

# 07291 Abstracts Collection

## Scientific Visualization

— Dagstuhl Seminar —

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**Abstract.** From 15.07. to 20.07.07, the Dagstuhl Seminar 07291 “Scientific Visualization” was held in the International Conference and Research Center (IBFI), Schloss Dagstuhl. During the seminar, several 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. Links to extended abstracts or full papers are provided, if available.

**Keywords.** Markov chains, numerical methods, web information retrieval, performance evaluation, intrusion detection, aggregation-disaggregation methods, graph-oriented decomposition

## 07291 Summary – Scientific Visualization

Scientific visualization (SV) is concerned with the use of computer-generated images to aid the understanding, analysis and manipulation of data. Since its beginning in the early 90’s, the techniques of SV have aided scientists, engineers, medical practitioners, and others in the study of a wide variety of data sets including, for example, high performance computing simulations, measured data from scanners (CAT, MR, confocal microscopy), internet traffic, and financial records. One of the important themes being nurtured under the aegis of Scientific Visualization is the utilization of the broad bandwidth of the human sensory system in steering and interpreting complex processes and simulations involving voluminous data sets across diverse scientific disciplines. Since vision dominates our sensory input, strong efforts have been made to bring the mathematical abstraction and modeling to our eyes through the mediation of computer graphics. This interplay between various application areas and their specific problem solving visualization techniques was emphasized in the proposed seminar.

*Keywords:* Markov chains, numerical methods, web information retrieval, performance evaluation, intrusion detection, aggregation-disaggregation methods, graph-oriented decomposition

*Joint work of:* Ebert, David S.; Hagen, Hans; Joy, Kenneth I. ; Keim, Daniel

*Extended Abstract:* <http://drops.dagstuhl.de/opus/volltexte/2008/1413>

## Computer-assisted shoulder replacement

*Charl P. Botha (Delft University of Technologies, NL)*

Pre-operative planning systems aid clinicians by giving insight into patient-specific issues before surgery is performed. The ability to perform a virtual shoulder replacement procedure enables the surgeon to explore the probable and plausible outcomes. Pre-operative planning software assists the surgeon in this complex decision-making process.

In our prototype pre-operative planning system for shoulder replacement, we create patient-specific bone-determined range of motion (ROM) predictions based on collision detection using segmented CT-data. The gleno-humeral ROM is visualised with motion envelopes, that indicate the maximum range of motion of the humerus in every direction. The prosthesis placement parameters can be adjusted interactively in our simulator, during which a novel visualisation technique depicts the differences between the current and previous range of motion. We have recently used a prototype intra-operative guidance module that we designed for performing a cadaver study in order to validate our ROM simulation.

*Joint work of:* Krekel, Peter R.; Botha, Charl P.; De Bruin, Paul W.; Valstar, Edward R.; Rozing, P.M.; Post, Frits H.

*Full Paper:*

<http://visualisation.tudelft.nl/Projects/ShoulderReplacement/RangeOfMotion>

## Quantity, Quality & Interpolation

*Hamish Carr (University College - Dublin, IRL)*

Scientific visualization requires not only qualitative but also quantitative results. But quantitation itself relies on the quality of acquisition, construction, representation, analysis, computation, images and conclusions. It is therefore necessary to consider the quality, and in particular, the effects of interpolation at all stages in the process.

*Keywords:* Quantity, quality, interpolation

## Revisit "On the Death of Visualization"

*Min Chen (University of Wales - Swansea, GB)*

– Juxtaposing with the UK Debate on "the Death of Computer Science"

Bill Lorensen wrote his well known article about the dying status of Visualization after Vis2003 to provoke discussions on the directions of Visualization as a field and community. In 2007, likely by sheer coincidence, a few months after the publication of a report by an International Review of ICT research (chaired by Bill Lorensen), an article by a (then) little known UK lecturer, Neil McBride, inflamed a heated debate on the dying status of computer science in the UK.

This talk draws parallels between these two articles, highlighting the common threads of arguments. In particular, both link the fact that computer (or visualization) is everywhere with the death of the subject of computer science (or visualization).

