09251 Abstracts Collection
Scientific Visualization
— Dagstuhl Seminar —

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Abstract. From 06-14-2009 to 06-19-2009, the Dagstuhl Seminar 09251 "Scientific Visualization " was held in Schloss Dagstuhl – Leibniz Center for Informatics. During the seminar, over 50 international participants presented their current research, and ongoing work and open problems were discussed. Abstracts of the presentations given during the seminar as well as abstracts of seminar results and ideas are put together in this paper. The first section describes the seminar topics and goals in general.

Keywords. Scientific visualization, Data analysis, Data modeling, Segmentation, Knowledge extraction, Ubiquitous visualization, Categorical visualization, Intelligent/automatic visualization, Point-based/mesh-free visualization

09251 Summary – Scientific Visualization

Resulting from a growth in data set size, complexity, and number of covered application areas, modern Scientific Visualization combines research from a wide variety of theoretical and practical fields such as mathematics, physics, biology and computer science. These research efforts yield a large number of different analysis, processing, and visualization techniques, allowing the efficient generation and presentation of visual results. This in turn directly contributes to the way domain experts are able to deduce knowledge from abstract data.

Emphasizing the heterogeneity of this research field, the Dagstuhl Scientific Visualization Seminar 2009 focused on a wide range of visualization topics such as "Knowledge Assisted Visualization", "Visual Exploration Environment", "Biomedical Visualization", and "Visualization of Vector- and Tensorfields". The seminar aimed to provide an open and international environment for the discussion of recent trends, breakthroughs and future directions of research in the area of visualization, fostering scientific exchange and collaboration among researchers of the Sci-Vis community and identifying new research directions.

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In the course of the seminar, leading international scientists presented state-of-the-art summaries as well as novel research results and ideas. Among the discussed key topics were:

Interaction Techniques/Frameworks
To efficiently perform visual data analysis, end users and domain experts need not just be presented with visualization results, but have to be offered intuitive and efficient real-time interaction techniques and frameworks. User-centered approaches demonstrate, how human factors can influence the way data is processed and presented. Presentations and results from this seminar illustrated and devised methods for interactive data exploration and analysis.

Feature Definition and Extraction/Reconstruction
New data types and application fields require new types of features, novel extraction techniques and visualization algorithms. Work from a broad context of feature extraction and reconstruction in areas such as scalar-, vector- and tensorfield visualization was presented in the course of this seminar.

Visualization Metaphors
Complex abstract data properties can only be visualized with suitable visualization metaphors. The conception and design of such visualization metaphors is a key problem in data visualization. To this end, several results of this seminar aimed towards answering abstract questions about "system safety", "document history", and "algorithmic space".

Optimization Techniques
As existing work from the field of visualization is adapted to new application areas or visualization problems, an increase in size, structure or complexity of the given data necessarily leads to the development of optimized algorithms. This seminar identified algorithms and data structures for performance and accuracy improvement in key areas of scientific visualization such as (vector) field analysis.

Besides these topics, participants gave valuable presentations about conceptual, philosophical and psychological questions in visualization regarding the impact and benefit of user-centered approaches, research classification and other topics.
The productive setting at Dagstuhl made it possible, that a selection of ideas presented at this seminar as well as scientific results of this gathering are made available as Proceedings.

Visualization of Petascale Data: Data-Intensive Computing on Numerically-Intensive Supercomputers

James Ahrens (Los Alamos National Lab., US)

With the advent of the era of petascale supercomputing, via the delivery of the Roadrunner supercomputing platform at Los Alamos National Laboratory, there is a pressing need to address the problem of visualizing massive petascale-sized results. In this presentation, I discuss progress on a number of approaches including in-situ analysis, multi-resolution out-of-core streaming and interactive rendering on the supercomputing platform. These approaches are placed in context by the emerging area of data-intensive supercomputing.

CakES: Cake Metaphor for Analyzing Safety Issues of Embedded Systems

Yasmin Al-Zokari, Taimur Khan, Daniel Schneider, Dirk Zeckzer, Hans Hagen

It is extremely difficult to analyze safety issues in complex embedded systems. It is even more difficult to relate the results of the safety analysis to the actual parts of these systems. These problems lead to a large amount of time and effort being spent searching through the data to be analyzed (i.e., fault tree data). Until now, there is a lack of sophisticated metaphors that support the efficient analysis of fault trees, basic events, and minimal cutsets and addresses the above mentioned issues. Further, no method is available to combine and link the existing knowledge of the two different domains of "engineering" and "safety analysis" and solve communication problem s between these domains. To overcome this, we take foundations from the different domains and apply visual analytics to them. We present a new metaphor called "CakES" implemented in a visualization system consisting of multiple views visualizing the physical model, the minimal cutsets, and the basic events of the fault tree. Together with sophisticated interaction techniques this allows the user to directly explore the most safety critical parts, without navigating through the whole fault tree and while retaining an overview of all critical aspects in the actual model.

Keywords: Fault trees, minimal cut sets, basic events, information visualization, scientific visualization, engineering , CakES metaphor, tiled-wall, multiple monitor system, color blindness, embedded systems, safety critical systems

A

Jean-Paul Balabanian and Eduard Groeller

This paper describes the concept of A-space. A-space is the space where visualization algorithms reside. Every visualization algorithm is a unique point in A-space.

Integrated visualizations can be interpreted as an interpolation between known algorithms. The void between algorithms can be considered as a visualization opportunity where a new point in A-space can be reconstructed and new integrated visualizations can be created.

Do we need more Perception in Visualization?

Dirk Bartz (Universität Leipzig, DE)

Perception plays a major role in the sensing and hence in the understanding of data. Yet, it's role is still limited in visualization.

In particular, perception research is used to compare visualization methods, or to exploit perceptual, low-level (pre-attentive) effects.

However, I do think that perception should play a significant role early on in the visualization design process to become a perceptual-aware method. While this idea is already pursuit in several visualization publication in the past years, it still has issues like the difficulties of balancing control of the experiment - and hence the ability to discover significant effects - and the relevance of the experiments to visualization.

When we design and later on conduct psychophysical experiments, there are several issues that need to be taken into account. If we use an interview/questionnaire-based paradigm, we are limited to retrospective and introspective information that only reflects what the participant thinks what happened, while task-based experiments are providing objective measures, which, unfortunately, are limited what they can measure, which is typically time performance and correctness.

Also, experiments must be conducted with a sufficiently rigorous design to allow a specific analysis of the answers. In contrast, however, having a too large parameter space, leads to the problem that the experiments become too complex to be conducted practically.

Finally, some high level experiments may require a certain number of participants. If these participants need to be experts in their field, it is often difficult to recruit a sufficient number at one institution.

All these factors have to be carefully considered when designing psychophysical experiment.

Keywords: Perception, psychophysical experiments, experiment design, low level effects

The EyeDome Light: Non-Photorealistic Shading for Interactive Exploration

Georges-Pierre Bonneau (INRIA Rhône-Alpes, FR)

We present the EyeDome Light, an image-based simple and efficient non-photorealistic shading technique inspired by ambient occlusion models.

Shading is performed on the sole basis of projected depth values, regardless of the geometric information, by considering a virtual dome of light centered on the viewer's eye. Computations performed locally and at multiple scales determine the amount of this dome that is visible per pixel. Fully implemented on the GPU, our approach takes advantage of the current graphics hardware to achieve real-time renderings of millions of primitives.

With enhanced edges and halos as a side effect to shading, the Eye- Dome Light is very powerful for interactive exploration of complex 3D scenes, ranging from intricate scientific visualizations and architectural designs to geographical data and technical or cultural artifacts.

Keywords: Shading, GPU, Image-Based, Visualization

Exploring Large Scale Turbulent Combustion

Peer-Timo Bremer (LLNL - Livermore, US)

The advent of highly accurate, large scale simulations has made data analysis and visualization techniques an integral part of the modern scientific process. To develop new insights from raw data, application scientists need the ability to easily define features of interest and to understand how changes in the feature parameters impact the subsequent segmentation of the data. Therefore, simply exploring the raw data is not sufficient. Scientists need the ability to study the feature spaces implied by the data analysis methods used and to reliably understand if and how they may lead to proper feature extraction algorithms.

