DATA VISUALIZATION:
THE STATE OF THE ART

Proceedings of the 4th Dagstuhl Seminar on Scientific Visualization CD-ROM

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Contents

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I

VISUALIZATION ALGORITHMS AND TECHNIQUES

EFFICIENT OCCLUSION CULLING FOR LARGE MODEL VISUALIZATION

D. Bartz, M. Meißner, G. Müller

Abstract   Occlusion and visibility culling is one of the major techniques to reduce the geometric complexity of large polygonal models. Since the introduction of hardware assisted-occlusion culling in OpenGL (as an extension), solely software-based approaches are losing relevance rapidly for applications which cannot exploit specific knowledge of the scene geometry. However, there are still several issues open on the software side for significant performance improvements. In this paper, we discuss several of these techniques.

Complete article

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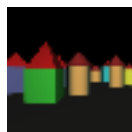
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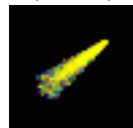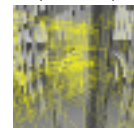
LOCALIZING VECTOR FIELD TOPOLOGY

G. Scheuermann, B. Hamann, K.I. Joy, W. Kollmann

Abstract   The topology of vector fields offers a well known way to show a condensed view of the stream line behavior of a vector field. The global structure of a field can be shown without time-consuming user interaction. With regard to large data visualization, one encounters a major drawback: the necessity to analyze a whole data set, even when interested in only a small region. We show that one can localize the topology concept by including the boundary in the topology analysis. The idea is demonstrated for a turbulent swirling jet simulation example. Our concept works for all planar, piecewise analytic vector fields on bounded domains.

Complete article

- [PDF](#)
- [PS](#)

FEATURE TRACKING WITH SKELETON GRAPHS

B. Vrolijk, F. Reinders, F.H. Post

Abstract   A way to analyse large time-dependent data sets is by visualization of the evo-
lution of features in these data. The process consists of four steps: feature
extraction, feature tracking, event detection, and visualization.

In earlier work, we described the execution of the tracking process by means
of basic attributes like position and size, gathered in ellipsoid feature descriptions.
Although these basic attributes are accurate and provide good tracking results,
they provide little shape information about the features. In other work, we pre-
sented a better way to describe the shape of the features by skeleton attributes.

In this paper, we investigate the role that the skeleton graphs can play in feature
tracking and event detection. The extra shape information allows detection of
certain events much more accurately, and also allows detection of new types of
events: changes in the topology of the feature.

Complete article

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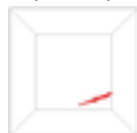
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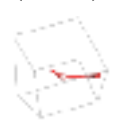
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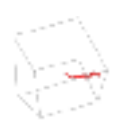
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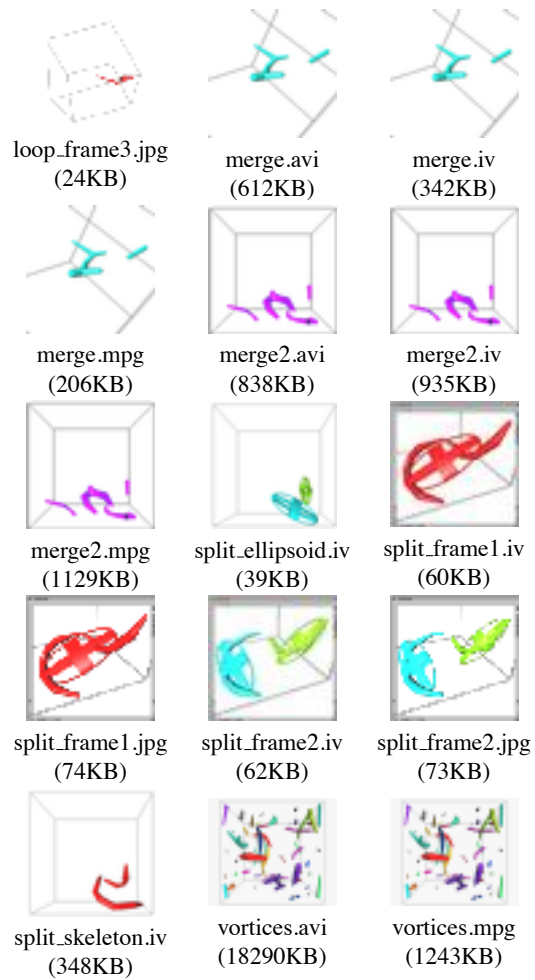
CORRESPONDENCE ANALYSIS: VISUALIZING PROPERTY-PROFILES OF TIME-DEPENDENT 3D DATASETS

