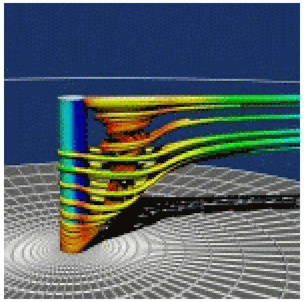
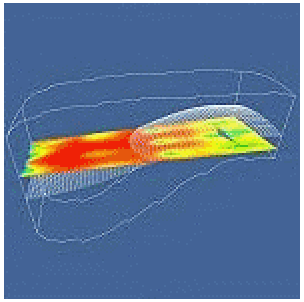
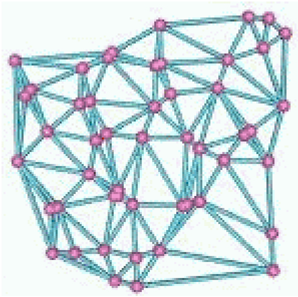
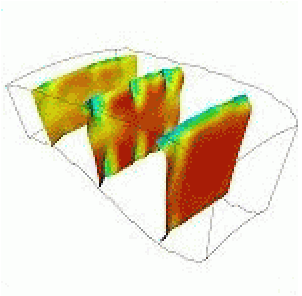
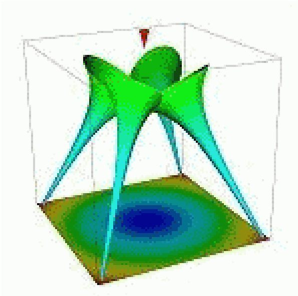
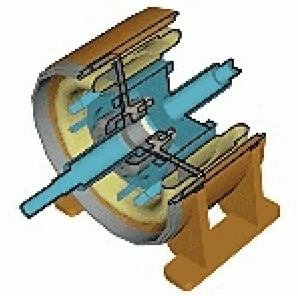
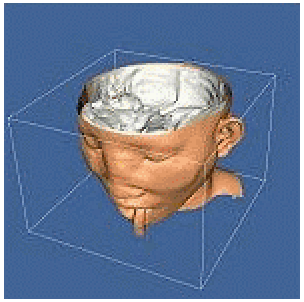
CEG7560

Visualization and Image Processing for Cyber Security

WRIGHT STATE UNIVERSITY

Department of Computer Science and Engineering

Outline

- Introduction
- From Graphics to Visualization
- Virtual Environments
- Data Representations
- The Visualization Pipeline
- Scalar Visualization
- The Quality of Visualization
- Information Visualization
- Image Processing
- Video Visualization
- Toolkit-based Visualization
- Web-based Visualization
- Cyber Security Visualization examples

Literature

- Will Schroeder, Ken Martin, Bill Lorenson, **The Visualization Toolkit - An Object-Oriented Approach To 3D Graphics**, Kitware, 2004
- Charles D. Hansen, Chris Johnson, **Visualization Handbook**, First Edition, Academic Press, 2004
- Woo, Neider, Davis, Shreiner, **OpenGL Programming Guide**, Addison Wesley, 2000, http://www.opengl.org/documentation/red_book_1.0
- http://www-static.cc.gatech.edu/scivis/tutorial/linked/classification.html

What is Visualization?

Visualization is the representation of data graphically as a means of gaining understanding and insight into the data. It is sometimes referred to as visual data analysis. This allows the researcher to gain insight into the system that is studied in ways previously impossible.

What it is not

It is important to differentiate between visualization and presentation graphics. Presentation graphics is primarily concerned with the communication of information and results in ways that are easily understood. In visualization, we seek to understand the data. However, often the two methods are intertwined.

What is Visualization?

From a computing perspective, visualization is part of a greater field called visualization. This involves research in **computer graphics, image processing, high performance computing**, and other areas. The same tools that are used for visualization may be applied to animation, or multimedia presentation, for example.

As a science, visualization is the study concerned with the **interactive display and analysis of data**. Often one would like the ability to do real-time visualization of data from any source. Thus our purview is **information, scientific, or engineering visualization** and closely related problems such as computational steering or multivariate analysis. The approaches developed are general, and the goal is to make them applicable to datasets of any size whatever while still **retaining high interactivity**. As an emerging science, its strategy is to develop fundamental ideas leading to general tools for real applications. This pursuit is **multidisciplinary** in that it uses the same techniques across many areas of study.