We present a new topological framework that allows one to explore interactively the complete parameter space of a threshold based segmentation of an entire time-dependent simulation. By pre-computing hierarchical merge trees and their corresponding segmentations we store a complete family of segmentations in a compact yet highly flexible representation. While the resulting data is more than two orders of magnitude smaller than the inital input, it allows the user complete flexibility to segment, select, and track features. Furthermore, we augment the hierarchies with additional attributes, such as feature volume, and enable fast conditional sub-selection. We use this representation to create tracking graphs describing the temporal evolution of features in time and provide a linked view interface to explore the time graph interactively along side the segmentation. The system can be then used to perform extensive data analysis. We demonstrate the effectiveness of our approach using simulations of low-swirl turbulent pre-mixed flames. We show how the topological hierarchies efficiently encode burning cells, the primar y feature of interest in this application, and how our system can provide new insight into the dynamics of the combustion process.

Induced Interpolants for Marching Cases

Hamish Carr (University College - Dublin, IE)

Marching Cubes are generally assumed to approximate a trilinear interpolant. An alternate approach asks what the interpolant induced by the cases is - i.e. for what interpolating function the cases are exact.

We present some early results on the interpolating function induced by Marching Squares & Cubes, with some implications for the extension of the Contour Spectrum to non-simplicial meshes.

Keywords: Isosurfaces, interpolants, Marching Cubes

Interpolants Induced by Marching Cases

Hamish Carr and Eoin Murphy

Visualization depends among other things on the interpolant used in generating images. One way to assess this is to construct case tables for Marching Cubes that represent the chosen interpolant accuracy. Instead, we show how to construct the interpolants induced by Marching Cases for comparison and assessment, how to extend this approach to Marching Squares, Cubes and Hypercubes, and how to construct an interpolant which is computationally equivalent to the digital rules conventionally used in image processing. Furthermore, we demonstrate that unlike tetrahedral meshes, geometric measurements over multi-linear mesh cells are inherently non-linear and cannot be summed as in the Contour Spectrum.

Keywords: Interpolation, Marching Cubes, Isosurfaces

Intergrating Semantics into the Visualization Process

Silvia Castro (Universidad Nacional del Sur - Bahia Blanca, AR)

Most of today's visualization systems give the user a considerable control over the visualization process. Many parameters might be changed until the obtention of a satisfactory visualization. The visualization process is a very complex exploration activity and, even for skilled users, it can be difficult to arrive at an effective visualization.

We propose the construction of a visualization prototype to assist users and designers throughout the stages of the visualization process, and the integration of such process with a reasoning procedure that allows the configuration of the visualization, based on the entailed conclusions.

We are working on a formal representation of the Visualization field.

We aim to establish a common visualization vocabulary, include the underlying semantics, and enable the definition of visualization specifications that can

be executed by a visualization engine with ontological support. An ontological description of a visualization should be enough to specify the visualization and, thus, to generate a runtime environment that be able to bring that visualization to life.

The visualization ontology defines the vocabulary. With the addition of inference rules to the system, we can derive conclusions about visualization properties that allow to enhance the visualization, and guide the user throughout the entire process toward an effective result.

Keywords: Semantic driven visualization, ontology, visualization, knowledge representation

Joint work of: Escarza, Sebastián; Urribarri, Dana; Larrea, MartÃŋn; Castro, Silvia; Martig, Sergio

When Does Graphics become Visualization?

Min Chen (Swansea University, GB)

Visualization has a strong connection with graphics, at least in the 1980s. In this talk, the speaker considers whether visualization has become a discipline on its own by asking the following question:

- What would be a visualization problem, but, definitely, not a computer graphics problem?
- What would be a visualization concept, but, definitely, not a computer graphics concept?
- What would be a visualization system, but, definitely, not a computer graphics system?

Keywords: Knowledge-assisted visualization

Abstractive of Sequential Textual Information

Wei Chen (Zhejiang University, CN)

Recently, sequential document visualization has attracted much attention for its superior capability on depicting the sequential semantic progression in a single document. However, existing methods commonly take abstractive visual forms (texts, numbers and glyphs), and require much user expertise for document exploration. We propose to sequentially visualize a single document as a two-dimensional picture-based representation to semantically enhance the comprehension of textual information. We introduce a new parametric modeling approach called the *hierarchical parametric histogram curve* (*hphc*), which encodes the statistical progression locally and adaptively. The new representation expresses the primary content of a general text with a graphical form, and allows for efficient multi-resolution and focus+context exploration to a long document.

Keywords: Document visualization, Sequential Visualization

Comparative Visualization Using Cross-Mesh Field Evaluations and Derived Quantities

Hank Childs, Sean Ahern, Jeremy Meredith, Mark Miller, and Kenneth I. Joy

We present a data-level comparative visualization system that utilizes two key pieces of technology: (1) cross-mesh field evaluation - algorithms to evaluate a field from one mesh onto another - and (2) a highly flexible system for creating new derived quantities. In contrast to previous comparative visualization efforts, which focused on "A - B" comparisons, our system is able to compare many related simulations in a single analysis. Types of possible novel comparisons include comparisons of ensembles of data generated through parameter studies, or comparisons of time-varying data. All portions of the system have been parallelized and our results are applicable to petascale data sets.

Multiresolution modeling of isosurfaces and interval volumes through isodiamond hierarchies

Leila De Floriani (University of Genova, IT)

Multiresolution tetrahedral models generated through longest edge bisection are among the most flexible representations for regularly sampled 3D scalar fields, since they enable the efficient extraction of highly adaptive field representations. On the other hand, it is important to have multiresolution models of single isosurfaces, or interval volumes, from which adaptive representations of these structures can be extracted more efficiently.

In the talk, we discuss multiresolution models for isosurfaces and interval volumes whose hierarchical structure is inherited from the multiresolution representation of the underlying 3D scalar field. Such models exploit the fact that an isosurface, or an interval volume, typically intersects only a small fraction of the tetrahedra in the hierarchy.

We consider as multiresolution scalar field model a hierarchy of tetrahedral clusters generated by longest edge bisection, that we call a hierarchy of diamonds. We present two multiresolution models for an isosurface or interval volume, which exploit the regular structure of the hierarchy of diamonds, and are defined by subsets of diamonds in the hierarchy enhanced with geometric and topological information for encoding the relation between the isosurface, or interval volume, and the diamond itself. Our results show that both models are much more compact than the representation of the scalar field as a hierarchy of diamonds and than a full-resolution representation of the isosurface, or interval volume.

This work is part of our research on dimension-independent multiresolution modeling of scalar fields based on diamond hierarchies, that we have applied to the representation of large terrains and we are currently applying to time-varying scalar fields.

Joint work with Kenneth Weiss

Keywords: Multi-dimensional scalar fields, multiresolution modeling, nested meshes, isosurfaces, interval volumes

Modeling Multiresolution Scalar Fields through Simplex and Diamond Hierarchies

Leila De Floriani

We review modeling techniques for multiresolution scalar fields based on a discretization of the field domain into nested simplicial meshes generated through simplex bisection. Such meshes are described through hierarchical data structures and their representation is characterized by the modeling primitive used. The primary conceptual distinction among the different approaches proposed in the literature is whether they treat top simplexes or clusters of top simplexes, called diamonds, as the modeling primitive. In this survey, we distinguish between representations that are dimension-specific and those that apply to all dimensions. We first focus on representations for the modeling primitive and for nested meshes. Next, we survey the applications of these meshes to modeling multiresolution scalar fields, with an emphasis on interactive terrain rendering and isosurface extraction. Finally, we discuss directions for further research.

Integral Curves in Block-structured AMR Simulations

Eduard Deines (University of California - Davis, US)

Integral curves, such as streamlines, streaklines, pathlines, and timelines, are an essential tool in the analysis of vector field structures, offering straightforward and intuitive interpretation of visualization results. While such curves have a long-standing tradition in vector field visualization, their application to Adaptive Mesh Refinement (AMR) has unique problems. We propose an approach for integral curve computation in block-structured AMR data sets.

On the Computation of Integral Curves in Adaptive Mesh Refinement Vector Fields

Eduard Deines, Gunther H. Weber, Christoph Garth, Brian Van Straalen, Sergey Borovikov, Daniel F. Martin, and Kenneth I. Joy

Integral curves, such as streamlines, streaklines, pathlines, and timelines, are an essential tool in the analysis of vector field structures, offering straightforward and intuitive interpretation of visualization results. While such curves have a long-standing tradition in vector field visualization, their application to Adaptive Mesh Refinement (AMR) simulation results poses unique problems. AMR is a highly effective discretization method for a variety of physical simulation problems and has recently been applied to the study of vector fields in flow and magnetohydrodynamic applications. The cell-centered nature of AMR data and discontinuities in the vector field representation arising from AMR level boundaries complicate the application of numerical integration methods to compute integral curves. In this paper, we propose a novel approach to alleviate these problems and show its application to streamline visualization in an AMR model of the magnetic field of the solar system as well as to a simulation of two incompressible viscous vortex rings merging.

