Key Problems and Thorny Issues in Multidimensional Visualization

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INTRODUCTION

Starting from early successes of visualization, like Dr. J. Snow's dot map in 1854 showing the connection of cholera to a water pump, visualization has grown to a powerful principal as well as supportive tool for data discovery. The 1992 IEEE Visualization Conference's Grand Challenge Panel identified fundamental problems for visualization. This panel will review the 1992 statements and will offer its view of the key problems and issues facing multidimensional visualization today.

The panelists will identify fundamental problems still facing multivariate visualization today. Discussed will be geometric issues (the data and its representations), perceptual issues (the human and its capabilities), and evaluation issues (the system and its effectiveness). These three fundamental areas are cornerstones of visualization and still provide a rich area for research.

POSITION STATEMENTS

Georges Grinstein

We are at a fork in the road. We have reached a fundamental display limit of about one million items with most of our current techniques. How can we break that barrier? The human perceptual system seems to be able to handle large quantities of data of few dimensions but has great difficulty as the dimensionality of the data increases. Is this another view of the curse of dimensionality? What fundamental element is holding us back?

I will argue that the key challenge is to focus not simply on the computer techniques of displaying large quantities of data but on the perceptual consumption of such large amounts of data. We must focus on how the process of computer visualization can be improved to mirror the process of natural visualization, that is, the visualization of nature. Our perceptual systems were designed specifically for survival in and understanding of the surrounding external environment, not abstract objects and images.

Simply put: how can we exploit human perception in the service of data visualization?

Sharon Laskowski

The thorny issue I would like to address is the difficulty of applying 3D to abstract information visualization. There are several questions that must be answered to overcome this inherent difficulty.

- When is 3-dimensional visualization useful?

- How can 3D be applied effectively for abstract information visualization?

- How does one know a visualization is effective? Or efficient? Just because it's good for entertainment, doesn't mean it's a good choice for serious work.

- There are many fine examples of 2D visualizations of large databases. But, why do we see so many examples of 3D that don't seem to get out of the lab and into actual practice?

These difficulties with 3D I believe stem from the following problems:

1. It is difficult to design good 3D visualizations.

2. 2D often can replace 3D because the third dimension is not being used wisely.

3. It is difficult to evaluate a 3D interface and we don't have a lot of guidelines as we do for GUI design.

4. 3D is clearly suitable for scientific visualization and computer-aided design applications because the dimensions map directly to physical world entities and/or the data is heavily numerical. Navigation in this context is easier as well. The artificial mapping required to represent abstract information in a 3D world increases the cognitive load on the user. The metaphor is once removed from the meaning and the data.

For this panel discussion, I will illustrate my points by describing an effort to use 3D for the visualization of document sets and our struggles in trying to evaluate the usability of these visualizations as compared to simple 1- and 2-dimensional structures.

In summary, it is time to get more serious about evaluation. For GUIs, visual design is important, of course, but there are also engineering methodologies, processes, and guidelines to test for usability. The visualization community needs this rigor as well.

Alfred Inselberg

Imagine a veritable mess of old bolts, nuts and what seems like minute parts of every conceivable kind mixed in deep amorphous piles. From such *data,* the best analysis can reveal very little. This must be in principle true for it can *not* be *distinguished* whether such objects derive from automobiles, airplanes, or a wide variety of machinery. If, on the other hand, these objects are assembled into components until they become *distinguishable* (e.g. many automobile parts can be distinguished from those of other machinery) the problem at least of identification and partial analysis is tractable. This is a simplistic but useful example.

We argue that looking at a set of disorganized high dimensional data is even less informative than the situation in the "Junkyard Metaphor" above. We maintain that it is *not* possible in general to identify an N-dimensional object by just looking at its points (which are 0-dimensional); not because Dimensionality is Curse but rather because we are using "spectacles" with the wrong "prescription". Specifically, we will show how an N-dimensional object can be identified from its (N-1)-dimensional components. This leads to a recursive construction where from the 0-dimensional components (points or 0-flats), lines (or 1-dimensional components — 1-flats) are formed, leading to the construction of 2-dimensional components (planes or 2-flats) and so on until the (N-1)-dimensional components are constructed to distinguish and identify the N-dimensional body. In turn this *geometrical* identification enables us to provide a rigorous description of the "structure" in the data, in terms of the geometrical properties of the N-D object which models them.

Examples will be provided of such recursion not only for "precise", in the mathematical sense, objects, but also those which have been perturbed and contain errors; showing that

"To Iterate is Human ... and to Recurse Divine!"

All this lead us that the conclusion that Dimensionality is *not* a curse. Rather it seems so because of the way we have unjustly treated it so far — i.e. "pursuing", "projecting" and even mutilating (i.e. "reducing") it. To ameliorate this wrong we will propose a prize for the best composition of a rousing ecumenical blessing ... to Dimensionality.

BIOGRAPHIES

Georges Grinstein is a full-time Professor of Computer Science at the University of Massachusetts Lowell, Director of the Graphics Research Laboratory, and Director of the Institute for Visualization and Perception Research. He received his B.S. from the City College of N.Y. in 1967, his M.S. from the Courant Institute of Mathematical Sciences of New York University in 1969, and his Ph.D. in Mathematics from the University of Rochester in 1978. He is a member of IEEE, ACM, Eurographics, and has served on the editorial boards of Computers and Graphics, Computer Graphics Forum, and Knowledge Discovery in Databases and Data Mining Journals. He served as a member of the executive board of ANSI X3H3, as chair of X3H3.6, and as vice-chair of IFIP WG 5.10 Computer Graphics Group. He has been involved with the IEEE Visualization and AAAI KDD Conferences since 1990, and has chaired numerous workshops related to visual and analytic data mining. His areas of research include graphics, imaging, virtual environments, user interfaces and interaction, with a very strong interest in the visualization and analysis of complex systems.

Alfred Inselberg received his Ph.D. in Applied Mathematics and Physics from the University of Illinois (Champaign-Urbana). He has held several academic positions abroad and in the USA (with the University of Illinois, UCLA, and USC), and was recently elected Senior Fellow in Visualization at the San Diego SuperComputing Center. Prior to that he was Senior Technical Corporate Staff Member at IBM doing research for about 30 years. He now has his own company, Multidimensional Graphs Ltd., and teaches at Tel Aviv University. He invented and developed Parallel Coordinates, on which he has contributed to several patents, has over 60 refereed technical papers, and is now writing a book on the subject.

Sharon Laskowski is a computer scientist and group manager of the Visualization and Virtual Reality Group in the Information Technology Laboratory of the National Institute of Standards and Technology, where she is currently investigating the use of information visualization techniques for information retrieval and exploration. She is also developing a set of rapid, remote, and automated tools and methods for Web usability evaluation and testing called WebMetrics. She has also been involved in research into evaluation methodologies for collaborative systems. She is a co-founder and organizer of the NIST series of Usability Engineering in Government Systems symposia. Previously, she conducted research and development in text analysis, information fusion, and plan recognition at the Artificial Intelligence Center of the MITRE Corporation. She received her Ph.D. in Computer Science from Yale University.