K. Fries, J. Meyer, H. Hagen, B. Lindemann

Abstract   The article presents a method to perform an analysis of correspondence between sets of points in three-dimensional euclidean space. Application-specific spatial data structures like the minimum (euclidean) spanning tree and several kinds of histograms assessing different transformations combined with quantities characterizing geometrical and topological qualities of point clusters are used to compute scores for point-to-point identification. These ratings are accumulated in a so-called match matrix, which is finally employed to extract a 1:1 match. The method used to track individual fluorescent spots (synapses) in a volume of tissue which undergoes uneven spatial distortion (swelling and shrinkage). This enables the creation of analysis of cell property-profiles.

Complete article

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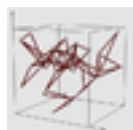
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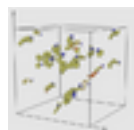
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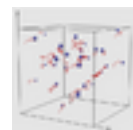
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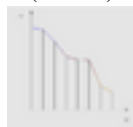
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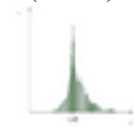
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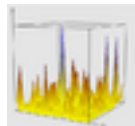
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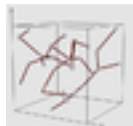
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SPECIALIZING VISUALIZATION ALGORITHMS

S. Diehl

Abstract   In this paper we look at the potential of program specialization techniques in the context of visualization. In particular we look at partial evaluation and pass separation and how these have been used to automatically produce more efficient implementations and how they can be used to design new algorithms. We conclude by discussing what we think are the applications where program specialization is most promising in visualization.

Complete article

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ISOSURFACE EXTRACTION FOR LARGE-SCALE DATA SETS

Y. Livnat, C. Hansen, C.R. Johnson

Abstract   Isosurface extraction is an important technique for visualizing large scale three-dimensional scalar fields. Recent years have seen many acceleration methods for isosurface extraction including the space space representation and view dependent methods. In this paper, we provide an overview of isosurface extraction; building upon our previous research to develop a superior model. We describe the differences between the two techniques and their relative advantages and disadvantages. These methods are particularly useful for remote visualization of very large datasets.

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II

VOLUME VISUALIZATION

TOPOLOGICALLY-ACCENTUATED VOLUME RENDERING

Issei Fujishiro, Yuriko Takeshima, Shigeo Takahashi, Yumi Yamaguchi

Abstract   In spite of many attempts at making volume visualization popular, it is still a hard task for novice users to adjust rendering-related parameter values for generating informative images. In our previous study, we took advantage of a 3D field topology analysis for semi-automatic design of transfer functions. In this paper, we address four specific issues to adapt the method for dealing with real world datasets. A medical CT-scanned dataset is used to prove the feasibility of the extended method.

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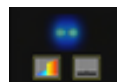
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RECONSTRUCTION ISSUES IN VOLUME VISUALIZATION

T. Theußl, T. Möller, J. Hladůvka, M.E. Gröller

Abstract   Although volume visualization has already grown out of its infancy, the most commonly used reconstruction techniques are still trilinear interpolation for function reconstruction and central differences (most often in conjunction with trilinear interpolation) for gradient reconstruction. Nevertheless, quite some research in the last few years was devoted to improve this situation. This paper surveys the more important methods, emphasizing selected work in function and gradient reconstruction, and gives an overview over the rather new development of exploiting second-order derivatives for volume visualization purposes.

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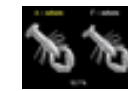
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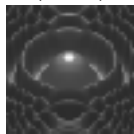
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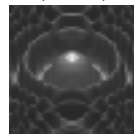
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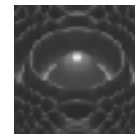
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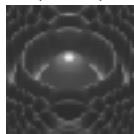
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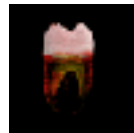
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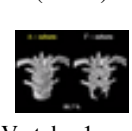
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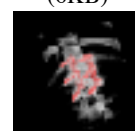
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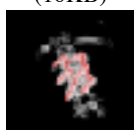
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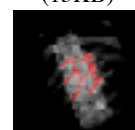
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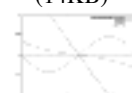
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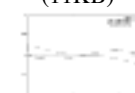
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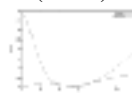
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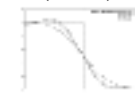
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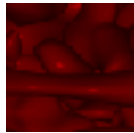
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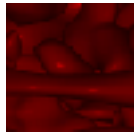
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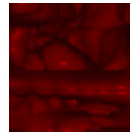
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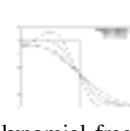
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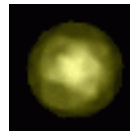
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Data Visualization: The State of the Art