Keywords: Integration-based visualization, streamlines, interpolation, adaptive mesh refinement

Visual Analytics: We Love Users

David S. Ebert (Purdue University, US)

In visual analytics, we use a user-centered approach to creating interactive visual discovery, hypothesis testing, and decision making environments. For these environments to be successful, they must be tailored to the user and their task. My presentation describes key factors to the success of this user tailoring as well as essential elements and research challenges for visual analytics.

Keywords: Visual analytics, user-centered design, visualization

KAV-DB: Towards a Framework for the Capture and Retrieval of Visualization Knowledge over the Web

Supriya Garg, Julia EunJu Nam, Kshitij Padalkar, Klaus Mueller, Ming-Yuen Chan, Huamin Qu, Sören Laue, Waqar Saleem, Joachim Giesen

Digital images have become a ubiquitous medium for information communication across a broad range of application domains. Along with this ubiquity has come an immense growth in the capabilities of the devices and tools used to produce and edit this imagery. New advances in algorithms and methods are made at a large pace, which makes staying on top of the learning curve difficult for general users and even experts. To accommodate this need, commercial devices and software packages typically provide a suite of presets and shortcuts for common tasks with intuitive descriptors, determined by extensive internal user studies and expert interaction but often without publishing the actual parameters and their settings. We describe an emerging framework which strives to externalize these practices into a centralized web-based community effort called KAV-DB (Knowledge-Assisted Visualization Data Bank), to allow coverage of algorithms and applications not currently driven by immediate commercial focus but of wide interest to the community of visualization researchers. The vision of KAV-DB is to provide a web service to capture, analyze, and retrieve parameter settings for visualization algorithms, given the data at hand. KAV-DB builds on a robust user study evaluation theory, called conjoint analysis, to formulate statistical models of method parameters extracted by ways of efficient user studies. We demonstrate the assessment and analysis stage our framework via two diverse example applications: relation-aware volume exploration and text annotation of color images.

Time + Streak Surfaces - Computation, Representation, Visualization

Christoph Garth (University of California - Davis, US)

We briefly discuss some recent work on time and streak surfaces for the visualization of time-varying vector fields. We introduce a novel discretization scheme for time and streak surfaces that allows a de-coupling of surface adaptation from pathline computation, allowing us to leverage the massive parallelism inherent in the latter. The surface adaptation scheme we choose gives rise to a compact representation of the surface evolution over time that allows full interaction with the temporal evolution of the surface after potentially lengthy computation. Finally, we show examples and discuss some visualization aspects of time and streak surfaces.

Scientific Visualization and Virtual Reality at DLR

Andreas Gerndt (German Aerospace Center - Braunschweig, DE)

The German Aerospace Center (DLR) consists of 29 research institutes and facilities at 13 locations in Germany. DLR's mission is not only the exploration of the earth and the solar system but also the research for protecting the environment and for promoting mobility, communication, and security. One of the topics of the DLR institute of simulation and software technology is the research of innovative methods for interactive exploration of large-scale datasets distributed to DLR's locations. It primarily aims at aerodynamic simulations and geology data exploration. Data parallelization, advanced data management, data streaming and multi-resolution approaches are some of the key features the DLR is work on to bring such datasets in interactive virtual environments for intuitive data exploration.

Keywords: Large-scale datasets, distributed data processing, parallelization, data management, data streaming, multi-resolution, virtual reality

A

Eduard Groeller (TU Wien, AT)

Illustrative Visualization generates computer supported interactive and expressive visualizations through abstractions as in traditional illustrations. Blending of different styles like line drawings and filled elements is one approach in illustrative visualization which combines quite heterogeneous algorithms. This raises the issue of generalizing this concept of "algorithm integration". Algorithm space A is presented where each algorithm is given as a point location. Starting from well known algorithms like direct volume rendering, maximum intensity projection, curved planar reformation, slicing, scatter plots, graph drawings, aso., example algorithms in between these scattered algorithm points are presented. More general questions concerning A are mentioned: dimensionality of A, is A a metric space, what is the gradient of a specific algorithm, what might be iso-algorithms, which subspaces of A might be of interest. In general algorithm space A may provide inspirations to extend data and image fusion to algorithm fusion, with going from linked views to integrated or combined views.

X

Charles Hansen (University of Utah, US)

Breakthroughs of scientific visualization

Levels of Interactive Visual Analysis

Helwig Hauser (University of Bergen, NO)

Interactive visual data exploration and analysis is a powerful methodology for enabling insight into complex and potentially also large data. In this talk we discuss different levels of this methodology (starting from the first level of "show & brush", and continuing via "relational analysis" to "complex analysis"). The hypothesis is made that it is useful to have different levels (in the sense of levels of complexity) for interactive visual analysis: a large share of all addressed problems can be sufficiently solved with the "simple" level of "show & brush", while the more complex levels (of "relational analysis" and "complex analysis") are useful for more specific cases.

Keywords: Interactive visual analysis

Features in uncertain data

Hans-Christian Hege (ZIB - Berlin, DE)

Almost all scientific data is affected by uncertainty. Error estimation is ubiquitous in science, and drawing conclusions from uncertain data is the normal case, not the exception. This motivates to strive for effective visualization techniques that display uncertain data. While the field of statistical graphics is well established, only a few 2D and 3D visualization methods have been developed that consider uncertainty in a satisfying way.

For complex and large data typically not just the raw data are displayed, but specific features, e.g., of topological or geometrical character. One important yet mainly unaddressed research issue is how to deal with such features in the case of uncertain data. The need for error analysis for a given feature can be read off from the condition number for computing it.

Among the various frameworks for representing and dealing with uncertain data we choose standard probability theory and statistics. The first question is, how to define uncertain or 'fuzzy' counterparts to crisp features. This is exemplified for a very basic feature: iso-surfaces in scalar fields. The potentially diverging condition number of the iso surface problem shows the need for this. The discretized scalar field is modeled as a random field. For visualization, however, some continuous representation is necessary. Level sets in parameter-continuous random fields are discussed and are shown to be rather pathologic. Furthermore, in many cases the auto-covariance structure of the random field is unknown. Modeling noise-affected deterministic and smooth phenomena on base of interpolated probability density functions therefore seems more appropriate. It is shown how for that case continuous feature densities can be defined that match our intuitive conception of a fuzzy iso-contour.

Example visualizations of fuzzy iso-contours in 2D and 3D are shown for data from medicine and climate research.

Keywords: Uncertain data, visualization, iso-contours

Joint work of: Hege, Hans-Christian; Pöthkow, Kai

Feature extraction from point-based data

Martin Hering-Bertram (Fraunhofer ITWM - Kaiserslautern, DE)

We present two novel approaches to the visualization of gridless point-based data sets. The first method extracts stream surfaces from simulation data modeling a mixing process, based on the finite pointset method (fpm).

We highlight the benefits and limitations of topological feature extraction for the analysis of mixing processes, also considering the non-stationary setting.

The second approach is concerned with the visualization of large-scale point clouds obtained from light detection and ranging (LiDaR) data, providing a classification of local features and extraction of curve and surface shapes complementing the visualization of raw point sets.

Simulation and Visualization of Medical Application to the Inner Ear of the Guinea Pig to Reduce Animal Experiments

Martin Hering-Bertram, Norbert Siedow, Oliver Tse, Stefan K. Plontke, Ruth Gill, and Alec N. Salt

We present a novel approach to simulate drug application to the inner ear of the guinea pig with the goal to reduce animal experiments and to increase the accuracy of measurements. The framework is based on a tetrahedral grid representing the individual compartments of the cochlea, associated with a finite element model used to simulate medical diffusion and clearance. In a first simulation scenario, we were able to compute transfer coefficients between the inner compartments of the ear, validating experiments from the literature, and to prove the existence of clearance at the inner scala tympani. In a second scenario, the cochlea was unwound to obtain a one-dimensional model for efficient simulation-based transfer coefficient identification. These coefficients are useful to predict the impact of novel medication application systems.