Motivation

Through the availability of increasingly powerful computers with increasing amounts of internal and external memory, it is possible to investigate incredibly complex dynamics by means of ever more **realistic simulations**. However, this brings with it **vast amounts of data**. To analyze these data it is imperative to have software tools which can **visualize these multi-dimensional data sets**. Comparing this with experiment and theory it becomes clear that **visualization of scientific data is useful yet difficult**. For complicated, time-dependent simulations, the running of the simulation may involve the calculation of many time steps, which requires a substantial amount of CPU time, and memory resources are still limited, one cannot save the results of every time step. Hence, it will be necessary to visualize and store the results selectively in `**real time**' so that we do not have to re-compute the dynamics if we want to see the same scene again. `Real time' means that the selected time step will be visualized as soon as it has been calculated.

Motivation (continued)

The main reasons for scientific visualization are the following ones: it will **compress a lot of data into one picture** (data browsing), it **can reveal correlations between different quantities both in space and time**, it can **furnish new space-like structures** beside the ones which are already known from previous calculations, and it opens up the **possibility to view the data selectively and interactively** in `real time'. By following the formation and the deformation as well as the motions of these structures in time, one will **gain insight into the complicated dynamics**. As was mentioned before, we also want to integrate our simulation codes into a visualization environment in order to analyze the data in 'real time' and to by-pass the need to store every intermediate result for later analysis. This is possible by means of *processing* in which the simulation is distributed over a set of high-performance computers and the **actual visualization is done on a graphical *distributive* workstation**. It is also very useful to have the possibility to interactively change the simulation parameters and immediately see the effect of this change through the new data. This process is called ***computational steering*** and it will increase the effective use of CPU time.

Common Questions and Concerns

The discussion is focused on the following questions:

- What is the improvement in the understanding of the data as compared to the situation without visualization?
- Which visualization techniques are suitable for one's data? Are direct volume rendering techniques to be preferred over surface rendering techniques?
- Can current techniques, like streamline and particle advection methods, be used to appropriately outline the known visual phenomena in the system?

Common Questions and Concerns (cont.)