This talk also briefly examines the historical ups and downs in the development of subjects such as mathematics, physics, engineering, psychology, etc., relating the patterns of the development with their approaches to users and applications. Taking the opportunity of being (almost) the last talk of this Dagstuhl seminar, the talk also groups the different visions presented by many senior faculties of this Dagstuhl into three clusters based on their similarity to routes of these subjects (e.g., mathematics, engineering, and psychology). The talk then suggests an ideal route for Visualization (and to a certain degree, computer science), that is, medicine, or in other words, the model of medical school + university hospital. This is my 7-minute vision.

*Keywords:* Visualization, Bill Lorensen

## Shape Modeling and Visualization

*Leila De Floriani (University of Genova, I)*

The talk gives an overview of our research activities on shape modeling for visualization, specifically: multi-resolution modeling for 3D and 4D scalar fields, representations for non-manifold unstructured meshes in two, three and higher dimensions, topology-driven approaches to shape annotation and reasoning.

In the second part of the talk, we present our experience on semantic-based shape Modeling within the European Network of Excellence AIM@SHAPE, and we illustrate the capabilities of the Digital Shape Workbench, a shape and tool repository developed inside the network.

*Keywords:* Multi-resolution modeling, multi-dimensional scalar fields, topology, shape annotation

## Slides from Dagstuhl

*Brian D. Fisher (Simon Fraser Univ. - Surrey, CA)*

Brief discussion of role of cognitive science in visual analytics. I argue that the interaction of cognitive science and visualization will change both fields as cognitive scientists explore perceptual, cognitive, and enactive use of VA applications and visualization researchers provide new VA tools to support this effort.

*Keywords:* Cognition, perception, interaction

## Visualization Design and Lifecycle Management

*Issei Fujishiro (Tohoku University, J)*

VIDELICET (VIsualization DEsign and Life Cycle management) is a novel cooperative visualization system which aims at not only assisting the users in designing their own visualization applications by utilizing the goal-oriented taxonomy of techniques and case example base, in conjunction with a commercially-available modular visualization software, but also providing them with an effective management mechanism of visualization exploration through sophisticated versioning and juxtaposition.

This paper presents the fundamental concepts and architecture of the VIDELICET system. The effectiveness of the system is empirically proven with an application to a hybrid wind tunnel project which is being conducted in Institute of Fluid Science, Tohoku University.

*Keywords:* Design, lifecycle management, taxonomy, case repository, versioning, juxtaposition

*Joint work of:* Fujishiro, Issei; Takeshima, Yuriko; Hayase, Toshiyuki

## Solving Large Scale Science: The Role of Visualization in Knowledge Discovery

*Kelly Gaither (University of Texas at Austin, USA)*

The age of petascale and exascale applications is rapidly approaching, and visualization will undoubtedly play a central role in the analysis process. It is unimaginable to think otherwise. But, the question remains: are we as a visualization community ready for these challenges at this scale? At the petascale, the traditional visualization pipeline/loop: (read data, transform data, generate pixels, write data to frame buffer) breaks down. But, what is our alternative? In this talk, I will discuss issues related to remote and collaborative visualization at the petascale and beyond, and will present some motivating applications that seek to address problems with enormous societal impact.

Presenting these issues will motivate lively intellectual discussion about both the problems and potential solutions.

*Keywords:* Visualization, Petascale, Remote and Collaborative Visualization

## **Visualization - I see it my way (Action without Interaction)**

*Eduard Gröller (TU Wien, A)*

Visualization provides computer-supported tools to enable users with insight into their data. Over the last 25 years visualization as a discipline has come a long way in terms of maturity and in providing a rich set of algorithms and systems for visual exploration, analysis, and presentation of data. Interaction is considered a key component in the analysis process. The talk will argue for a sparse and cautious usage of interaction in visualization. The importance of a user centric structuring of interaction functionality will be illustrated with several research examples from our group.

*Keywords:* Visualization, no interaction

## **Volume Preservation of Multiresolution Meshes**

*Stefanie Hahmann (LMC-IMAG - Grenoble, F)*

Geometric constraints have proved to be efficient for enhancing the realism of shape animation. Our presentation addresses the computation and the preservation of the volume enclosed by multiresolution meshes.