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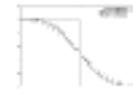
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HIGH QUALITY SPLATTING AND VOLUME SYNTHESIS

R. Crawfis, J. Huang

Abstract   Our recent improvements to volume rendering using splatting allow for an accurate functional reconstruction and volume integration, occlusion-based acceleration, post-rendering classification and shading, 3D texture mapping, bump mapping, anti-aliasing and gaseous animation. A pure software implementation requiring low storage and using simple operations has been implemented to easily support these operations. This paper presents a unified framework and discussion of these enhancements, as well as extensions to support hypertextures efficiently. Discussions on appropriate volume models for effective usage of these techniques is also presented.

Complete article

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CELLFAST: INTERACTIVE UNSTRUCTURED VOLUME RENDERING AND CLASSIFICATION

C.M. Wittenbrink, H.J. Wolters, M. Goss

Abstract   CellFast is an interactive system for unstructured volume visualization. Our CellFast system uses optimizations of OpenGL triangle fans, customized quicksort, memory organization for cache efficiency, display lists, tetrahedral culling, and multithreading. The optimizations improve the performance of an approach similar to Shirley and Tuchman's projected tetrahedra rendering to provide 1 frame/second for 240,122 tetrahedral cells, 3 frames/second for 70,125 tetrahedral cells, and 15 frames/second for 12,936 tetrahedral cells. CellFast also performs fully automated classification to assist rendering. Demonstration of fluid flow, medical simulation, and medical imaging datasets are provided. CellFast provides for very high resolutions (up to 3840x1024), at frame rates that are orders of magnitude higher in performance compared to those in the literature. The CellFast system combines an interactive renderer and automatic classifcation to make unstructured volume rendering more useful.

Complete article

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CELL PROJECTION OF MESHES WITH NON-PLANAR FACES

M. Max, P. Williams, C. Silva

Abstract   We review the cell projection method of volume rendering, discussing back-to-front cell sorting, and approximations involved in hardware color computation and interpolation. We describe how the method accommodates cells with non-planar faces using view dependent subdivision into tetrahedra.

Complete article

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SEGMENTATION AND TEXTURE-BASED HIERARCHICAL RENDERING TECHNIQUES FOR LARGE-SCALE REAL-COLOR BIOMEDICAL IMAGE DATA

J. Meyer, R. Borg, I. Takanashi, E.B. Lum, B. Hamann

Abstract   Hierarchical, texture-based rendering is a key technology for exploring largescale data sets. We describe a framework for an interactive rendering system based on a client/server model. The system supports various output media from immersive 3-D environments to desktop based rendering systems. It uses web-based transport mechanisms to transfer the data between the server and the client application. This allows us to access and explore large-scale data sets from remote locations over the Internet. Hierarchical space-subdivision, wavelet compression, and progressive data transmission are used to visualize the data on the client side.

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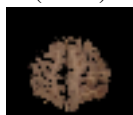
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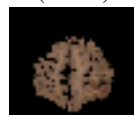
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III

INFORMATION VISUALIZATION

EBUSINESS CLICK STREAM ANALYSIS

S.G. Eick

Abstract   Click stream data represents a rich source of information for understanding web site activity, browsing patterns to purchasing decisions. Standard tools produce hundreds of reports that are not particularly useful. The problem with fixed web reports, and report-based analysis in general, is that reports only answer specific, predefined questions that are insufficient for today s highly competitive and rapidly changing businesses. To overcome this problem, we have developed a click stream analysis tool called eBizInsights. eBizInsights consists of a web log parser, a click stream warehouse, a reporting engine, and a rich visual interactive workspace. Using the workspace, analysts perform ad hoc analysis, discover patterns, and identify correlations that are impossible to find using fixed reports.