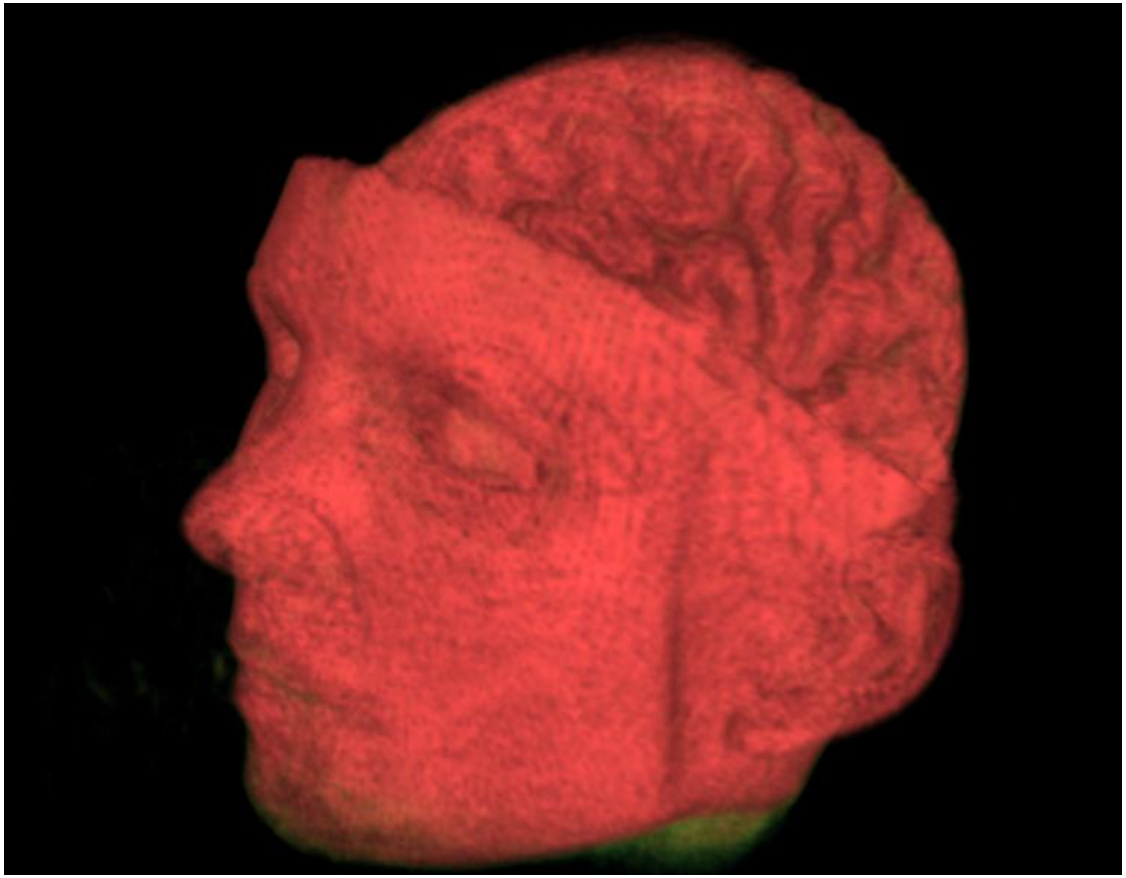
The success of visualization not only depends on the results which it produces, but **also depends on the environment** in which it has to be done. This environment is determined by the **available hardware**, like graphical workstations, **disk space**, color printers, video editing hardware, and **network bandwidth**, and by the **visualization software**. For example, the graphical hardware imposes constraints on interactive speed of visualization and on the size of the data sets which can be handled. Many different problems encountered with visualization software must be taken into account. **The user interface, programming model, data input, data output, data manipulation facilities, and other related items are all important**. The way in which these items are implemented determines the convenience and effectiveness of the use of the software package as seen by the scientist. Furthermore, whether software supports **distributive processing and computational steering** must be taken into account.

Application examples

- Engineering
- Computational Fluid Dynamics
- Finite Element Analysis
- Electronic Design Automation
- Simulation
- Medical Imaging
- Geospatial
- RF Propagation
- Meteorology
- Hydrology
- Data Fusion
- Ground Water Modeling
- Oil and Gas Exploration and Production
- Finance
- Data Mining
- Cyber Security

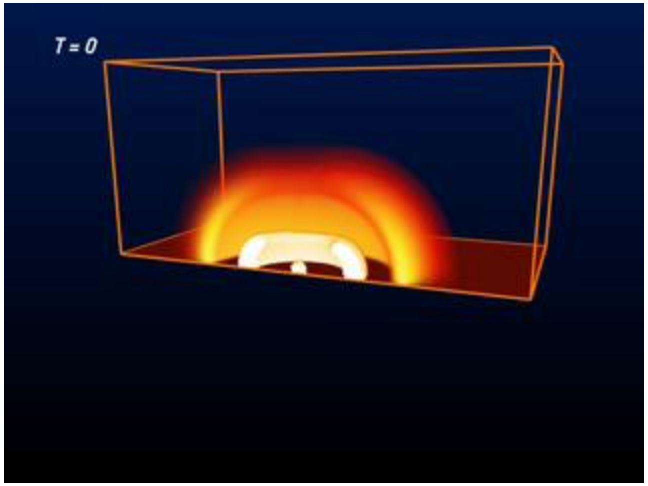
Application examples (continued)

Volume visualization of an MRI scanned brain data set



Application examples (continued)

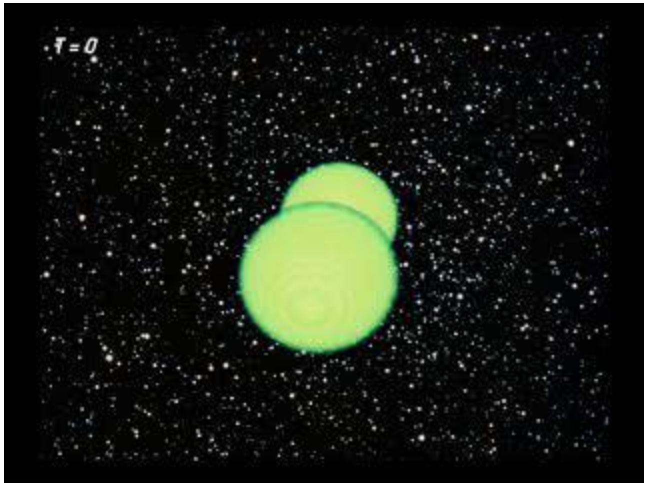
General relativistic simulation of gravitational energy



Visualization by W. Benger, Simulation by AEI Potsdam.