A wavelet based representation allows the mesh to be handled at any level of resolution. The key contribution is the calculation of the volume as a trilinear form with respect to the multiresolution coefficients. Efficiency is reached thanks to the pre-processing of a sparse 3D data structure involving the transposition of the filters while represented as a lifting scheme. A versatile and interactive method for preserving the volume during a deformation process is then proposed. It is based on a quadratic minimization subject to a linearization of the volume constraint. A closed form of the solution is derived.

*Joint work of:* Hahmann, Stefanie; Sauvage, Basile; Bonneau, Georges-Pierre

*See also:* B. Sauvage, S. Hahmann, G.-P. Bonneau: Volume preservation of multiresolution meshes, Computer Graphics Forum (Proc. of Eurographics 2007), Volume 26, Number 3 (2007)

## Og hva språk snakker du?

*Helwig Hauser (University of Bergen, N)*

Visualization is an enabling technology for users to better communicate (present) as well as to better explore and analyze, e.g., to end up at better decisions, whenever large and often also complex datasets are involved (either from measurements, simulation, or from modeling). The data items as we read them from disk usually are a low-level representation of what the users are interested in. To establish this match between the semantic concepts of the user and the low-level data form is a challenge in visualization. This talk is a reflection about some selected aspects of considering semantics in visualization, also including a sketch of a few related future challenges.

*Keywords:* Semantics in Visualization

## Why didn't we invent Google Earth ? Will we miss the next chance, too ?

*Hans-Christian Hege (ZIB - Berlin, D)*

The visualization community has developed many pieces of the technology used in Google Earth, but did not invent a research prototype of a similar system. Some of the reasons, why this did not happen, are discussed. They are mainly caused by academic traditions, academic habits, the academic reward system and the funding conditions.

In the second part of the talk a challenging undertaking is outlined: A visual 3D information system, allowing the user to interactively explore a biological system, like e.g. a fruit fly, mouse, or human. The system would provide to the user an overview on many length scales (molecular, subcellular, cellular, tissue, organ and organism level) and, in an extension, maybe even time scales. Such a development would have a great impact in science and education and the visualization community could be instrumental in developing it. The most important aspect from the research point of view is that the system would provide a spatial or even spatiotemporal reference into which all experimental data with such references could be integrated. Thereby an account of such relations in biological systems could be achieved, and understanding of such relations could be significantly facilitated and improved. The system would also constitute a natural reference system for systems biology, helping to answer fundamental questions, e.g. how components within cells interact, in order to bring about their structure and to realize their functioning - and - how cells interact, in order to develop and maintain higher levels of organization and function.

The empirical base of such a visual information system and some of the technical challenges and research tasks in data processing and visualization are shortly sketched.

*Keywords:* Visual information systems, system biology, future challenges in visualization

## Recent Advances in Wave-based and Geometric Methods for the Simulation and Exploration of Room Acoustics

*Martin Hering-Bertram (TU Kaiserslautern, D)*

We present our recent contributions to the simulation of room acoustics regarding wave-based methods, geometric acoustics, interactive visualization, and auralization.

The first approach projects the solution of a wave equation onto a much smaller basis composed of eigenmodes, obtaining a discrete state-space model. This reduced model is used to compute the response to the low-frequency part of an anechoic input signal. The mid- and high-frequency range is processed by the second method, the improved phonon trace using raytracing to calculate space-dependent pulse response filters. A virtual-reality powerwall is used to visualize and explore our simulation results. Auralization based on a multi-channel audio system is obtained by a sound-field synthesis method. Therefore, we sample the time-dependent pressure field on a circle around the listener position and compute the best fitting speaker signals to locally reproduce the directed sound environment.

*Keywords:* Simulated Room Acoustics, Phonon Tracing, Wave Equation, Finite Elements, Model Reduction

*Joint work of:* Hering-Bertram, Martin; Mohring, Jan

## Dense Glyph Sampling for Visualization

*Ingrid Hotz (Zuse Institute Berlin, D)*

A method is introduced to generate a dense set of anisotropic, spatially varying glyphs over a two-dimensional domain. Such glyph samples are useful for many visualization and graphics applications. The glyphs are embedded in a set of non-overlapping ellipses whose size and density match a given anisotropic metric.

An additional parameter controls the arrangement of the ellipses on lines, which can be favorable for some applications, e.g., vector fields, and distracting for others.