Keywords: Cochlea, Perilymph, Spiral Ligament, Round Window Application, Modiolar Communication Routes, Numerical Simulation, Parameter Identification

Hotz, Ingrid; Jan Reininghaus

Ingrid Hotz (ZIB - Berlin, DE)

In this talk a combinatorial approach to vector field topology is presented. The theoretical basis is given by Robin Forman's work on a combinatorial Morse theory for dynamical systems defined on general simplicial complexes. Forman's theory is formulated in a graph theoretic setting. A simple algorithm to compute a combinatorial vector field hierarchy is provided.

On base of this hierarchy it is possible to extract the topological skeletons and explore the vector field on multiple scales.

Due to the solid theoretical foundation we know that the resulting structure is always topologically consistent.

Keywords: Vector Field Topology, Combinatorial Methods, Simplification

Joint work of: Hotz, Ingrid; Jan Reininghaus

2D Tensor Field Segmentation

Ingrid Hotz (ZIB - Berlin, DE)

We present a topology-based segmentation as means for visualizing 2D symmetric tensor fields.

The segmentation uses directional as well as eigenvalue characteristics of the underlying field to delineate cells of similar (or dissimilar) behavior in the tensor field. A special feature of the resulting cells is that their shape expresses the tensor behavior inside the cells and thus also can be considered as a kind of glyph representation. This allows a qualitative comprehension of important structures of the field.

The resulting higher-level abstraction of the field provides valuable analysis. The extraction of the integral topological skeleton using both major and minor eigenvector fields serves as a structural pre-segmentation and renders all directional structures in the field. The resulting curvilinear cells are bounded by tensorlines and already delineate regions of equivalent eigenvector behavior. This pre-segmentation is further adaptively refined to achieve a segmentation reflecting regions of similar eigenvalue and eigenvector characteristics. Cell refinement involves both subdivision and merging of cells achieving a predetermined resolution, accuracy and uniformity of the segmentation. The buildingblocks of the approach can be intuitively customized to meet the demands or different applications. Application to tensor fields from numerical stress simulations demonstrates the effectiveness of our method.

Keywords: Tensor field visualization, Segmentation, Topology

Joint work of: Auer, Cornelia; Sreevalsan-Nair, Jaya; Zobel, Valentin; Hotz, Ingrid

Steady Visualization of Unsteady Data

Heike Jaenicke (University of Wales - Swansea, GB)

The visualization of unsteady scientific data is still a challenging problem.

Most techniques rely on the animation of individual time-steps. In this paper we propose a steady visualization of the dynamics in fluids using ϵ-machines. ϵ-machines are a concept from computational mechanics and can be thought of as finite state machines that can be visualized as directed graphs. The nodes are the causal states of the process. Given a local past of a position, causal states comprise all the information needed to predict the future of this position. As causal states stem from information theory, it can be shown that they are the most compressed representation of local dynamics that still allows for this prediction. Edges in the graph indicate transition probabilities between causal states in successive time-steps. Hence, the visualization of the ϵ-machine graph provides a concise and highly compressed steady visualization of the system's dynamics that still allows for an in-depth examination. In this presentation we describe the construction and visualization of ϵ-machines and how interaction mechanisms with the physical domain allow for a detailed analysis of data sets describing fluid dynamics.

Information-theoretic Analysis of Unsteady Data

H. Jänicke

The temporal evolution of scientific data is of high relevance in many fields of application. Understanding the dynamics over time is a crucial step in understanding the underlying system. The availability of large scale parallel computers has led to a finer and finer resolution of simulation data, which makes it difficult to detect all relevant changes of the system by watching a video or a set of snapshots. In recent years, algorithms for the automatic detection of coherent temporal structures have been developed that allow for an identification of interesting areas and time steps in unsteady data. With such techniques, the user can be guided to interesting subsets of the data or a video can be automatically created that does not occlude relevant aspects of the simulation. In this paper, we give an overview over the different techniques, show how their combination helps to gain deeper insight and look at different directions for further improvement. Two CFD simulations are used to illustrate the different techniques.

Interactive Rendering of Functional Representation in Quantum Chemistry

Yun Jang (ETH Zürich, CH)

In this work, we study the volumetric representations of the results from quantum chemistry computations, and evaluate and visualize the representations directly on the GPU without resampling the result in grid structures. Our visualization tool handles the direct evaluation of the approximated wavefunctions described as a combination of Gaussian-like primitive basis functions. For visualizations, we use a volume rendering technique with a 2D transfer function, volume clipping, and illustrative rendering in order to reveal and enhance the quantum chemistry structure. Since there is no need of resampling volume from the functional representations, two issues, data transfer and resampling resolution, can be ignored, therefore, it is possible to interactively explore large amount of different information in the computation results.

Keywords: Quantum Chemistry Visualization

X

Ken Joy (University of California - Davis, US)

Breakthroughs of scientific visualization

When does Visualization become Visual Analytics? - On the open question on how SciVis & InfoVis are related to Visual Analytics

Daniel A. Keim (Universität Konstanz, DE)

In many presentations and discussions the question has come up whether and how Visual Analytics is different from Scientific Visualization and Information Visualization. Inspired by the presentation "When does Graphics become Visualization?" by Min Chen and the fruitful discussion after the talk, I will present a number of questions about the relationship between Visualization and Visual Analytics such as "Are there visual analytics problems/concepts/systems, that are definitely not visualization problems/concepts/systems?"*. The goal of the talk is to steer the discussion on the relationship of the two disciplines and present thoughts on how to make real visual analytics happen.

(* questions adapted from the presentation by Min Chen)

Keywords: Visual Analytics, Information Visualization, Scientific Visualization

Construction of Implicit Surfaces from Point Clouds Using a Feature-based Approach

Patric Keller, Oliver Kreylos, Eric S. Cowgill, Louise H. Kellogg, Martin Hering-Bertram, Bernd Hamann, and Hans Hagen

We present a novel feature-based approach to surface generation from point clouds in three-dimensional space obtained by terrestrial and airborne laser scanning. In a first step, we apply a multiscale clustering and classification of local point set neighborhoods by considering their geometric shape. Corresponding feature values quantify the similarity to curve-like, surface-like, and solid-like shapes. For selecting and extracting surface features, we build a hierarchical trivariate B-spline representation of this surface feature function. Surfaces are extracted with a variant of marching cubes (MC), providing an inner and outer shell that are merged into a single non-manifold surface component at the field's ridges. By adapting the isovalue of the feature function the user may control surface topology and thus adapt the extracted features to the noise level of the underlying point cloud. User control and adaptive approximation make our method robust for noisy and complex point data.

Keywords: 3D Point Clouds, Surface Reconstruction, Implicit Surfaces

Framework for Comprehensive Size and Resolution Utilization of Arbitrary Displays

Taimur Khan, Daniel Schneider, Yasmin Al-Zokari, Dirk Zeckzer, and Hans Hagen

Scalable large high-resolution displays such as tiled displays are imperative for the visualization of large and complex datasets. In recent times, the relatively low costs for setting up large display systems have led to an highly increased usage of such devices. However, it is equally vital to optimally utilize their size and resolution to effectively explore such data through a combination of diverse visualizations, views, and interaction mechanisms. In this paper, we present a lightweight dispatcher framework which facilitates input management, focus management, and the execution of several interrelated yet independent visualizations. The approach is deliberately kept flexible to not only tackle different hardware configurations but also the amount of visualization applications to be implemented. This is demonstrated through a scenario that executes four interrelated visualizations equally well on both a 5 PC tiled-wall and a single desktop. The key contribution of this work is the ability to extend the tiled-wall to work with multiple applications for enhanced size and resolution utilization of such displays.

Salient Frame Detection for Molecular Dynamics Simulations

Youngmin Kim, Robert Patro, Cheuk Yiu Ip, Dianne P. O'Leary, Andriy Anishkin, Sergei Sukharev, and Amitabh Varshney

Recent advances in sophisticated computational techniques have facilitated simulation of incredibly- detailed time-varying trajectories and in the process have generated vast quantities of simulation data. The current tools to analyze and comprehend large-scale time-varying data, however, lag far behind our ability to produce such simulation data. Saliency-based analysis can be applied to time-varying 3D datasets for the purpose of summarization, abstraction, and motion analysis. As the sizes of time-varying datasets continue to grow, it becomes more and more difficult to comprehend vast amounts of data and information in a short period of time. In this paper, we use eigenanalysis to generate orthogonal basis functions over sliding windows to characterize regions of unusual deviations and significant trends. Our results show that motion subspaces provide an effective technique for summarization of large molecular dynamics trajectories.