Complete article

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HIERARCHICAL EXPLORATION OF LARGE MULTIVARIATE DATA SETS

J. Yang, M.O. Ward, E.A. Rundensteiner

Abstract   Multivariate data visualization techniques are often limited in terms of the number of data records that can be simultaneously displayed in a manner that allows ready interpretation. Due to the size of the screen and number of pixels available, visualizing more than a few thousand data points generally leads to clutter and occlusion. This in turn restricts our ability to detect, classify, and measure phenomena of interest, such as clusters, anomalies, trends, and patterns. In this paper we describe our experiences in the development of multi-resolution visualization techniques for large multivariate data sets. By hierarchically clustering the data and displaying aggregation information for each cluster, we can examine the data set at multiple levels of abstraction. In addition, by providing powerful navigation and filtering operations, we can create an environment suitable for interactive exploration without overloading the user with dense information displays. In this paper, we illustrate that our hierarchical displays are general by successfully applying them to four popular yet non-scalable visualizations, namely parallel coordinates, glyphs, scatterplot matrices and dimensional stacking.

Complete article

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VISUALIZATION OF MULTIDIMENSIONAL DATA USING STRUCTURE PRESERVING PROJECTION METHODS

W. de Leeuw, R. van Liere

Abstract   Multi Dimensional Scaling is a structure preserving projection method that allows for the visualization of multidimensional data. In this paper we discuss our practical experience in using MDS as a projection method in three different application scenarios. Various reasons are given why structure preserving projection methods are useful for the analysis of multidimensional data. We discuss two visual forms (glyphs, heightfields) which can be used to represent the output of the projection methods.

Complete article

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VISUALIZING PROCESS INFORMATION AND THE HEALTH STATUS OF WASTEWATER TREATMENT PLANTS - A CASE STUDY OF THE ESPRIT PROJECT WATERCIME

P. Dannenmann, H. Hagen

Abstract   In this case study we present an approach to support the operators of wastewater treatment plants by supervising the health status of the plant with an online diagnosis software and by visualizing the process data and the diagnosis results. In addition to measuring the available on-line data, we simulate the behavior of the biological processes in order to retrieve data on-line that normally only can be determined by analyzing water samples in the laboratory. Based on the automated analysis of these data we provide to the operator a view of the states of the biological processes within his plant. This information allows an early reaction in the case of deviations from an optimal process behavior. Thus the plant can always be operated in an optimal state so that we can be sure that the treated water always meets the environmental standards that are required.

Complete article

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IV

MULTIRESOLUTION METHODS

DATA STRUCTURES FOR 3D MULTI-TESSELLATIONS: AN OVERVIEW

E. Danovaro, L. De Floriani, P. Magillo, E. Puppo

Abstract   Multiresolution models support the interactive visualization of large volumetric data through selective refinement, an operation which permits to focus resolution only on the most relevant portions of the domain, or in the proximity of interesting field values. A 3D Multi-Tessellation (MT) is a multiresolution model, consisting of a coarse tetrahedral mesh at low resolution, and of a set of updates refining such a mesh, arranged as a partial order. In this paper, we describe and compare different data structures which permit to encode a 3D MT and to support selective refinement.

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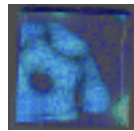
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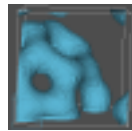
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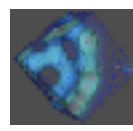
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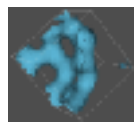
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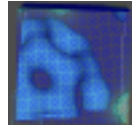
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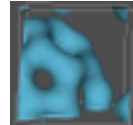
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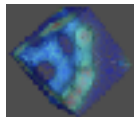
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A DATA MODEL FOR ADAPTIVE MULTI-RESOLUTION SCIENTIFIC DATA

P.J. Rhodes, R.D. Bergeron, T.M. Sparr

Abstract   Representing data using multiresolution is a valuable tool for the interactive exploration of very large datasets. Current multiresolution tools are written specifically for a single kind of multiresolution data. As a step toward developing general purpose multiresolution tools, we present here a model that represents a wide range of multiresolution data within a single paradigm. In addition, our model provides support for working with multiresolution data in a distributed environment.

Complete article

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MULTIRESOLUTION REPRESENTATION OF DATASETS WITH MATERIAL INTERFACES

B.F. Gregorski, K.I. Joy, D.E. Sigeti, J. Ambrosiano, G. Graham, M. Wolinski, M.A. Duchaineau

Abstract   We present a new method for constructing multiresolution representations of data sets that contain material interfaces. Material interfaces embedded in the meshes of computational data sets are often a source of error for simplification algorithms because they represent discontinuities in the scalar or vector field over mesh elements. By representing material interfaces explicitly, we are able to provide separate field representations for each material over a single cell. Multiresolution representations utilizing separate field representations can accurately approximate datasets that contain discontinuities without placing a large percentage of cells around the discontinuous regions. Our algorithm uses a multiresolution tetrahedral mesh supporting fast coarsening and refinement capabilities; error bounds for feature preservation; explicit representation of discontinuities within cells; and separate field representations for each material within a cell.