To generate samples with the desired properties we combine ideas from sampling theory and mesh generation. We start with constructing a first set of non-overlapping ellipses whose distribution closely matches the underlying metric. This set of samples is used as input for a generalized anisotropic *Lloyd relaxation* to distribute samples more evenly.

## Functional Approximation

*Yun Jang (Swiss National Supercomputing Centre, CH)*

Functional approximation of scattered data is a popular technique for compactly representing various types of datasets in computer graphics, including surface, volume, and vector datasets. Typically, sums of Gaussians or similar radial basis functions are used in the functional approximation and PC graphics hardware is used to quickly evaluate and render these datasets.

While truncated radially symmetric basis functions are quick to evaluate and simple for encoding optimization, they are not the most appropriate choice for data that is not radially symmetric and are especially problematic for representing linear, planar, and many non-spherical structures.

Therefore, the functional approximation system is extended to using more general basis functions, such as ellipsoidal basis functions (EBFs) that provide greater compression and visually more accurate encodings of volumetric scattered datasets.

In addition to static data approximation, temporal data is encoded using results from encoding previous timestep to speed the encoding time.

## Computer Aided Detection

*Arie Kaufman (SUNY at Stony Brook, USA)*

As information and data sizes explode, we propose a discovery process which starts with a step of computer-aided detection (CAD) for abstraction and data reduction. Then, a user-centric user interface is employed for the discovery stage. As an example, we describe CAD of colonic polyps, assisting radiologists in locating polyps when using a virtual colonoscopy (VC) system. Our CAD pipeline automatically detects polyps while reducing the number of false positives (FPs). It integrates volume rendering and conformal colon flattening with texture and shape analysis. Using our colon flattening method, the CAD problem is converted from a 3D into a 2D problem. Suspicious polyps are detected by applying a clustering method on the flattened volume rendered image. The FPs are reduced by analyzing shape and texture features of the suspicious areas detected by the clustering step. The CAD results are seamlessly integrated into a VC user-specified user interface, providing the user (i.e., radiologist) with visual cues and likelihood indicators of areas likely to contain polyps.

*Keywords:* Computer-aided detection, CAD; Virtual colonoscopy, Computer Aided Polyp Detection, Colon flattening, Conformal mapping, Electronic biopsy, Volume rendering, Digital cleansing, Clustering

## Visualization of Diffusion Image Data and its Models

*Gordon Kindlmann (Harvard Medical School - Boston, USA)*

Diffusion Tensor MRI has become a popular way of non-invasively assessing micro-structural orientation and organization in biological tissue, especially the central nervous system. Diffusion tensor data is in fact the result of a model-fitting post-process run on the original diffusion-weighted image (DWI) data acquired by MRI. The single tensor fit of the DWI data has enabled many scientific and medical applications of DWI (e.g., tractographic connectivity studies, region-of-interest anisotropy measurements), but a single tensor is not the only way to model DWI data. Some recent work, for example, has explored fitting two tensors per voxel. With more complicated models, however, come more complicated algorithms for doing the model fitting. Visualization can play a role in understanding the behavior of DWI modeling algorithms, so that the relationship between known anatomy, underlying DWI data, and estimated models can be explored in a quantitative but intuitive way. This talk will describe new software for interactively visualizing DWI data and its models with the goal of better understanding the properties and potential of DWI data.

## Can There Be a Theory of Visualization?

*David H. Laidlaw (Brown Univ. - Providence, USA)*

This talk will present a thought experiment by positing the form of an overarching theory of visualization. The theory would predict the utility of any visualization method, where utility might measure how accurately or quickly a user could use the method. I will describe the ingredients of a putative theory and give examples of how current research areas could be laying its foundations.

## Towards New Visual Interfaces

*Aidong Lu (University of North Carolina at Charlotte, USA)*

This talk proposes to develop new visualization approaches that can serve as new types of visual interfaces for exploring and analyzing large, complex datasets. I will also briefly introduce our previous work along this effort, including an example-based volume illustration method, an interactive volume illustration approach using Wang Cubes, and an automatic volume composition method using eye tracking data.

