Visualization

0.Preface

This document is based on the slides of the lecture "Visualization" held in the summer term 2002 at the University of Stuttgart.

0.1.Outline

The following topics will be discussed in this course:

- Basics (visualization pipeline, data types)
- Filtering and data reconstruction
- Basic mapping techniques
- Volume visualization
- Vector and tensor field visualization

1.Introduction

Data is often presented visually on computers for an efficient analysis and communication. The process of generating this visual representations is called visualization.

1.1.Definitions and goals

Some definitions of the term visualization:

> B. McCormick, T. DeFanti, and M. Brown:
>
> Visualization is a method of computing. It transforms the symbolic into the geometric, enabling researchers to observe their simulations and computations. Visualization offers a method for seeing the unseen. It enriches the process of scientific discovery and fosters profound and unexpected insights. In many fields it is already revolutionizing the way scientists do science.
>
> ***McCormick, B.H., T.A. DeFanti, M.D. Brown, Visualization in Scientific Computing, Computer Graphics Vol. 21.6, November 1987***

> R. Friedhoff and T. Kiley:
>
> The standard argument to promote scientific visualization is that today's researchers must consume ever higher volumes of numbers that gush, as if from a fire hose, out of supercomputer simulations or high-powered scientific instruments. If researchers try to read the data, usually presented as vast numeric matrices, they will take in the information at snail's pace. If the information is rendered graphically, however, they can assimilate it at a much faster rate.
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> ***R.M. Friedhoff and T. Kiely, The Eye of the Beholder, Computer Graphics World, Vol. 13.8, pp. 46-, August 1990***

R.B. Haber and D. A. McNabb:

The use of computer imaging technology as a tool for comprehending data obtained by simulation or physical measurement by integration of older technologies, including computer graphics, image processing, computer vision, computer-aided design, geometric modeling, approximation theory, perceptual psychology, and user interface studies.

R.B. Haber and D. A. McNabb, Visualization Idioms: A Conceptual Model for Scientific Visualization Systems, in Visualization in Scientific Computing, IEEE Computer Society Press 1990.

R.A. Earnshaw:

Scientific Visualization is concerned with exploring data and information in such a way as to gain understanding and insight into the data. The goal of scientific visualization is to promote a deeper level of understanding of the data under investigation and to foster new insight into the underlying processes, relying on the humans' powerful ability to visualize. In a number of instances, the tools and techniques of visualization have been used to analyze and display large volumes of, often time-varying, multidimensional data in such a way as to allow the user to extract significant features and results quickly and easily.

K.W. Brodlie, L.A. Carpenter, R.A. Earnshaw, J.R. Gallop, R.J. Hubbard, A.M. Mumford, C.D. Osland, P. Quarendon, Scientific Visualization, Techniques and Applications, Springer-Verlag, 1992.

J. Foley and B. Ribarsky:

A useful definition of visualization might be the binding (or mapping) of data to representations that can be perceived. The types of bindings could be visual, auditory, tactile, etc., or a combination of these.

J. Foley and B. Ribarsky, Next-generation Data Visualization Tools, in Scientific Visualization, 1994, Advances and Challenges, Academic Press.

H. Senay and E. Ignatius

Scientific data visualization supports scientists and relations, prove or disprove hypotheses, and discover new phenomena using graphical techniques.

The primary objective in data visualization is to gain insight into an information space by mapping data onto graphical primitives.

H. Senay and E. Ignatius, A Knowledge-Based System for Visualization Design, IEEE Computer Graphics and Applications, pp. 36-47, November 1994.

Oxford English Dictionary:

to visualize: form a mental vision, image, or picture of (something not visible or present to sight, or of an abstraction); to make visible to the mind or imagination.

The goal of visualization is to enable the user to easily extract the information content of the data. Coherences which are not apparent from the data itself are made visible. The data can be analyzed by means of the visual representation.
Moreover visualization makes communication easier. Even non-experts should be able to understand specific information.
Steering, i.e. the interactive control of the visualization process, should make it possible to understand the phenomena as soon as possible.

1.2.History

Techniques for finding visual representations for abstract data are not new. Examples can be found in astronomy, meteorology or cartography.

One example is a map of an excavation at Catal Hyük from 6200 BC. Even vector field visualization can be found on a sea map from 1686 where the streams of the oceans are represented by small arrows.
1987 the NSF Advisory Panel on Graphics and Image Processing took place. There was discussed that since real experiments are too expensive, too dangerous, etc. computer experiments allow access to new worlds. Simulation and visulization make it possible to handle arbitrarily large and small time scales and spatial dimensions.

> The data flood from super computer simulations can only be dealt with visually. This task needs a visualization specialist and an interdisciplinary team. New developments in hardware, software, nets, and standards are necessary.
> The advantages of visualization in the long term are faster insight, faster product-development cycles, and a stronger position in global competition.
> Therefore, it is useful to spend enough research efforts and money for scientific visualization.

1.3.Related Fields

Fields related to visualization are image synthesis, geometric modeling, and image processing.
Image synthesis deals with photo realistic rendering, i.e., the synthesis of an image of a scene as it would look like in reality.
Geometric modeling is used for the effective representation and efficient modification of geometric shape on a computer.
The task of image processing and computer vision is the manipulation of images and the extraction of object-specific information from images.

1.4.Further Reading

More detailed information about the topics discussed here can be found in the following references.
Books:

G.M. Nielson, H.Hagen, H.Müller, Scientific Visualization, IEEE Computer Society Press, Los Alamitos, 1997

Richard S. Gallagher (Ed.), Computer Visualization: Graphics Techniques for Scientific and Engineering Analysis, CRC Press, 1995

R. A. Earnshaw, N. Wiseman (Eds.), An Introductory Guide to Scientific Visualization, Springer, 1992

K.W. Brodlie u.a. (Eds.), Scientific Visualization - Techniques and Applications,

Springer 1992

H. Schumann, W. Müller, Visualisierung - Grundlagen und allgemeine Methoden, Springer-Verlag, Heidelberg 2000

Proceedings of annual conferences on visualization:

IEEE Visualization (USA)

EG / IEEE TCVG Symposium on Visualization (Europe)

Proceedings of annual conferences that cover apsects of visualization:

SIGGRAPH

Eurographics

Journals:

IEEE Transactions on Visualization and Computer Graphics