Complete article

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GENERALIZING LIFTED TENSOR-PRODUCT WAVELETS TO IRREGULAR POLYGONAL DOMAINS

M. Bertram, M.A. Duchaineau, B. Hamann, K.I. Joy

Abstract   We present a new construction approach for symmetric lifted B-spline wavelets on irregular ploygonal control meshes defining two-manifold topologies. Polygonal control meshes are recursively refined by stationary subdivision rules and converge to piecewise polynomial limit surfaces. At every subdivision level, our wavelet transforms provide an efficient way to add geometric details that are expanded from wavelet coefficients. Both wavelet decomposition and reconstruction operations are based on local lifting steps and have linear-time complexity.

Complete article

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RANKED REPRESENTATION OF VECTOR FIELDS

B. Nakshatrala, D. Thompson, R. Machiraju

Abstract   Browsing and visualizing large datasets is often a tedious chore. Locating features, especially in a wavelet transform domain is usually offered as a possible solution. Wavelet transforms decorrelate data and facilitate progressive access through streaming. The work reported here describes a scheme that allows the user to first visualize regions containing significant features. Various region and coefficient ranking strategies can be incorporated into this approach so that a progressively encoded bitstream can be constructed. We examine four wavelet ranking schemes and demonstrate the usefulness of the feature-based schemes for a 2D oceanographic dataset.

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V

MODELLING TECHNIQUES

PROCEDURAL VOLUME MODELING RENDERING, AND VISUALIZATION

D. Ebert, P. Rheingans

Abstract   Volume visualization techniques have advanced dramatically over the past fifteen years. However, the increase in scale of visualization tasks has been increasing at even a faster rate. Today, many problems require the visualization of gigabytes to terabytes of data. Additionally, the number of variables and dimensionality of many scientific simulations and observations has increased, while the resolution of computer graphics displays has not changed substantially (still a few million pixels). These factors present a significant challenge to current visualization techniques and approaches. We propose a new approach to visualization to solve these problems and provide flexibility and extensibility for visualization challenges over the next decade: procedural visualization. In this approach, we encode and abstract datasets to a more manageable level, while also developing more effective visualization and rendering techniques.

Complete article

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SURFACE APPROXIMATION TO POINT CLOUD DATA USING VOLUME MODELING

A. Huang, G.M. Nielson

Abstract   Given a collection of unorganised points in space, we present a new method of constructing a surface which approximates this point cloud. The surface is defined implicitly as the isosurface of a trivariate volume model. The volume model is piecewise linear and obtained as a least squares fit to data derived from the point cloud. The original point cloud input is assigned a zero value. Additional points are derived for the interior and exterior and assigned positive and negative values respectively.

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ENRICHING VOLUME MODELLING WITH SCALAR FIELDS

M. Chen, A.S. Winter, D. Rodgeman, S. Treavett

Abstract A scalar eld is a generalisation of a surface function in dimension. Visualisation traditionally focuses on discrete specifications of scalar fields (e.g., volume datasets). This paper discusses the role of continuous and procedural field specifications in volume visualisation and volume graphics, and the inter-operations between continuous and discrete specifications. It demonstrates the different use of scalar fields through several modelling aspects, including constructive volume geometry and non-photorealistic textures, and presents our approaches to the creation of more photorealistic effects in direct volume rendering.

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FAST METHODS FOR COMPUTING ISOSURFACE TOPOLOGY WITH BETTI NUMBERS

S.F. Konkle, P.J. Moran, B. Hamann, K.I. Joy

Abstract   Betti numbers can be used as a means for feature detection to aid in the exploration of complex large-scale data sets. We present a fast algorithm for the calculation of Betti numbers for triangulated isosurfaces, along with examples of their use. Once an isosurface is extracted from a data set, calculating Betti numbers only requires time and space proportional to the isosurfaces, not the data set. Because the overhead of obtaining Betti numbers is small, our algorithm can be used with large data.

Complete article

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SURFACE INTERPOLATION BY SPATIAL ENVIRONMENT GRAPHS

R. Mencl, H. Müller

Abstract   A new algorithm for the reconstruction of surfaces from three-dimen- sional point clouds is presented. Its particular features are reconstruc- tion of open surfaces with boundaries from data sets with variable den- sity, and treatment of sharp edges, that is, locations of infinite curva- ture. While these properties can be demonstrated only empirically, we outline formal arguments which explain why the algorithm works well for compact surfaces of limited curvature without boundary. They are based on a formal definition of "reconstruction", and on demonstration of existence of sampling sets for which the algorithm is successful.