*Keywords:* Visualization, Visual Interface, Visual Analytics

## The occlusion problem in 3D vector field and flow visualization

*Nelson Max (LLNL - Livermore, USA)*

Dense vector icons or streak lines hide and overlap each other. It is difficult to understand the flow structure, even with stereo and/or motion parallax. Haloed or cylindrically shaded streak lines help sort out occlusion order, but depth complexity is still a problem. Possible solutions are to show the icons only at detected features, near contour surfaces of a scalar function, where a scalar function exceeds a threshold, near rigid objects inside the flow, or at interactively selected points. Also one space the icons at some minimum distance from each other, or place icons only near features of interest. One can let the icons move and deform with the flow, fading in and out to keep a sparse density. Finally, one can place icons to illustrate topological features of the flow, or near other automatically recognized features of interest.

*Keywords:* Flow visualization

## Hybrid Volume Rendering for Quantitative Orthodontics

*Jörg Meyer (Univ. California - Irvine, USA)*

Computed tomography (CT) is an excellent tool for measuring bone density in natural tissues as it is based on X-ray absorption. When natural tissues are combined with biocompatible materials, such as titanium implants, the integration of such implants into the surrounding bone tissue is critical to the lifetime and durability of the implant.

A hybrid volume rendering technique has been developed that uses a three-dimensional color and opacity transfer function to render a color-coded density representation of the bone near the implant sites. In addition, a glyph-like, two-dimensional density profile for each implant is superimposed on the volumetric display. The glyph also shows the value of the line integral on two sides of the implant. The readings from these glyphs are correlated to mechanical stress tests that were conducted on the same specimen.

The visualization procedure described in this presentation consists of 2-D cross-sectional CT imaging, 3-D gradient-based hardware-accelerated volume rendering using 3-D texture mapping, implant site extraction using 3-D selection of a 2-D cross-sectional, tri-linearly interpolated 2-D image, computation of a bone density profile and line integral along the implant, glyph generation, and 3-D hybrid rendering of the implant site together with the glyph.

This method has been demonstrated to be successful in enabling the mapping of information derived from virtual bone density measurements onto data obtained from mechanical testing or mechanical simulations.

*Keywords:* Biomedical imaging, image analysis, volume rendering, hybrid rendering

*Joint work of:* Meyer, Jörg; Espiritu, Raymund; Earthman, James C.

*Full Paper:*

<http://imaging.eng.uci.edu/~jmeyer>

## **A Matter of Time: Intertwining Interactive Visualization and Data Mining of Time-Oriented Data and Information**

*Silvia Miksch (Donau-Universität Krems, A)*

Time is an important data dimension with distinct characteristics that is common across many application domains. The analysis of time-oriented data is an important task in many application scenarios. Both, interactive visualization and computational analysis.

In this talk, we introduce a concept for designing visual analytics frameworks and tailored visual analytics systems for time and time-oriented data.

(work done in cooperation with Wolfgang Aigner, Alessio Bertone, Tim Lamarsch, Thomas Turic, Christian Tominski, and Heidrun Schumann)

*Keywords:* Interactive Visualization, data Mining, Time-Oriented Data & Information

*Full Paper:*

<http://www.donau-uni.ac.at/ike>

## **Who Needs Visualization?**

*Robert Moorhead (Mississippi State Univ. - Mississippi State, USA)*

Visualization is not dead. Many scientists and engineers are vehement about the necessity of visualization to understand their simulation results and their measurements. This talk presents two brief case studies of scientists who found visual data analysis crucial to understand their simulation results and reported such to program managers when the program managers removed visualization support in a cost-cutting measure.

*Keywords:* Visualization, users, and funding

## **Regular Multi-Dimensional Sampling**

*Torsten Möller (Simon Fraser University, CA)*

Simulation systems or general tools often have many parameters to tune their performance. I.e. the exploration of complicated structures is really a multi-dimensional data problem.

Creating tools that allow visual guidance during this exploration step are complex tools in their own right. One crucial sub component of such tools will have to be the determination of interesting parameter combinations, which are basically samples in a multi-dimensional space. The difficulty of placing proper samples is typically known as the "Curse of Dimensionality". However, this curse, is based on the philosophy of Cartesian lattices. In this talk I was trying to demonstrate that the placement of such samples on the best known sampling lattices (for dimensions lower than 24) is not plagued with any curse and might be called the "Blessing of Dimensionality" instead.