Symmetry and Continuity in Visualization and Tensor Glyph Design

Gordon Kindlmann (University of Chicago, US)

The mathematical concepts of symmetry and continuity should in principle play a concrete role in the design and evaluation of scientific visualization, since they provide useful rules of thumb for visualization design. The meaning of the visualization should be invariant with respect to transforms that leave the underlying data essentially unchanged (symmetry), and the visualization should probably not change abruptly with small changes in the underlying data (continuity). Giving precise mathematical definitions to symmetry and continuity in visualization requires semantic difference measures on the visualization, which can be hard to define in a useful way. More specifically, symmetry and continuity can be used to constrain the design of glyphs for symmetric tensors with both positive and negative eigenvalues, which seems to be an unsolved problem in scientific visualization. Worksheets will be provided to allow participants to sketch out glyph shapes that meet the symmetry and continuity constraints, possibly resulting in a collaborative solution to tensor glyph design.

Mathematical Invariants for Visual Representation

Gordon Kindlmann (University of Chicago, US)

Documents associated with "Mathematical Invariants for Visual Representation" working group

Keywords: Mathematical Invariants for Visual Representation

Verifiable Visualization

Robert M. Kirby (University of Utah, US)

Visualization is often employed as part of the simulation science pipeline. It is the window through which scientists examine their data for deriving new science, and the lens used to view modeling and discretization interactions within their simulations. We advocate that as a component of the simulation science pipeline, visualization itself must be explicitly considered as part of the Validation and Verification (V&V) process. In this talk, we define V&V in the context of computational science, discuss the role of V&V in the scientific process, and present arguments for the need for verifiable visualization. As a concrete example of a verifiable visualization effort, we present techniques to assess the behavior of isosurface extraction codes. Where applicable, these techniques allow us to distinguish whether anomalies in isosurface features can be attributed to the underlying physical process or to artifacts from the extraction process. More concretely, we derive formulas for the expected order of accuracy (or convergence rate) of several isosurface features, and compare them to experimentally observed results in the selected codes. This technique is practical: in two cases, it exposed actual problems in implementations. We provide a range of responses that the practitioner can expect to encounter with isosurface techniques, both under "normal operating conditions" and also under adverse conditions. Armed with this information - the results of the verification process - practitioners can judiciously select the isosurface extraction technique appropriate for their problem of interest, and have confidence in its behavior.

3D Reconstruction of Human Ribcage and Lungs and Improved Visualization of Lung X-ray Images Through Removal of the Ribcage

Christopher Koehler, Thomas Wischgoll

The analysis of X-ray imagery is the standard pre-screening approach for lung cancer. Unlike CT-scans, X-ray images only provide a 2D projection of the patient's body. As a result occlusions, i.e. some body parts covering other areas of the body within this projected X-ray image, can make the analysis more difficult. For example, the ribs, a predominant feature within the X-ray image, can cover up cancerous nodules, making it difficult for the Computer Aided Diagnostic (CAD) systems or even a doctor to detect such nodules. Hence, this paper describes a methodology for reconstructing a patient-specific 3D model of the ribs and lungs based on a set of lateral and PA X-ray images, which allows the system to calculate simulated X-ray images of just the ribs. The simulated X-ray images can then be subtracted from the original PA X-ray image, resulting in an image where most of the cross hatching pattern caused by the ribs is removed to improve on automated diagnostic processes.

SmoothViz

Lars Linsen (Jacobs University - Bremen, DE)

Smoothed Particles Hydrodynamics Simulations are Lagrangian, meshfree schemes that have gained increasing popularity for modeling physical phenomena. Its main strength is it high adaptivity, which imposes a challenge to visualization, as it impedes interpolation over a structured grid. We present visualization methods that operate directly on the unstructured, point-based volume data. Our approach addresses individual magnitudes as well as the entire multifield data set. For single scalar magnitudes, we present the direct extraction of isosurfaces in point cloud surface representation, a level-set approach to obtain smooth segmenting surfaces, and point-based rendering of the extracted surfaces. For the entire multifield data, we present a multidimensional feature space clustering, interactive cluster exploration, and linked views to the imposed object-space segmentation using enclosing surfaces.

Keywords: Isosurfaces, level sets, point-based visualization, multifield data visualization

Variational Level-Set Detection of Local Isosurfaces from Unstructured Point-based Volume Data

Lars Linsen, Vladimir Molchanov, and Paul Rosenthal

A standard approach for visualizing scalar volume data is the extraction of isosurfaces. The most efficient methods for surface extraction operate on regular grids. When data is given on unstructured point-based samples, regularization can be applied but may introduce interpolation errors. We propose a method for smooth isosurface visualization that operates directly on unstructured point-based volume data avoiding any resampling. We derive a variational formulation for smooth local isosurface extraction using an implicit surface representation in form of a level-set approach, deploying Moving Least Squares (MLS) approximation, and operating on a kd-tree. The locality of our approach has two aspects: first, our algorithm extracts only those components of the isosurface, which intersect a subdomain of interest; second, the action of the main term in the governing equation is concentrated near the current isosurface position. Both aspects reduce the computation times per level-set iteration. As for most level-set methods a reinitialization procedure is needed, but we also consider a modified algorithm where this step is eliminated. The final isosurface is extracted in form of a point cloud representation. We present a novel point completion scheme that allows us to handle highly adaptive point sample distributions. Subsequently, splat-based or mere (shaded) point rendering is applied. We apply our method to several synthetic and real-world data sets to demonstrate its validity and efficiency.

Keywords: Level-set, isosurface extraction, visualization in astrophysics, particle simulations

Of Mice and Men - Visualization for Biology and Biologists :)

Raghu Machiraju (Ohio State University, US)

In this talk, I will describe inter-disciplinary work that my graduate research colleagues and I have been conducting with biologist and scientists over the last few years. I will focus mostly on the computational and algorithmic challenges required to capture the full architectural details of the micro environment of tumors in complex mammalian organisms. The ultimate goal is to be able to demonstrate phenotypical differences through a variety of algorithms. Some of the challenges arise from the difficulty of imaging thick tissue sections with optical microscopes, other arise from the ill-posed nature of the problem. The presentation will describe the reconstruction of structures at the cellular scale in the mammalian breast tissue. Additionally, I will also describe some of the cultural and logistical issues I faced during the course of this work.

Keywords: Systems biology, imaging, reconstruction,micro-structure characterization, microenvironment

Abstract Feature Space Representation for Volumetric Transfer Function Exploration

Ross Maciejewski, Yun Jang, David S. Ebert, and Kelly P. Gaither

The application of n-dimensional transfer functions for feature segmentation has become increasingly popular in volume rendering. Recent work has focused on the utilization of higher order dimensional transfer functions incorporating spatial dimensions (x, y, and z) along with traditional feature space dimensions (value and value gradient). However, as the dimensionality increases, it becomes exceedingly difficult to abstract the transfer function into an intuitive and interactive workspace. In this work we focus on populating the traditional two-dimensional histogram with a set of derived metrics from the spatial (x, y and z) and feature space (value, value gradient, etc.) domain to create a set of abstract feature space transfer function domains. Current two-dimensional transfer function widgets typically consist of a two-dimensional histogram where each entry in the histogram represents the number of voxels that maps to that entry. In the case of an abstract transfer function design, the amount of spatial variance at that histogram coordinate is mapped instead, thereby relating additional information about the data abstraction in the projected space. Finally, a non-parametric kernel density estimation approach for feature space clustering is applied in the abstracted space, and the resultant transfer functions are discussed with respect to the space abstraction.

Structuring Feature Space for Transfer Function Design

Ross Maciejewski (Purdue University, US)

The use of multi-dimensional transfer functions for direct volume rendering has been shown to be an effective means of extracting materials and their boundaries for both scalar and multivariate data. The most common multi-dimensional transfer function consists of a two-dimensional (2D) histogram with axes representing a subset of the feature space (e.g., value vs. value gradient magnitude), with each entry in the 2D histogram being the number of voxels at a given feature space pair. Users then assign color and opacity to the voxel distributions within the given feature space through the use of interactive widgets (e.g., box, circular, triangular selection). Unfortunately, such tools lead users through a trial-and-error approach as they assess which data values within the feature space map to a given area of interest within the volumetric space. In this work, we propose the addition of non-parametric clustering within the transfer function feature space in order to extract patterns and guide transfer function generation.