Application examples (continued)

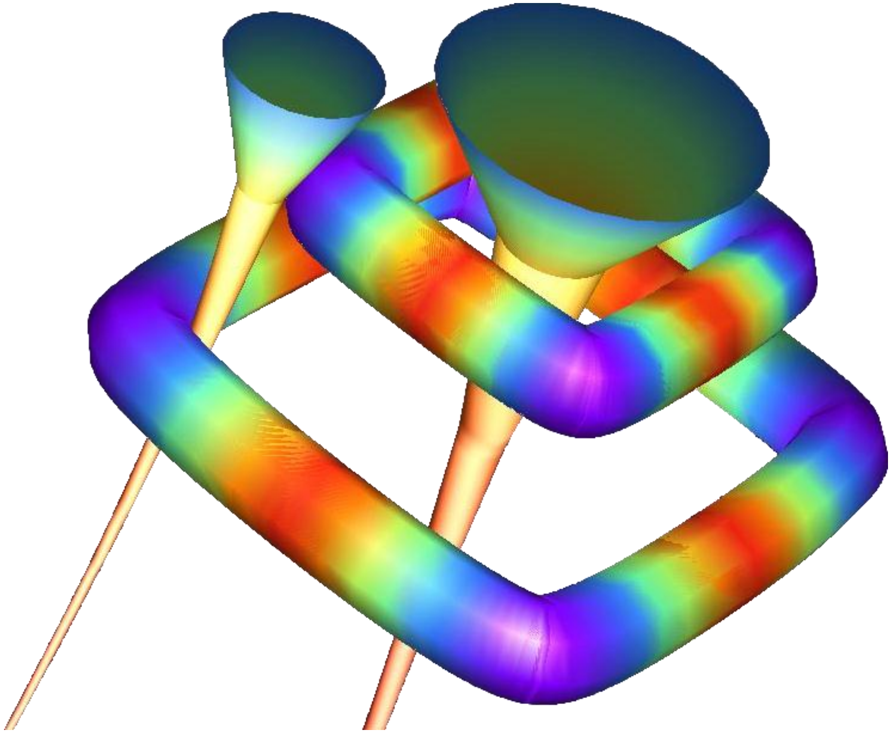
Merger of orbiting binary neutron stars. Visualization of energy density and mass density with volume rendering.



Visualization by W. Benger, Simulation by AEI Potsdam.

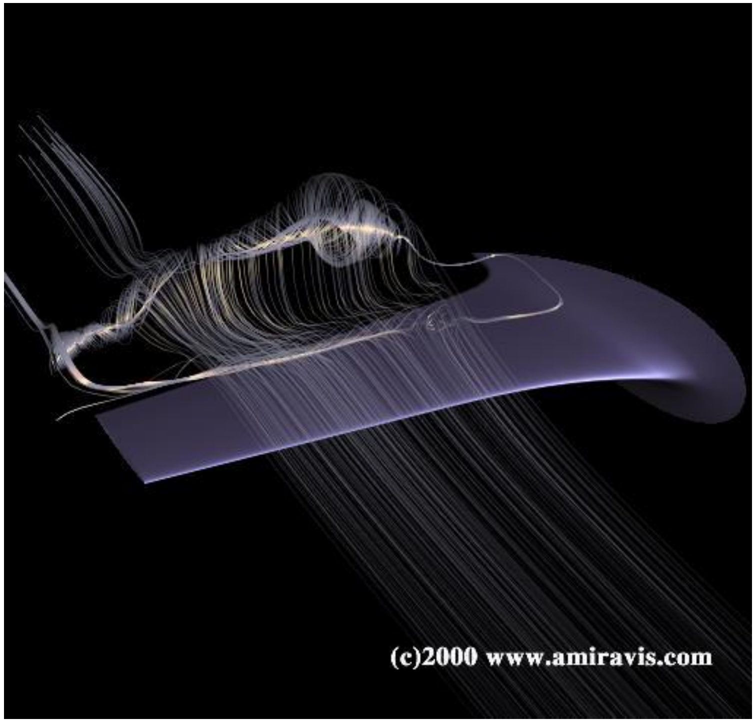
Application examples (continued)