*Keywords:* Multi-dimensional sampling, exploration of multi-dimensional data

## **A framework for effective user study design and evaluation**

*Klaus Müller (SUNY at Stony Brook, USA)*

Visualization algorithms can have a large number of parameters, making the space of possible rendering results rather high-dimensional. Only a systematic analysis of the perceived quality can truly reveal the optimal setting for each such parameter.

However, it is obvious that an exhaustive search in which all possible parameter permutations are presented to each user within a study group would be infeasible to conduct. Additional complications may result from possible parameter co-dependencies.

In this talk, I will introduce an efficient user study design and analysis strategy to measure the perceived quality in volume rendering within the context of large parameter spaces. The user feedback is fast and easy to obtain and does not require exhaustive parameter testing. To enable such a framework, we have modified a preference measuring methodology that originated in psychology and is now also widely used in market research. Further far-reaching applications of this general framework will be discussed as well.

*Keywords:* User study design, statistical evaluation methods

## **A framework for effective user study design and evaluation**

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*Keywords:* Visualization, user studies

## Vortex detection in time-dependent flow

*Ronald Peikert (ETH Zürich, CH)*

Feature extraction methods are an indispensable means for the visual analysis of flow data. Many of the techniques in today's use were developed in the early nineties where flow simulations predominantly produced steady solutions. Some of these techniques, based not physical but rather geometric or topological properties, become invalid in the context of a time-dependent flow. While this was known for a long time, the results of applying those techniques were accepted as approximations. In this work, we provide an error analysis in a synthetic model case as well as adaptations of two methods to the time-dependent domain.

*Keywords:* Flow visualization, vector fields, time-dependent data, vortex detection

## Why does it do that?: Visualizing Models and Other Explanations

*Penny Rheingans (University of Maryland Baltimore County, USA)*

Visualization has evolved over the years to allow us to answer new questions. In 3D visualization, this progression has proceeded from isosurface rendering (what is this thing?) to direct volume rendering (where are the internal features?) to temporal visualization (how did it get this way?). One key current challenge is to answer the next logical question in this chain – why does it do that?

This question lies at the heart of the quest for scientific understanding. One key scientific tool for understanding dynamic processes is the model – specifically, a computational model of how input condition seed theorized mechanisms to produce expected outcomes. Visualization researchers have spent much energy on visualizing both the input conditions (sampled data) and predicted outcomes (simulation results). We need to turn our attention to understanding the models themselves. This requires new visualization techniques which enable domain researchers to answer qualitatively different questions, including: how does observed reality correspond to the range of expected outcomes? how does changing input conditions or model parameters impact outcomes? which parts of the model are sensitive to changing parameters of mechanisms? what is the high-dimensional structure of predictions of the model?

## Symbiotic Visualisation

*Jos B.T.M. Roerdink (University of Groningen, NL)*

In this talk, I discuss an approach towards working with scientists from other fields. Taking life science as an example, I first observe that, contrary to what is often held, visualisation tools are widely used. Also, exciting developments (funded!) occur outside the Visualisation community where new visualisations are developed.

On the negative side, there is an explosion of ad-hoc tools which come up and die, are hard to integrate, and contain duplications of existing visualisation work. One approach towards this is to develop visualisation tools as plug-ins to existing bioinformatics tools, which contain many ingredients (data import, filters, annotations, ontologies) which the visualisation person does not have to repeat.

An example is presented where gene network visualisation tools are offered as plug-ins to an existing bioinformatics tool so that both sides can profit, in analogy to symbiosis in nature.

*Keywords:* Visualisation, life science

## Towards Automatic Feature Based Visualization

*Gerik Scheuermann (Universität Leipzig, D)*

Currently, it is established knowledge in the visualization community that there is no universal definition of a feature. Therefore, all feature detection methods in the field are based either on specific hard-coded feature definitions or user interaction to define features. Furthermore, features are only vaguely defined as "phenomena, structures or objects in a data set of interest to the underlying problem". It also means that features are said to depend on the application and sometime on the user. This hinders cross-domain use of automatic feature detection algorithms and is also not pleasant on a conceptual level.

