Perceptualization: Techniques for Effective Image Generation, Visualization, and Communication of Information

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Abstract

Most scientists, doctors, analysts, and even computer animators are faced with a data deluge. They must analyze, extract meaningful information, and create solutions from huge quantities of data whose size is increasing at an enormous rate. However, screen resolution, image generation techniques, and visualization techniques are only making modest improvements. This has led us to take a different approach to image generation and visualization that we call perceptualization. We describe our initial work in perceptualization, the main challenges, and our current research directions.

1 Introduction

Throughout history, man has tried to effectively convey important information through the use of images, using techniques such as illustrations, photographs, and detailed technical drawings. These techniques harness the enormous bandwidth and pre-attentive processing of the human visual system. Many disciplines of study have evolved to to further these techniques, including photography, technical and medical illustration, and now visualization. While illustration and photography both are successful at capturing and conveying information, they utilize different techniques and characteristics of the human visual system to convey information. Photography concentrates on conveying information with light and color variation, while illustrations additionally tries to effectively convey information by omitting unimportant details, enhancing the most significant components of the image, simplifying complex features, and exposing hidden features [8]. Scientific illustrations have been used for centuries because of their effective communicative ability [4].

The effectiveness of illustration techniques, the amazing power of the human perceptual system, and the enormous data deluge facing information analysts, medical and scientific researchers have motivated our work on extending visualization techniques to *perceptualization*. The goal of this research is to concisely convey information to the user through the creation of effective perceptual human inputs (visual, proprioceptive, and haptic).

2 Overview of Perceptualization Research

We are currently exploring the following three aspects of perceptualization research:

- **Perceptually Effective Minimally-Immersive Visualization** This project explores and develops techniques to effectively convey information from large multidimensional, multivariate datasets. One area of this research is interactive visualization that successfully harnesses human perception (e.g., stereopsis, proprioception, shape cues) to increase the quantity and clarity of information conveyed from visualizations. We have developed and will continue to develop improved, perceptually motivated visualization tools for applications in medicine, and scientific and information analysis. Improved training techniques for physicians, improved diagnosis and treatment planning, and improved development time for scientific techniques and information analysis can be achieved by these new visualization techniques [2, 6, 7, 3]. This work combines research in perception, psychology, computer graphics, and image processing that has produced and will continue to produce major advances in interactive visualization techniques.

- **Effective Visualization of Terabyte Datasets** The other active area of our effective visualization research is combining procedural and advanced rendering techniques with traditional volume visualization techniques. In collaboration with Dr. Penny Rheingans at University of Maryland Baltimore County (UMBC), researchers at the flow simulation center at the NSF Engineering Research Center at Mississippi State University, Dr. John Hart at the University of Illinois, and Dr. Ron Fedkiw at Stanford University, we are exploring the functional abstraction, representation, and visualization of extremely large (terabyte) multivariate data sets using procedural modeling and visualization techniques. The goal of this research is to present perceptually accurate visualizations of large-scale datasets to scientists on desktop PCs and allow them to interact, navigate, analyze, and explore their datasets at a higher, more manageable level than traditional visualization systems.
- **Volume Illustration: Creating Effective Visualizations by Incorporating Illustration Techniques** As mentioned earlier, technical and medical illustrators have developed techniques over the past several centuries to very compactly and effectively convey the important information in an illustration. Traditional visualization techniques create complex images that may be difficult to interpret. We are developing techniques to capture the enhancement capability of illustrators and applying these techniques to enhance the presentation of data in the visualization of scientific and medical datasets. This project involves extending the research that has occurred in art-based computer graphics (non-photorealistic rendering) to volume visualization and creating images that are very effective for training, education, and presentation of medical and scientific data. We have introduced the volume illustration approach, combining the familiarity of a physics-based illumination model with the ability to enhance important features using non-photorealistic rendering techniques. Since features to be enhanced are defined on the basis of local volume characteristics rather than volume sample value, the application of volume illustration techniques requires less manual tuning than the design of a good transfer function. Volume illustration provides a flexible unified framework for enhancing structural perception of volume models through the amplification of features and the addition of illumination effects [1, 5]. The results of this approach can be seen by comparing the abdominal CT renderings in Figures 1 and 2. Figure 1 has no enhancement, whereas Figure 2 has boundary and silhouette enhancement performed. Also, comparing the left kidney to the right kidney in Figure 3 shows the effectiveness of illustration techniques.
- **Perceptual Haptic Texture Rendering Research** In collaboration with Dr. Hong Tan at Purdue University, we are performing research to answer the following questions regarding haptic texture rendering:
  1. What is the perceptual dimensionality of haptic texture perception (perceptual model)?
  2. How are the physical and perceptual spaces related (mapping)?
  3. What is the most natural, intuitive and efficient way to produce a synthetic texture sample with a well-defined feel (rendering)?

3 Conclusion

We have described the need to create perceptually significant visualizations and haptic renderings to attack the data deluge facing scientists, doctors, and information analysts. We have also described some of our initial work in this area to create more effective ways of communicating the most important information from datasets to the user.

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