those few. Among papers that describe methodological approaches to information visualization, the 1996 paper is usually cited. Those who develop information visualization systems and who conduct new research recognize it. Notably, those who work primarily outside the information visualization community *also* cite the paper when they describe novel systems that they are creating. This suggests that the Mantra has substantial value for practitioners who may not be intimately familiar with ongoing work within academia. It is incumbent upon domain experts in information visualization to validate and improve upon guidelines that are useful to a wider audience. Moreover, they should situate this knowledge in the context of a robust design method. It is upon their expertise that others rely.

2. The Mantra, dismantled

To understand why and whether the Mantra is an important methodological contribution, why other researchers and practitioners frequently cite it, and what makes it an important subject for research, it is first necessary to dissect the several components into discrete parts so that they may be better understood. Here, we describe each of the different elements of the Mantra, relying on Shneiderman's initial articulation, but clarifying certain points and adding relevant details, as they are appropriate. It is important to note that we focus this analysis on the user tasks and not the data types.

2.1 Why "overview first"?

Overview provides a general context for understanding the dataset; it paints a "picture" of the whole data entity that the information visualization represents. Patterns and themes in the data that may be helpful can often be seen only from a vantage point that comprises the whole view. From this perspective, major components and their relationships to one another are made evident. Simply the overall shape of the data itself can provide assistance in understanding the information that is encoded. Significant features can be discerned and selected for further examination. Such features might not be readily viewable from another part of the data representation or might be obscured from certain vantage points. Revealing these features at the outset can aid the user in filtering the extraneous information so that they can complete their task more efficiently by excluding unimportant aspects of the representation.

2.2 Why "zoom and filter"?

Zooming and filtering both involve reducing the complexity of the data representation by removing extraneous information from view and allowing for further data organization. "Zooming" refers to the adjustment by the user of the size and position of data elements on the screen. "Zooming-in" enlarges smaller data elements of interest and usually simultaneously removes from view or reduces the size of larger data elements that are not of interest. "Zooming out" effects the opposite result. Significantly, while the results of both adjustments are symmetrical, i.e., zooming-in and zooming-out are procedurally and visually symmetrical; they have quite different implications for cognition.

Zooming can be regarded as filtering by navigation and change of representational vantage point. Zooming facilitates two *different* cognitive tasks, depending on whether it is zooming-in or zooming-out. In the case of zooming-in, it removes extraneous information from the visual field, allowing higher processing centres to further organize the information into meaningful patterns for interpretation and decision-making. The significance of this is described by Resnikoff's Principle of Selective Omission [9], which posits that organisms require that information from the sensory organs be aggregated into manageable inputs by simplification and organization. In the case of zooming-out, it reveals hidden information, usually contextual information that is already known, but which is cannot be recalled. This allows the user to rediscover his location within the information space, so that newly learned details about the data representation, usually discovered by close inspection though zooming-in, can be integrated into a larger understanding. Unfortunately, "zooming" is often used as a generic, shorthand expression for either "zooming-in" or "zooming-out". This dilution of precision in the meaning of the term can lead to confusion precisely because the cognitive activities that it facilitates are so different. The term "zooming" is often employed by users to refer generically to scalar changes in representations of elements on the screen, rather than changes in vantage point. Anecdotal examples are found in conversations about dynamically changing toolbars that can be exploded or contracted to reveal more finely grained levels of adjustment, or the scalar change of menu items that are represented with a fisheye type distortion to accommodate limited screen real-estate [6]. This vagueness of the meaning has probably evolved because of a lack of colloquial terminology about scalar changes, and a lack of distinction between scalar changes of space (i.e., vantage point) and scalar changes of discrete screen objects, such

as text or icons. Filtering accomplishes much the same reduction of complexity in the display, but without changing the data representation or the user's view of it. The adjustment of widgets in the interface allows for control of which data points are visible. The user can thereby selectively hide or reveal data of interest so that the information can be simplified to aid cognition. However, this is hindered if there are long delays between the cause and effect relationship of adjusting a widget and seeing the results in the display. Thus, the best implementations of filtering are those that immediately update the display as widgets are adjusted. These *dynamic filters* allow users quickly see how the changed variable affects the data representation. If the widgets adjust the parameters of a database query in order to return results, these are referred to as *dynamic queries* [1]. Card, et al., provides a thorough review of the numerous examples of the efficacy of dynamic queries [9].