The basic idea behind the talk is to question this established knowledge based on recent work in complex systems. This work allows to define and detect features solely on the given data in cellular automata. It is possible to transfer these ideas to finite difference simulations of time-dependent partial differential equations. Of course, there are still open questions about the underlying mathematics, but we give evidence based on theoretical considerations and examples that automatic measurement of importance of points in space-time is possible in this case, leading to a scalar importance value allowing for feature definitions based on a single value instead of the complete multi-field data. The shown examples are an isotropic diffusion simulation, two different flow simulations and a one-year period in an established climate model.

*Keywords:* Feature detection, visualization, complex systems

## Scientific Visualization and Information Visualization: A Data-Driven Comparison

*Alexandru Telea (TU Eindhoven, NL)*

Scientific visualization (SciVis) and information visualization (InfoVis) are two well-established branches of the visualization research field. However, there are still ongoing discussions about the similarities and differences of the two. There exist considerable overlaps in aims, methods, techniques, and data types used in the two fields in practice. It is yet unclear where the clear border is between the two fields, if such a border does indeed exist. In this talk, I will present a comparison of the two fields from the perspective of their datasets. The aim of this comparison is to outline some of the intrinsic properties which make SciVis and InfoVis datasets different, and thereby attempt to understand some of the differences present in approaches in the two fields.

*Keywords:* Scientific visualization, information visualization, taxonomies

## Vector Field Modeling for Shape Deformations

*Holger Theisel (Universität Bielefeld, D)*

We present an approach to define shape deformations by constructing and interactively modifying  $C^1$  continuous time-dependent divergence-free vector fields. The deformation is obtained by a path line integration of the mesh vertices. This way, the deformation is volume-preserving, free of (local and global) self-intersections, feature preserving, smoothness preserving, and local. Different modeling metaphors support the approach which is able to modify the vector field on-the-fly according to the user input. The approach works at interactive frame rates for moderate mesh sizes, and the numerical integration preserves the volume with a high accuracy.

In the second part of the talk we apply the approach to model elastic secondary deformations of shapes. The deformations are steered by the simulation of a low number of simple mass-spring sets. The result of this simulation is used to define time-dependent divergence-free vector fields whose numerical path line integration gives the new location of each vertex. The approach also avoids unwanted intersections in the case of collisions in the primary animation.

## Thoughts on the Science of Interaction: Fundamental Changes Required in the Discourse for Discovery

*Jim Thomas (Pacific Northwest National Lab., USA)*

Visual Analytics is an emerging field of study that brings talents from many disciplines including statistics, mathematics, knowledge representation and synthesis, scientific and information visualization, cognitive and perceptual sciences, communications, decision sciences and more.

The demand for visual analytics is being stimulated by new requirements for homeland security but similar needs are present in science, commerce, home, and almost any domain that deals with complex, large information sources that require human judgement to §detect the expected and discover the unexpectedŒ. A gap in the technology is the science of interaction referenced from the recent book *Illuminating the Path: the Research and Development Agenda for Visual Analytics*, <http://nvac.pnl.gov/>. Jim will address the demanding requirements for a new science of interaction, the core concepts within this new science, hopefully to stimulate interest by others to join the efforts to invent, develop, and demonstrate a new science enabling a discourse for discovery within billions of information items.

*Keywords:* NVAC

## **Thoughts on the Science of Interaction: Fundamental Changes Required in the Discourse for Discovery**

*Jim Thomas (Pacific Northwest National Lab., USA)*

Definition of Visual Analytics, Why Interaction Must Change, and 10 Characteristics of New Science of Interaction.

Visual Analytics is an emerging field of study that brings talents from many disciplines including statistics, mathematics, knowledge representation and synthesis, scientific and information visualization, cognitive and perceptual sciences, communications, decision sciences and more. The demand for visual analytics is being stimulated by new requirements for homeland security but similar needs are present in science, commerce, home, and almost any domain that deals with complex, large information sources that require human judgement to §detect the expected and discover the unexpectedŒ. A gap in the technology is the science of interaction referenced from the recent book *Illuminating the Path: the Research and Development Agenda for Visual Analytics*, <http://nvac.pnl.gov/>. Jim will address the demanding requirements for a new science of interaction, the core concepts within this new science, hopefully to stimulate interest by others to join the efforts to invent, develop, and demonstrate a new science enabling a discourse for discovery within billions of information items.