Feature detection: closed hyperstreamlines



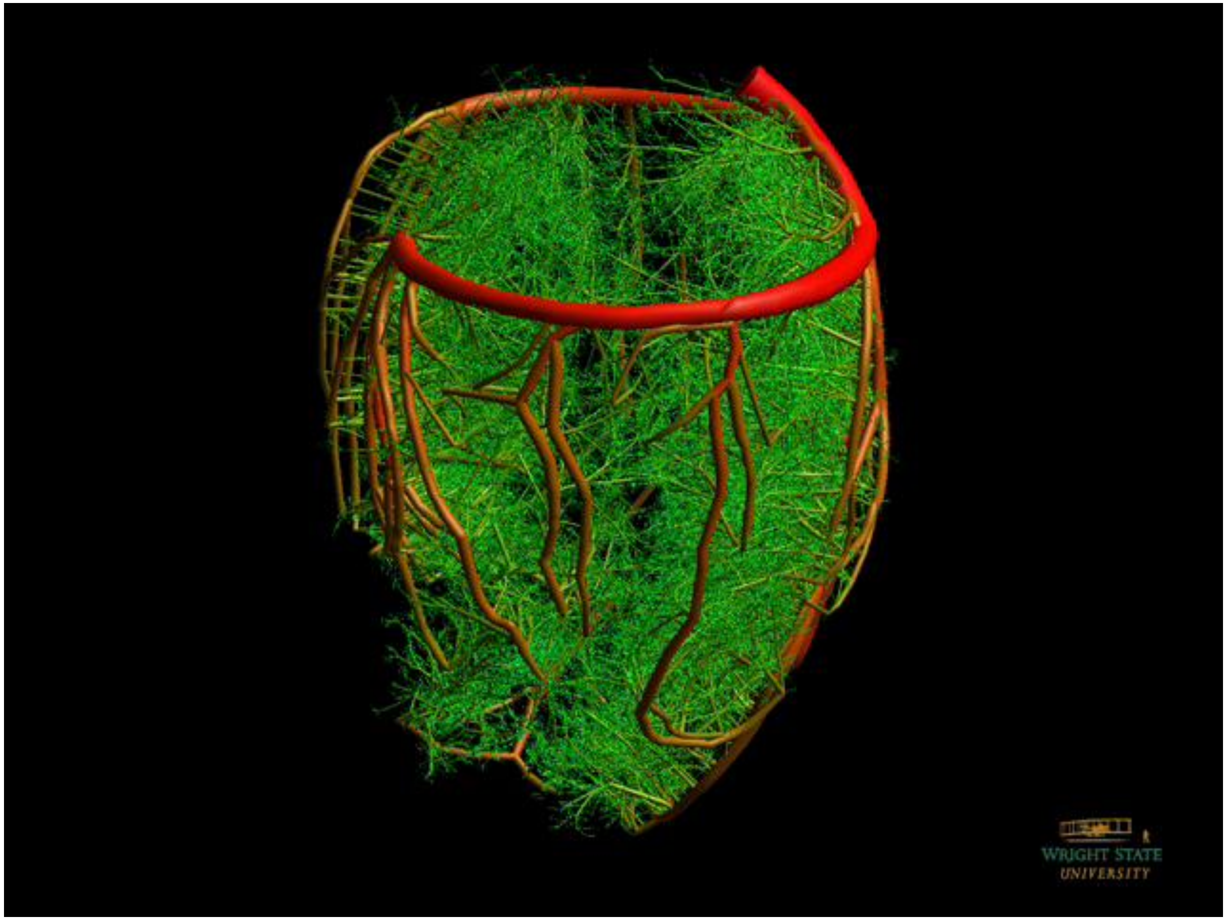
Application examples (continued)

Simulation of the air flow around a wing. Visualized using Amira's illuminated field line module.