We apply a non-parametric kernel density estimation to group voxels of similar features within the 2D histogram. These groups are then binned and colored based on their estimated density, and the user may interactively grow and shrink the binned regions to explore feature boundaries and extract regions of interest. We also extend this scheme to temporal volumetric data in which time steps of 2D histograms are composited into a histogram volume. A three-dimensional (3D) density estimation is then applied, and users can explore regions within the feature space across time without adjusting the transfer function at each time step. Our work enables users to effectively explore the structures found within a feature space of the volume and provide a context in which the user can understand how these structures relate to their volumetric data. We provide tools for enhanced exploration and manipulation of the transfer function, and we show that the initial transfer function generation serves as a reasonable base for volumetric rendering, reducing the trial-and-error overhead typically found in transfer function design.

Keywords: Transfer functions, kernel density estimation, volume rendering

Large-scale Volume Rendering on a 200 Megapixel Tiled Display

Joerg Meyer (Univ. California - Irvine, US)

3D Volume Rendering on GPUs uses the 3D texture memory of the graphics card to store volumetric data sets. The GPU takes care of compositing using its alpha blending capabilities. Current graphics cards come with a few gigabytes of video RAM, which is an improvement over video cards that were available about five years ago. However, if a volume data sets doubles in resolution in x, y, and z, eight times more texture memory is needed to render a volumetric data set. Video RAM has become the main limitation in high-resolution volume rendering.

We have developed a distributed version of a volume renderer, which is capable of rendering 800 megavoxel data sets on a 200 megapixel tiled display wall. The display wall, which measures 23 x 9 feet, consists of 10 x 5 LC flat panels (30" Apple Cinema). Each rendering node accesses a data structure based on octree space subdivision and a hierarchical wavelet storage scheme, clips the volume according to the viewing frustum, and then displays a segment of the volume at dynamically increasing levels of detail in near real-time. The system is controlled by a head node, which displays a preview image of the data set.

The system, which also features volume illumination and multi-dimensional transfer functions, is currently used primarily for medical applications, but can also be used in other areas.

Keywords: Large-scale volume rendering, tiled displays

Joint work of: Meyer, Joerg; Thelen, Sebastian

KAV-DB: Web-based Capture of Visualization Knowledge

Klaus Mueller (SUNY - Stony Brook, US)

The ever-growing arsenal of methods and parameters available for data visualization can be daunting to the casual user and even to domain experts. Furthermore, comprehensive expertise is often not available in a centralized venue, but distributed over sub-communities. As a means to overcome this inherent problem, efforts have begun to store visualization expertise directly with the visualization method and possibly the dataset, to then be utilized for user guidance in the data visualization, suggesting to the user both the visualization method and its best parameters for the data and task at hand. While this is certainly an immensely useful and promising development, one requirement remains - the matching of a newly acquired dataset with the appropriate segment of the library storing the expert knowledge. This requires one to detect and recognize the dataset's category at some level of granularity and then use this information as a library index.

We describe a possible framework for accomplishing the both stages of this process. The first stage [1] is comprised of a data categorization, using data classification via a rich set of feature vectors sufficiently sensitive to detect critical variations. We demonstrate the utility of our framework by ways of a set of medical and computational datasets and visualize the resulting categorization as a layout in 2D. At thi s stage we have built our models only by ways of k-means clustering to determine descriptive feature groupings based on similarity. This worked already quite well. We demonstrated the capabilities for a variety of scenes of sampled objects and phenomena, consisting of medical and flow data. However, we believe that a richer set of object dichotomies could be obtained by introducing probabilistic techniques, such as EM, into the framework, to discover more specific objects in the data.

The second stage [2] is a framework that strives to externalize these practices into a centralized web-based community effort called KAV-DB (Knowledge-Assisted Visualization Data Bank), to allow coverage of algorithms and applications not currently driven by immediate commercial focus but of wide interest to the community of visualization researchers. The goal of KAV-DB is to advise users on the best settings for their algorithm parameters, given the data at hand. KAV-DB builds on a robust user study evaluation theory, called conjoint analysis, to formulate statistical models of method parameters extracted by ways of efficient user studies.

References:
[1] J. Nam, M. Maurer, K. Mueller, "A High-Dimensional Feature Clustering Approach to Support Knowledge-Assisted Visualization", (in press), Computers & Graphics, 2009.
[2] S. Garg, K. Padalkar, K. Mueller, S. Laue, W. Saleem, J. Giesen, M. Chan, H. Qu, "KAV-DB: Towards a Web-Based Framework for Acquiring and For-

matting Visualization Knowledge", (in revision), IEEE Computer Graphics & Applications, 2010.

Biology is Destiny: Of Graphs and Genes

Tamara Munzner (University of British Columbia - Vancouver, CA)

For many biologists who explore networks of interacting proteins and genes, the topological structure of these node-link graphs is only one part of the story. Cerebral supports graph layout in a style inspired by hand-drawn pathway diagrams, where location of the proteins within the cell constrains the location within the drawing, and functional groups of proteins are visually apparent as clusters. We support exploration of expression data using linked views, to show these multiple attributes at each node in the graph.

Joint work with Aaron Barsky, Jennifer Gardy, and Robert Kincaid.

Full Paper:
http://www.cs.ubc.ca/labs/imager/tr/2008/cerebral/

Reflections on QuestVis: A Visualization System for an Environmental Sustainability Model

Tamara Munzner, Aaron Barsky, and Matt Williams

We present lessons learned from the iterative design of QuestVis, a visualization interface for the QUEST environmental sustainability model. The QUEST model predicts the effects of policy choices in the present using scenarios of future outcomes that consist of several hundred indicators. QuestVis treats this information as a high-dimensional dataset, and shows the relationship between input choices and output indicators using linked views and a compact multilevel browser for indicator values. A first prototype also featured an overview of the space of all possible scenarios based on dimensionality reduction, but this representation was deemed to be be inappropriate for a target audience of people unfamiliar with data analysis. A second prototype with a considerably simplified and streamlined interface was created that supported comparison between multiple scenarios using a flexible approach to aggregation. However, QuestVis was not deployed because of a mismatch between the design goals of the project and the true needs of the target user community, who did not need to carry out detailed analysis of the high-dimensional dataset. We discuss this breakdown in the context of a nested model for visualization design and evaluation.

Keywords: High-dimensional visualization, dimensionality reduction, linked views, simulation visualization, design study

Visualization Process and Collaboration

Tamara Munzner (University of British Columbia - Vancouver, CA)

Some of my work is technique-driven, but a lot is problem-driven across many application domains. I will present a few highlights from a previous talk about the collaboration process, and expand on one case where things went wrong. My thinking about how things can go wrong led to a model of visualization that gives guidance on how to validate different stages of design decisions.

Jacobi Sets

Vijay Natarajan (Indian Inst. of Science - Bangalore, IN)

The Jacobi set extends the notion of critical points to multiple functions and helps describe the relationship between multiple scalar functions. The Jacobi set of two Morse functions defined on a common manifold-domain is the collection of points where the gradients of the two functions align with each other. Similar to the successful use of topological structures like Reeb graphs and Morse-Smale complexes for scalar data visualization, we believe that Jacobi set could play an important role in multi-field and time-varying data visualization. Jacobi sets have been used for applications like tracking features in molecular interactions and combustion simulation, silhouette extraction, and cross parametrization. However, current applications are limited because of the lack of robust methods for computing the Jacobi set for piecewise linear functions. Moreover, the Jacobi set, in this case, may contain several components indicative of noisy or a feature-rich dataset. We describe an algorithm to compute and simply Jacobi sets in a robust manner. Our approach involves a reformulation of the simplification step as an offset contour computation.

This is joint work with Suthambhara (IISc Bangalore).

Keywords: Multifield analysis, topology simplification, time-varying data

Generation of Adaptive Streak Surfaces Using Moving Least Squares

Harald Obermaier, Martin Hering-Bertram, Jörg Kuhnert, and Hans Hagen

We introduce a novel method for the generation of fully adaptive streak surfaces in time-varying flow fields based on particle advection and adaptive mesh refinement. Moving least squares approximation plays an important role in multiple stages of the proposed algorithm, which adaptively refines the surface based on curvature approximation and circumradius properties of the underlying Delaunay mesh. We utilize the grid-less Moving Least Squares approximation method for both curvature and surface estimation as well as vector field evaluation during particle advection. Delaunay properties of the surface triangulation are guaranteed by edge flipping operations on the progressive surface mesh. The results of this work illustrate the benefit of adaptivity techniques to streak surface generation and provide the means for a qualitative analysis of the presented approach.