Complete article

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VI

INTERACTION TECHNIQUES AND ARCHITECTURES

PRESET BASED INTERACTION WITH HIGH DIMENSIONAL PARAMETER SPACES

J.J. van Wijk, C.W.A.M. van Overveld

Abstract   Many systems require the setting of a large number of parameters. This is often a difficult and time consuming task, especially for novice users. A framework is presented to simplify this task. Settings are defined as a weighted sum of a number of presets, thereby bridging the gap between the expert mode of setting all individual parameters and the novice user mode of selecting presets. Several methods are presented to set the weights of the presets. With an interactive graphical widget, the preset controller, the user can change many parameters simultaneously in an easy and natural way. Also, methods for automated scanning of the parameter space are described. Two applications are presented: morphing of drawings and the control of a sound synthesizer.

Complete article

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VISUAL INTERACTION TO SOLVE COMPLEX OPTIMIZATION PROBLEMS

A. Hinneburg, D.A. Keim

Abstract   Many real world problems can be described as complex optimization problems. Some of them can be easily formalized and are amenable to an automated solution using some (usually heuristic) optimization algorithm. Other complex problems can not be solved satisfactory by automated algorithms. The reason is that the problems and the corresponding optimization goals can either not be fully formalized or that they vary depending on the user and the task at hand. In both cases, there is no chance to obtain a fully automatic solution of the problem. The only possibility is to make the user an integral part of the process. In this article, we therefore propose an interactive optimization system based on visualization techniques to guide the optimization process of heuristic optimization algorithms. To show the usefulness of our ideas, we provide two example applications: First, we apply the idea in the framework of similarity search in multimedia databases. Since it is difficult to specify the search task, we use visualization techniques to allow an interactive specification. As basis for the automated optimization we use a genetic algorithm. Instead of having an a-priori fully-specified fitness function, however, we let the user interactively determine the fitness of intermediate results based on visualizations of the data. In this way, an optimization with user-dependent and changing optimization goals is possible. The second example is a typical complex optimization problem - the time tabling problem. In most instantiations of the problem, it is not possible to completely specify all constraints, especially the potentially very large number of dependencies and soft constraints. In this application example, we also use visualization techniques in combination with automated optimization to improve the obtained solutions.

Complete article

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VISUALIZING COSMOLOGICAL TIME

A.J. Hanson, C.-W. Fu, E.A. Wernert

Abstract   Time is a critical aspect of visualization systems that invoke dynamic simulations and animation. Dealing with time at the scales required to conceptualize astrophysical and cosmological data, however, introduces specialized problems that require unique approaches. In this paper, we extend our previous investigations on interactive visualization across extremely large scale ranges of space to incorporate dynamical processes with very large scale ranges of time. We focus on several issues: time scales that are too short or too long to animate in real time, those needing complex adjustment relative to the scale of space, time simulations that involve the constant finite velocity of light (special relativity) in an essential way, and those that depend upon the dynamics of the coordinate system of the universe itself (general relativity). We conclude that a basic strategy for time scaling should ordinarily track the scaling of space chosen for a particular problem; e.g., if we are adjusting the interactive space scale, we scale time in a similar way. At cosmological scales, this has the interesting consequence that the time scale adjusts to the size of each era of the universe. If we make a single tick of the viewer s clock correspond to an enormous time when viewing an enormous space, we see motions in viewer s time of increasingly larger, and usually appropriate, scales. Adding interactive time-scale controls then permits the user to switch the focus of attention among animations with distinctly different time features within a single spatial scale. Objects may have an entire time hierarchy of alternate icons, with different representations for different time-step scales, exactly analogous to the choice of spatial level-of-detail models.
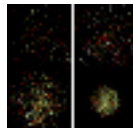
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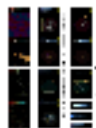
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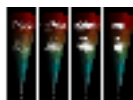
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COMPONENT-BASED
INTELLIGENT VISUALIZATION

H. Hagen, H. Barthel, A. Ebert, M. Bender

Abstract   In this paper we propose a visualization system architecture combining component technology with multi agent technology. Component technology is used as a development platform on which visualization modules as well as agents are implemented as reusable software components. The agents in our approach are used to automatically satisfy individual user demands and to dynamically adapt to changing system loads and different hardware configurations

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