Advanced Computer Graphics Techniques for Volume Visualization

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1 Introduction

Computer Graphics provides techniques for visualizing graphical primitives which are derived from geometric elements. Data in real life - gathered by sensors - may represent a continuum. Data in real life does not correspond directly to abstract geometric elements.

Special rendering methods have been developed in Computer Graphics to make data visible, and manifold data conversion techniques are applied to the original data samples.

Modern high-performance workstations fairly well equipped with main memory allow users to handle massive data sets and to make a particular data set visible sample by sample. Depending on the quality of the visual representation of the data, the image generating time takes some seconds or even minutes - still far from an interactive scientific analysis of data.

This paper describes the various steps to be executed in the visualization process of volume data, i.e., to make data values in a 3-dimensional space visible. Tools are discussed that provide user assistance in allowing a more comfortable interactive handling of this data.
2 Volume Data

Volume data is produced by many different sources in many application areas. The data sets are the result of a simulation or observation process. Typical application areas according to [1,2] are:
- molecular modeling,
- medical imaging (diagnostic medicine, radiation treatment planning, orthopedic prosthesis, etc.),
- mathematics,
- geosciences (cartography, geology, meteorology),
- space exploration,
- astrophysics,
- computational fluid dynamics,
- finite element analysis,
- urban design (simulation of landscape architectures) and
- environment engineering.

The dimension of the data set is equal to the smallest number of independent variables which span the set. The data set can depend on one dimension only, e.g., the amplitude of a signal versus time, or on two dimensions, e.g., topographical maps. Data sets that depend on three spatial dimensions are called volume data. As we live in three-dimensional space these data sets are very common. Time appears often as the fourth dimension. In many cases there may be more independent variables. In material strength analysis, e.g., the material properties and the type of load on the test specimen are non-spatial independent variables. In these multi-dimensional cases, it is appropriate to restrict the visualized data to a lower-dimensional subset in order to obtain a good understanding of the data.

The dependent variables of the data can be scalar, vector or tensor fields. For example, the temperature in a room is a scalar field depending on spatial location. Wind velocity is a vector field, as its quantity has a direction as well as a magnitude. Further examples of volume data sets are stacks of two-dimensional images, e.g., CT or MRI scans. The field values in volume data are generally available at a finite number of locations in space. These may be organized into a regular grid with constant distances between the grid points, or in an irregular mesh.