Keywords: Scattered, flow, streak surface, adaptivity, moving least squares

Interactive Isocontouring of High-Order Surfaces

Christian Pagot, Joachim Vollrath, Filip Sadlo, Daniel Weiskopf, Thomas Ertl, and João L. D. Comba

Scientists and engineers are making increasingly use of hp-adaptive discretization methods to compute simulations. While techniques for isocontouring the high-order data generated by these methods have started to appear, they typically do not facilitate interactive data exploration. This work presents a novel interactive approach for approximate isocontouring of high-order data. The method is based on a two-phase hybrid rendering algorithm. In the first phase, coarsely seeded particles are guided by the gradient of the field for obtaining an initial sampling of the isosurface in object space. The second phase performs ray casting in the image space neighborhood of the initial samples. Since the neighborhood is small, the initial guesses tend to be close to the isosurface, leading to accelerated root finding and thus efficient rendering. The object space phase affects the density of the coarse samples on the isosurface, which can lead to holes in the final rendering and overdraw. Thus, we also propose a heuristic, based on dynamical systems theory, that adapts the neighborhood of the seeds in order to obtain a better coverage of the surface. Results for datasets from computational fluid dynamics are shown and performance measurements for our GPU implementation are given.

Keywords: High-order finite elements, isosurface visualization, GPU

Recent developments in stream surface based flow visualization

Ronald Peikert (ETH Zürich, CH)

Stream surfaces and their time-dependent variations have recently obtained new attention, especially to their algorithmic aspects. Topological considerations, in particular the controlled handling of singularities of the vector field, are typically not done. We believe, however, that combining the two lines of research not only enables the selection of more meaningful stream surfaces, but also makes their extraction more robust. We propose a novel scheme for constructing seed curves and integrating stream surfaces with these consideration staken into account.

Y and Zzzz

Hanspeter Pfister (Harvard University, US)

Statistics of the Vis 2009 papers review process. And suggestions for the Vis 2010 papers review process.

Keywords: Vis 2009

Joint work of: Pfister, Hanspeter; Moeller, Torsten

HCI aspects in computer-assisted surgery

Bernhard Preim (Universität Magdeburg, DE)

This talk is based on the hypothesis that the use of visual computing in surgical applications could be strongly enhanced by carefully considering HCI aspects. The talk discusses recent progress in input devices for controllling intraoperative visualization, user interface issues for surgical planning and training. I will argue that a wider range of input devices should be taken in consideration for medical image analysis and visualization, such as virtual endoscopy or exploration of vascular structures.

Keywords: Medical Visualization, user interfaces, input devices

HCI in Medical Visualization

Bernhard Preim

Research in medical visualization lead to a remarkable collection of algorithms for efficiently exploring medical imaging data, such as CT, MRI and DTI. However, widespread use of such algorithms requires careful parameterization, integration of individual algorithms in solutions for real-world problems in diagnosis, treatment planning and intraoperative navigation. In the field of HCI, input devices, interaction techniques as well as a process for achieving usable, useful, and attractive user interfaces are explored. Findings from HCI may serve as a starting point to significantly improve visual computing solutions in medical diagnosis and treatment. We discuss general issues, such as 2D and 3D input devices for medical visualization, and selected examples.

Keywords: Medical visualization, Human Computer Interaction, Input devices, Scenarios

Intuitive Direct Volume Rendering

Huamin Qu (The Hong Kong Univ. of Science & Technology, CN)

Despite the powerful capability of direct volume rendering for exploring volume data, its inherent complexity of specifying rendering parameters and multi-layer transparency make volume rendering hard to use. In this talk, I will present four methods for improving the intuitiveness of direct volume rendering and facilitatig its wider adoption in practice.
1) An editing framework for direct volume rendered images, allowing users to interactively explore complex volumetric datasets by directly editing direct volume rendered images.
2) Two image quality enhancement approaches to ensure that the features in the volume are faithfully presented in the rendered images and correct perception of the volumes is obtained by viewers.
3) A relation-aware visualization pipeline for the extraction, representation, exploration, and visualization of spatial relations in volumetric data.
4) A set of quantitative effectiveness measures to evaluate the effectiveness of a direct volume rendered image or a whole visualization process from different perspectives.

Keywords: Volume rendering; editing; relation; metrics; perception

Visualizing Alternative Spatial Partitions: Finding Research Inspiration on Municipal TV

Penny Rheingans (University of Maryland Baltimore County, US)

Just as life can imitate art, research can imitate life. A TV broadcast of the local School Board sparked a research project integrating approaches from data visualization and artificial intelligence. The driving application is the design and evaluation of plans for the spatial partitioning of neighborhood into school assignments at three educational levels. Research challenges include identifying effective heuristic search techniques for multi-parameter optimization and designing effective visualizations to show plans, measured outcome criteria, alternatives, and interrelationships. This talk will discuss application goals, technical approaches, some rewards and trials of working on real-world problems, and questions remaining.

Mathematics and Visualization

Gerik Scheuermann (Universität Leipzig, DE)

The author presents some thoughts on the import of mathematical concepts into visualization.

Based on a rough look over all mathematical areas, some comments are given on mathematical fields used by visualization and fields rarely used. It has to be noted that the talk is not intented as a complete survey but rather as a start to think about this.

The idea is that there may be mathematical fields related to some questions in visualization that are not used but might be helpful. In addition, the talk intends to let the audience debate about the part of mathematics needed in various areas of visualization.

A Maximum-Enhancing Glyph for Higher-Order Tensors

Thomas Schultz (MPI für Informatik - Saarbrücken, DE)

Generalized Reynolds glyphs are a standard tool to visualize the homogeneous forms of higher-order tensors, but they make it difficult to see the exact locations of maxima. As part of a previous talk, we have presented a higher-order tensor glyph that depicts maxima more clearly and equals the tensor ellipsoid in the second-order case.

This talk presents a number of novel theoretical and practical results on that glyph. Theoretically, we prove a number of properties that ensure that the glyph faithfully reproduces extrema and develops sharp features around the maxima. Moreover, we clarify the relation of our glyph to the algebraic surfaces derived from higher-order tensors in a paper by L. Qi. Practically, we propose a novel coloring scheme, show results in 3D, and demonstrate an efficient implementation that allows for interactive exploration of data from High Angular Resolution Diffusion Imaging (HARDI) using our glyph.

Keywords: Homogeneous form; HARDI; tensor inverse; tensor decomposition

Feature Extraction for DW-MRI Visualization: The State of the Art and Beyond

Thomas Schultz

By measuring the anisotropic self-diffusion rates of water, Diffusion Weighted Magnetic Resonance Imaging (DW-MRI) provides a unique noninvasive probe of fibrous tissue. In particular, it has been explored widely for imaging nerve fiber tracts in the human brain. Geometric features provide a quick visual overview of the complex datasets that arise from DW-MRI. At the same time, they build a bridge towards quantitative analysis, by extracting explicit representations of structures in the data that are relevant to specific research questions. Therefore, features in DW- MRI data are an active research topic not only within scientific visualization, but have received considerable interest from the medical image analysis, neuroimaging, and computer vision communities. It is the goal of this paper to survey contributions from all these fields, concentrating on streamline clustering, edge detection and segmentation, topological methods, and extraction of anisotropy creases. We point out interrelations between these topics and make suggestions for future research.

Keywords: Diffusion-Weighted MRI, dMRI, DT-MRI, DTI, HARDI, Streamline Clustering, Edge Detection, DW-MRI Segmentation, Tensor Topology, Crease Surfaces

Analyzing Time-Varying Data Sets with Lagrangian and Eulerian Views

Han-Wei Shen (Ohio State University, US)

In fluid mechanics two ways can be used to describe the behavior of a flow field. One is the Lagrangian method which describes the time rate of change in the flow properties along the traces of identifiable flow parcels. The other is the Eulerian method which observes the properties of flow at a fixed position over time. In this talk, I will discuss the analogies of Lagrangian and Eulerian methods in visualization of time-varying scalar data. I will briefly overview some traditional visualization methods for time-varying data, which I will argue are mostly Lagrangian. Then I will describe our recent research in analyzing time-varying scientific data with Eulerian approaches. The new approaches allow us to obtain more accurate spatio-temporal information about the features in time-varying data sets. I will discuss the essential components of our analysis environment including multiscale data representations, distance metrics and classification schemes, and a method for multivariate data visualization. Our goal is to complement the existing visualization techniques, and provide the scientists with better quantitative data analysis tools.