2.3 Why "details-on-demand"?

In a typical information visualization, many data points are visible in the overview, often from more than one vantage point. Depending on the visualization, the number of represented data items can number from dozens to millions. Limitations of screen real estate and visual complexity make it difficult to provide supplementary information that a data point represents, as providing in-depth detail about all of the displayed items is impractical. The details-on-demand technique provides this additional information on a point-by-point basis, without requiring a change of view. This can be useful for relating the detailed information to the rest of the data set or for quickly solving particular tasks, such as identifying a specific data element amongst many, or relating attributes of two or more data points. Providing these details by a simple action, such as a mouse-over or selection (the "on-demand" feature) allows this information to be revealed without changing the representational context in which the data artefact is situated.

2.4 Why "relate"?

This allows the user to view relationships between the data items. Selection of a particular data item can reveal, by changes in representation, items that are related by similarity. Supporting discovery of relationships is particularly important where comparisons need to be made among the characteristics of different data objects in the display.

2.5 Why "history"?

Users should be able to easily return to a previous state in the process of exploring the data. It is very common that comparing the current state of representation to a previous state can yield a better understanding of the data. In addition, if the user makes a mistake, he should be able to easily recover from it. An optimal interface permits these activities by providing an easily accessible history of the commands issued or a widget that returns the interface to a previous state. In addition, history supports the ability to replay a sequence of changes and assist the user in progressively refining data exploration.

2.6 Why "extract"?

In the process of using information visualization tools, users are frequently engaged in lengthy and complex operations. Information and knowledge that they discover may be important for several different tasks or ongoing work projects. Accordingly, they should be able to extract important findings for use in other computing systems. Extraction can also provide a means of saving work, thereby preventing the need to repeat data manipulations for future projects.

2.7 But why?

Understanding these techniques, one must ask for what kinds of visualization design problems can these several techniques provide the most benefit? Indeed, other guidelines may conflict with the Mantra's suggestions. It is not clear whether all elements should be designed into a given implementation, whether some elements are more appropriate than others are, or what compromises should be made when constraints of the system or the supported activity require them. Neither is it clear whether they are useful for all of the different data types. In his 1996 work, Shneiderman provides little guidance regarding these questions. Several authors have recognized these shortcomings (described below), even as they praise the Mantra's utility. To understand why people use the Mantra, and how they deal with these contradictions, we performed a comprehensive literature review.

3. Literature Review

Were it not a frequently referenced article, the utility of validation might be less obvious. However, there are many citations of the Mantra in the literature. At the time of this writing, there are at least 52 citations of the 1996 paper. They are found in many different publications, including conference proceedings, peer-reviewed journals and symposia, Master's theses, and Doctoral dissertations.

Thus, the population of authors is very diverse, as are their skills and familiarity with methods of information visualization design. This diversity is significant. As the Mantra represents summary knowledge gained by experience, occasional empirical evidence, and practice in designing visualizations, it can be considered a heuristic or guideline. As such, it offers benefits to novices by highlighting important concepts and to experts by further defining the domain of visualization methodology. This wide appeal and the relative scarcity of methodological knowledge may account for the frequency of the Mantra's citation.

Roughly, these citations can be placed into 5 different categories: implementations (34), methods (7), evaluations (6), taxonomies (4), and other (1). It is useful here to discuss these different categories in more detail. We refer to all of the documents as papers, for the sake of convenience.

3.1 Implementations

Implementations papers describe novel information visualization systems where the Mantra or Task-by-Data Type Taxonomy contributed to the design method used by the authors. In a typical example describing a document analysis visualization tool, the authors detail how each aspect of the Mantra forms their design approach, writing that it is "a central principle for information visualization"[12]. In another example, the design for a software visualization tool, the authors write, "Our analysis is based on Shneiderman, who presents seven high level tasks that an information visualization application should support"[17]. Another group writes, "We designed our interface to support the visualization tasks described by Shneiderman." before going on to describe how each part of the Mantra was realized in their system [24]. Still other authors use techniques of the Mantra to propose design implementations [4]. A small number of papers within this category cite the Mantra primarily in the context of describing previous research that has informed information visualization design, often describing its importance as a methodological guide (for example, [23] and [20]). Overall, these implementations papers all rely on the Mantra as a design justification, though they rarely describe why the Mantra, in particular, was selected as a methodological guide. Presumably, the stature of the author and the scarcity of lucid methodological guides motivate authors to build upon the clear and simple recommendations made by the Mantra. Those few papers that do not explicitly state that the Mantra informs implementations do recognize its significance in the evolution of information visualization systems.