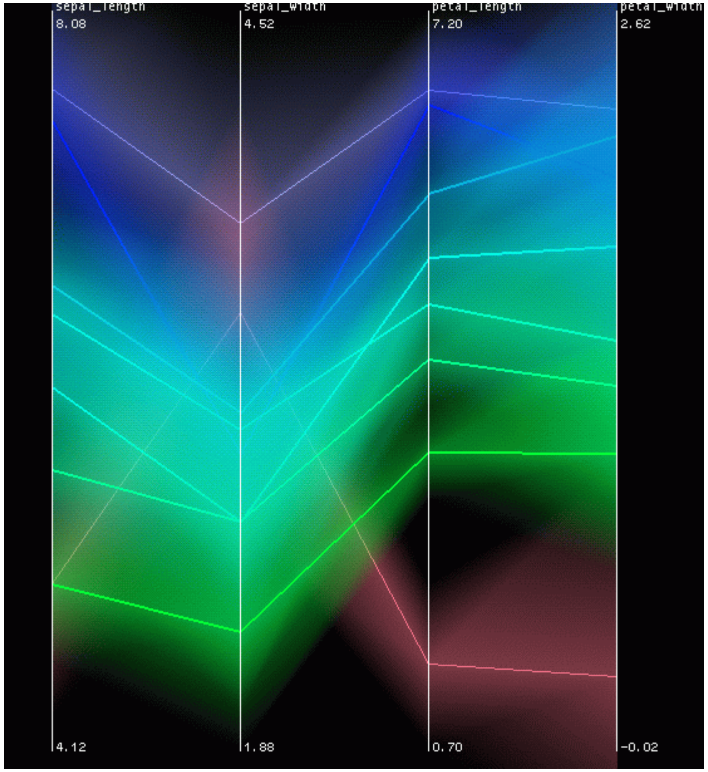
Application examples (continued)

Medical visualization: arterial tree



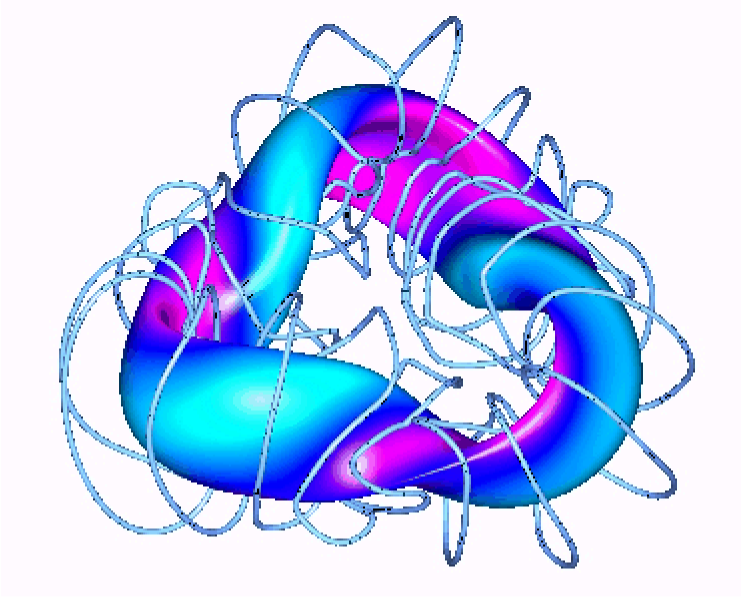
Application examples (continued)

Information visualization: parallel coordinates



Application examples (continued)

Magneto-Hydrodynamics (MHD) models are extensively used in the analysis of magnetic fusion devices, industrial processing plasmas, and ionospheric/astrophysical plasmas. MHD is the extension of fluid dynamics to ionized gases, including the effects of electric and magnetic fields. Time-independent MHD equilibria also form the basis for more advanced kinetic and particle-based models of plasma behavior.



Classification of techniques

Classification of visualization techniques is often based on the dimension of the domain of the quantity that is visualized, i.e. the number of independent variables of the domain on which the quantity acts, and on the type of the quantity, i.e. scalar, vector, or tensor.