Applying Manifold Learning Techniques to Visualizing Spatiotemporal Complexities

Shigeo Takahashi (University of Tokyo, JP)

Manifold learning techniques provide nonlinear mappings for dimensionality reduction when the given samples are asummed to lie on a low-dimensional manifold embedded in a high-dimensional space. In this talk, I will describe how the manifold learning techniques can be applied to illuminate the underlying complex spatiotemporal behaviors in various kinds of datasets.

Keywords: Manifold learning, time-varying datasets

Visualizing the past: Visualization in archaeology

Ayellet Tal (Technion - Haifa, IL)

Many of the tasks that are currently performed manually by the archaeologists, can be assisted by developing automatic or interactive visualization techniques.

We will discuss some of the challenges that we have learned from our collaboration with the group of archaeologists who excavate the city of Dor - a vibrant multi-cultural port city, inhabited from the Bronze age until the Roman period. We will then focus on a particular problem - illustration of artifacts and present some results.

Streak Surfaces in Flow Visualization

Holger Theisel (Universität Magdeburg, DE)

Streak surfaces are interesting objects for experimental flow visualization because they describe the advection of external material such as dye or hydrogen bubbles along seeding line structures in the flow. However, up to now streak surfaces are rarely applied in computer-aided visualization because they may change their shape everywhere and at any time of the integration. Because of this, every part of the streak surface has to be monitored at any time of the integration for adaptive refinement/coarsening. This is a fundamental difference to stream and path surfaces which are only constructed at their front line and remain unchanged after the front has passed.

This talk presents approaches to interactively visualize streak surfaces. We introduce smoke surfaces - semitransparent streak surfaces leading to cancellation effects of problematic surface parts: parts where an adaptive refinement is necessary are rendered less opaquely. In this way, smoke like structures are obtained by a streak surface integration without any adaptive refinement. We show modifications of the approach to mimic smoke nozzles, wool tufts, and time surfaces. We apply the methods to a number of flow simulation data sets.

Lagrangian Coherent Structures: Challenges and Opportunities for Visualization

Xavier Tricoche (Purdue University, US)

Lagrangian Coherent Structures: Challenges and Opportunities for Visualization

Xavier Tricoche, Purdue University

Lagrangian Coherent Structures (LCS) are becoming increasingly popular in the fluid mechanics community where they have been shown to automatically identify material boundaries in fluid flows. In the last couple of years, LCS have also attracted the attention of some flow visualization researchers due to the compelling graphic representations that they can create.

This talk discusses LCS in the context of 20 years of flow visualization research and review recent contributions made to their efficient computation. It also analyzes the challenges that are specific to this approach. Finally, it presents some ongoing research projects that underscore the significant promises associated with LCS to tackle a variety of challenging visualization problems.

Visualization of Regular Maps

Jarke J. Van Wijk (TU Eindhoven, NL)

A puzzle:

1) Take an elastic fabric;
2) Cut out F polygons each with p sides;
3) Sew them together, such that a closed surface is obtained, where at each corner q polygons meet;
4) Stuff tightly.

What shape could you get?

Solve this puzzle for (F, p, q) =

1. (6, 4, 3);
2. (6, 2, 6);
3. (36, 4, 4);
4. (16, 6, 3);
5. (6, 4, 6);
6. (4, 4, 8);
7. (12, 8, 3);
8. (32, 5, 4);
9. (24, 8, 3);
10. (36, 6, 4).

Keywords: Surface topology, mathematical visualization

Joint work of: Van Wijk, Jarke;

Summarizing Molecular Dynamics Simulations

Amitabh Varshney (University of Maryland - College Park, US)

We explore the use of the center-surround mechanism to guide the selection of representative and anomalous time steps for summarization of molecular dynamics simulations.

We develop a multiscale keyframe selection procedure that automatically provides keyframes representing the simulation at varying levels of detail.

Parameter Sensitivity Visualization in DTI Fiber Tracking

Anna Vilanova (Eindhoven University of Technology, NL)

Fiber tracking of Diffusion Tensor Imaging (DTI) data offers a unique insight into the three-dimensional organisation of white matter structures in the living brain. However, fiber tracking algorithms require a number of user-defined input parameters that strongly affect the output results. Usually the fiber tracking parameters are set once and then re-used for several patient datasets.

However, the stability of the chosen parameters is not evaluated and a small change in the parameter values can give very different results. The user remains completely unaware of such effects. Furthermore, it is difficult to reproduce output results between different users. I will present our first approach to address this issue, and discuss the pros and cons of such an approach.

The Contour Spectrum Revisited

Gunther Weber (Lawrence Berkeley National Laboratory, US)

The contour spectrum describes the evolution isosurface properties such as surface area and enclosed volume as a function of chosen isovalue. For data given on tetrahedral meshes using linear interpolation, these properties can be expressed as a BSpline or a piecewise polynomial function. Motivated by applications in computational chemistry and other data analysis applications, we extend the contour spectrum to include integrated function value (e.g., enclosed charge in molecular modeling applications). This addition makes it possible to compare different simulations more accurately since it is possible to define isosurfaces based on an enclosed charge percentage instead of a fixed charge level. We furthermore introduce a more efficient implementation of combining BSpline functions for individual tetrahedra into the cumulative contour spectrum. Finally, we show how the contour spectrum can be define on a branch decomposition of the contour tree, making it possible to associate measured area with individual connected isosurface components.

Keywords: Topology, data analysis, isosurface, contour spectrum

Joint work of: Weber, Gunther; Pascucci, Valerio

Continuous Statistical Visualization

Daniel Weiskopf (Universität Stuttgart, DE)

A rather recent trend in visualization is to combine traditional scientific visualization methods (such as volume rendering) with information and statistical visualization techniques (such as scatterplots). This combination of techniques is particularly useful for multi-attribute data defined on spatial grids because the spatial relationships and the characteristics of the data attributes can be shown simultaneously. However, statistical and information visualization methods such as scatterplots and parallel-coordinates plots have traditionally been applied to intrinsically discrete data points and, therefore, treat data as a collection of independent data samples. In contrast, I propose to include continuous data models in statistical visualization applied to continuous data. Main advantages are that visual artifacts from data sampling are avoided and that the visualization process becomes scalable with respect to data set size.

Keywords: Scatterplot, parallel coordinates, information visualization, interpolation

Parameterizing high-dimensional data sets with kernel map manifolds

Ross Whitaker (University of Utah, US)

Understanding collections of data in high-dimensional spaces often entails learning low-dimensional representations. Manifold learning algorithms provide schemes for assigning low-dimensional parameters, and kernel map manifolds extend this capability to provide a general, robust mechanism for reconstructing smooth, optimal manifold representations and visualizing their differential structure. This allows us to systematically describe very rich structures, such as the "space of brain images".

Joint work of: Whitaker, Ross; Gerber, Samuel

Reconstruction of the Upper Torso Using X-Ray Imagery

Thomas Wischgoll (Wright State University, US)

To help mimic some of the useful features of CT scans for early detection of diseases like lung cancer at a fraction of the cost, an improved 3D ribcage reconstruction algorithm as well as a unique knowledge based interactive 3D lung reconstruction algorithm is proposed. The ribcage and lung reconstructions are both based on the typical PA and Lateral X-ray images that are already being acquired during preemptive screenings for lung cancer. A user's knowledge of human anatomy is combined with image processing techniques and mesh transformation algorithms to get around the fact that all the true patient specific 3D data is lost during the X-ray process. An example of how the reconstructed lung geometry can be used to clip the important portion of an approximate volume reconstruction to provide a supplementary interface to search for potential diseased areas is also presented.

Direct Volume Rendering in the Forensic Workflow

Anders Ynnerman (Linköping University, SE)

This talk will present the virtual autopsy project a collaborative project between the Center for Medical Image Science and the Norrköping Visaulization Center both at Linköping University in Sweden. The presentation will take its starting point in the forensic workflow and show how visualization techniques have been introduced to enable collaboration between pathologists and radiologists. Several cases will be shown to demonstrate how DVR has been used to solve difficult cases. The project has recently been given support by the Swedish National Visualization funding program to further integrate volume rendering in the workflow and to tailor methods for the specific user demands resulting in a forensic medical workstation demonstrator.

Keywords: Direct Volume Rendering, Medical Visualization, Forensic Science, Virtual Autopsies