3.2 Methodologies

Methodology papers describe methodological approaches to designing information visualization software or describe new models of interaction in information visualization. Laying the groundwork for their approach, Amar and Stasko write that, "Shneiderman's mantra of 'Overview first, zoom and filter, details-on-demand' nicely summarizes the design philosophy of modern information visualization systems." [3] Hetzler et al. recognize the Mantra as important, though they suggest, "no single paradigm or visual method is sufficient for many analytical tasks" [16]. In an unusual example that describes a method for development of a specific task-model, Becks and Seeling [5] combine Shneiderman's work with the task-models of Wehrend & Lewis [25] and Belkin et al. [7] to create their own novel task-model for analysis of collections of documents within the domain of knowledge management. While the authors do not describe a methodology for information visualization, their paper is notable because they describe Shneiderman's work as a "domain-independent model[s] for visual retrieval and analysis tasks." The high level nature of the Mantra is of particular utility because its coarse granularity allows them to develop a more specific domain-dependent model. This approach, leveraging the Mantra toward further ends, is typical for those authors who describe new methods.

3.3 Evaluations

Evaluation papers use the Mantra as a metric by which to measure the effectiveness of information visualization implementations or refer other authors' use of it as such. Citing Shneiderman's contributions, Miller, et al., note that the identification of data types is important for evaluation, because such identification makes it easier to compare the similarities and differences of a variety of different visualization types [18]. Wiss, et al., use the Mantra as a specific measure against which three different 3D visualizations of hierarchies are measured [29]. In their evaluation design of these hierarchy browsers, they write, "Our task analysis is based on Shneiderman, who presents seven high level tasks that information visualization *should* support" (emphasis added). Interestingly, these authors are perhaps unaware of Shneiderman's caveat that his recommendations were not meant to be prescriptive. Constructing a matrix by which to compare the tasks against the three interfaces, they evaluate each one based on whether it conforms to the tasks described by the Mantra. They conclude that, aside from considerations of data type, the design of a particular visualization may not always be able to support all of the tasks, suggesting that several different designs might have to be implemented in the same application. This

conclusion echoes the motivations described by the authors of the Snap-Together Visualization environment [20]. Among these papers, a common complaint is that beyond usability studies, there are few established metrics by which to measure the effectiveness of various visualizations.

3.4 Taxonomies

Taxonomy papers describe ways of classifying information visualization, its characteristics, and salient concepts. Not surprisingly, as "The Eyes Have It" [21] describes a taxonomy, other authors who catalogue the artefacts of information visualization in taxonomies refer to this work. These papers involve developing frameworks for organizing and understanding ideas in information visualization or offer categorizations of existing tools. Ed Chi's oft-cited taxonomy [11] references Shneiderman's paper as one of the previous contributions in this area. Notably, Tory and Möller [23] problematize classification based on data type alone. They suggest a system that divides visualization into Discrete or Continuous models, dispensing entirely with the distinctions between "scientific" and "information" visualizations. Their proposal represents a substantial departure from descriptions proposed by Card, et al. [9] and therefore, highlights potential shortcomings of the Mantra that warrant further examination.

3.5 Others

One type of citation that does not fall into one of the above categories is the general discussion of information visualization as a discipline. For example, Chen [10] cites Shneiderman in his 2002 editorial column for the journal, *Information Visualization,* though he does not specifically address it in the text. We are certain that similar examples exist that were not uncovered during our review.