In MHD, two scalar quantities occur, i.e. temperature (or pressure) and density, and two vector quantities, i.e. magnetic field and velocity field. These quantities are defined on a four-dimensional domain which is spanned up by the space and time coordinates. The time dependence is treated differently than other dependencies. In particular, animation is used to visualize this dependency (see below).

Visualization techniques can also be divided into *surface rendering techniques*, and *(direct) volume rendering* techniques. Surface rendering is an indirect geometry based technique which is used to visualize structures in 3D scalar or vector fields by converting these structures into surface representations first and then using conventional computer graphics techniques to render these surfaces. Direct volume rendering is a technique for the visualization of 3D scalar data sets without a conversion to surface representations.

Visualization techniques

Different techniques are used to visualize different data sets. These techniques can be, for example:

- Surface rendering
- Information visualization
- Graph-based visualization
- Video visualization

Surface rendering

Isosurfaces

This technique produces surfaces in the domain of the scalar quantity on **which the scalar quantity has the same value**, the so-called *isosurface value*. The surfaces can be **colored according to the isosurface value** or they can be colored according to another scalar field using the texture technique. The latter case allows for the search for correlation between different scalar quantities.

There are different **methods to generate the surfaces from a discrete set of data points**. All methods use interpolation to construct a continuous function. The correctness of the generated surfaces depends on how well the constructed continuous function matches the underlying continuous function representing the discrete data set. The common method which is implemented in many software packages is the **Marching Cube Algorithm**.

Information visualization

The rise of the Information Age and the ascendancy of Computer Graphics come together in the area of Information Visualization, where interactive graphical interfaces are used for revealing structure, extracting meaning, and navigating large and complex information worlds.

Increasing amounts of data and information and the availability of fast digital network access (e.g., in the information highway environment) have created a demand for querying, accessing, and retrieving information and data. However, information technology will not transform business, science, medicine, engineering, and education if the users cannot use it easily and efficiently. Technology must come to the users, taking their needs into account. If we do not involve the users, we will develop useless systems. One of the concerns of this field is the **human-information interface**, and **how advances in interactive computer graphics hardware, mass storage, and data visualization could be used to visualize information**.

Graph-based Visualization

Lots of data sets are encoded as a graph, for example, network representations or linked data. Different techniques are available for visually representing graph-type data sets that can range from encoding the graph directly to more abstract representations.

Video Visualization

Video material can be challenging to visualize. Due to the amount of material, one typically does not want to represent each frame individually but instead find a summarizing encoding to enable the user to get an overview of the video. On demand features let the user then dive into sections of the video to obtain more detail.

Visualization toolkits

Different software or toolkits are available:

- Amira (Zuse Institute Berlin (ZIB))
- Fast (NASA)
- OpenDX (formerly IBM Data Explorer)
- AVS (Advanced Visual Systems)
- Visualization toolkit (vtk) (Kitware)
- OpenGL
- …

Throughout this course, we will focus on OpenGL as this provides us with the necessary flexibility.

Disclaimer

Some images and material used in these slides is based on material from different external sources referenced here:

- The text book written by Alex Telea
- The slides describing the VR hardware in chapter 2 are based in part on Yan Liu's material of her class on Virtual Environments: http://www.cecs.wright.edu/~yan.liu/IHE631/VirtualEnvironment.pdf
- Some slides of chapter 10 are based on the IEEE VisWeek 2008 Titan Tutorial: http://www.kitware.com/InfovisWiki/images/6/6f/Information_Visualization_In_VTK.ppt
- The slides discussing the VTK Widgets are based on William J. Schroeder's slides: http://www.powershow.com/view1/297e42-ZDQxN/VTK_Widgets_powerpoint_ppt_presentation
- The chapter 12 slides are based on the 2010 WebGL Seminar by Arto Salminen, Matti Anttonen (http://lively.cs.tut.fi/seminars/WebGL2011/) and the D3 Tutorial slides by Vadim Ogievetsky (https://graphics.stanford.edu/wikis/cs448b-11-fall/D3_Tutorial?action=AttachFile&do=get&target=d3_intro.pptx)