4. Analysis

What is interesting in most of these cases, but particularly the implementations, is that while the authors cite the Mantra as an important starting point for designing their tools, many don't actually specify how they use it; they do not cite specifics of its application. With noted exceptions (above), there is rarely a relationship described between the specific tasks or data types Shneiderman details and the particular characteristics of the visualization system under discussion. Most often, the Mantra is cited as a guiding principle for information visualization design. Indeed, this is what its author intended. However, if this is the case, that the Mantra is used as a "guiding principle" in implementation, it is reasonable to question which aspects of it are particularly relevant and can be proved to demonstrate an improvement in the final information visualization design, as measured by specific indices.

Also, while implementers developing new information visualization tools recognize that the Mantra is important for their work, those writers discussing Methodology or Taxonomy *per se*, suggest that it is an only a single component in a much larger puzzle. This may reflect the utility of a recommendation that is immediately useful to many practitioners precisely because it is high-level and domain-independent. It is a guideline. Paradoxically, these same characteristics are problematic for theorists who are involved in understanding and precisely describing models, taxonomies, and methods. In this light, it is useful describe guidelines and their shortcomings.

4.1 The Mantra, applied

We have described the Mantra as a guideline. Colloquially, guidelines serve as recommendations for a certain approach to particular problems. They are typically described by domain experts and based on summarised knowledge gained from years of experience, on evidence from practice, and on successes and failures. They are therefore succinct, precise, and practical. These benefits are particularly appealing for naïve designers in search of quick solutions to problems that arise in processes of visualization design. However, these benefits are limited in the type and complexity of the problems they can address, particularly as the nature of the visualization design means that difficulties will arise in areas as widely varying as representational semantics, navigation, interaction, data retrieval, etc.

While guidelines have proved useful for many designers and play an important role in the design process, they have some shortcomings as noted by Welie, et al. [26]:

- They are numerous and difficult to select.
- They are usually compact, but their validity depends on their design context.
- They do not always tell the designer *when*, *how*, and *why* they should be applied.
- They do not include a rationale.
- They are often too simplistic or too abstract.
- They can be difficult to interpret.
- They can conflict with other guidelines.
- Their validity may not be proved.

Overcoming these limitations requires providing a framework to unify the recommendations so that they are consistent with one another. We must also clarify the problem context and a rationale must be given for decisions taken. Such a rationale should be supported by

examples known to work and these solutions should be related to one another whenever possible.

Drawing on the work of Alexander [2] and Gamma, et al. [13], Fincher [14], and Griffiths and Pemberton [15], Wilkins [27] proposes a pattern-supported methodology for visualization design, incorporating aspects of the Mantra into design patterns for use in a user-centred software development life-cycle. This work is an important step toward developing ideas in the Mantra into a fully-articulated methodology for design that addresses developer needs and the design process, as a whole.

5. Beyond Guidelines

We recognize that guidelines can be useful for the development of novel visualizations. The frequent use of the Mantra is evidence that many practitioners find it helpful in different design scenarios. It could be proposed that the utility of guidelines for design problems justifies their use. However, we argue that validation by further research which demonstrates the usability of the resulting systems is essential to the development of visualization methodology. Such research is only occasionally performed.

Further, to describe a robust methodological approach that will address a wide variety of visualization design problems, guidelines alone are not sufficient. Recognizing this, others such as Chi and Wilkins have studied frameworks and patterns, respectively. While we recognize that software patterns address these needs, to be fully effective in a visualization design scenario, design patterns must overcome their own limitations. We call for a *holistic design methodology* to remedy the problems we have described. Such a methodology would:

- take into account the useful techniques that guidelines and patterns suggest
- have measurable validity
- be based upon a user-centred development framework
- provide step-by-step approach
- be useful for both novices and experts

Currently, these characteristics are poorly represented or absent in the literature on information visualization methodology. Many practitioners, particularly novices, are finding guidance from fragmented and varied sources, applying this knowledge in a patchwork fashion. We advocate further research into techniques, such as patterns, which attempt to overcome these problems. A more lucid approach is needed. We believe the very success of the Mantra demonstrates this need and advocate research toward a holistic methodology of information visualization design to address it.

6. Mantra Bibliography

We provide here a full list of the papers we reviewed for this analysis, arranged by category. In addition to documenting our categorization of the data, we hope the reader will find it useful as a reference of citations of the Mantra, and easier interpret than endnotes.

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