*Keywords:* Visual Analytics

## **Visualization and Rhetorics**

*Amitabh Varshney (University of Maryland - College Park, USA)*

Aristotle defined rhetoric as the faculty of discovering in any particular case all of the available means of persuasion. In any given situation, there are a vast number of elements and a rhetor’s task is to make the most relevant object or concept rise to a level of dominance in the consciousness of the audience.

Large-data visualization can benefit from a study of visual rhetorics in so far it too faces a similar challenge. Given vast quantities of data, how can we uncover the most salient attributes and features, and then how best can we present them so that they serve the needs of our users in the best way possible. Every visual communication medium, including visualization, imputes a certain importance to different visual elements. Whether intentional or not, this message is conveyed to the viewer by the choice of scene, camera, illumination, and animation parameters. Traditional art, illustration, and photography have long explored the principles of visual rhetorics. In this talk I shall give an overview of visual rhetorics as used in art and photography and discuss how some elements of it may have relevance for 3D visualization.

## **Generalized Hypercylinders: a Mechanism for Modeling and Visualizing N-D Objects**

*Matthew Ward (Worcester Polytechnic Institute, USA)*

The display of surfaces and solids has usually been restricted to the domain of scientific visualization; however, little work has been done on the visualization of surfaces and solids of dimensionality higher than three or four. Indeed, most high-dimensional visualization focuses on the display of data points. However, the ability to effectively model and visualize higher dimensional objects would be quite useful in studying their shapes and relationships.

In this talk I will describe a method for the description, extraction, and visualization of N-dimensional surfaces and solids. The approach is to extend generalized cylinders, an object representation used in geometric modeling and computer vision, to arbitrary dimensionality, resulting in what we term Generalized Hypercylinders (GHCs). A basic GHC consists of two N-dimensional hyper-ellipsoids connected by a hyper-cylinder whose shape at any point along the cylinder is determined by interpolating between the endpoint shapes. More complex GHCs involve more complex endpoint shapes and curved spines connecting the points. Several algorithms for extracting GHCs from multivariate data sets will be proposed. Once extracted, the GHCs can be visualized using dimensionality reduction techniques to project the endpoints into display space. Finally, a suite of tools will be proposed for interactively exploring data displayed with GHCs.

*Keywords:* Multivariate data visualization, high-dimensional visualization, solid modeling

## **Group Theory and 2D Vector Field Topology**

*Daniel Weiskopf (Universität Stuttgart, D)*

We demonstrate that group theory can be used to find and classify critical points in cell-wise barycentrically or bilinearly interpolated 2D vector fields.

The Poincare index of these points is determined by investigating the qualitative behavior of 0-levelsets of the interpolants of the vector field components using precomputed combinatoric results. Determining the index of a critical point can be seen as a coloring problem of cell edges and a complete classification of all possible colorings in terms of the types and number of critical points yielded by each coloring can be given by using computational group theory.

Similarly to the marching cubes algorithm, our method allows for an efficient extraction of critical points by making use of precomputed classifications.

*Keywords:* Vector field visualization, vector field topology, critical points, group theory

## Modeling and Simulation of Cardiovascular Systems

*Thomas Wischgoll (Wright State University, USA)*

Different disciplines explore the human body at various levels ranging from the entire body to organ level over the tissue structure down to the protein and gene level. However, there seems to be a lack of bridges between these disciplines. This presentation tries to show how visualization can help bridge between these disciplines by presenting an ongoing project that incorporates two of these levels: the organ and the tissue structure. Different methodologies are presented that abstract from volumetric imagery and extract quantitative data in order to - in the long term - develop a model of the human heart. The volumetric images used throughout this project stem from the organ itself to derive geometric and morphometric properties of the vasculature as well as from tissue samples to determine mechanical properties of the individual vessels.

## Two successes and a maybe

*Anders Ynnerman (Linköping University, S)*

The first part of this talk discusses two visualization applications that have had large impact and been rapidly introduced in production workflows. The first one is the software package UniView that enables real time navigation and rendering of astronomical data for planetariums. The second is the introduction of virtual autopsies into the forensic workflow.

The second part of the talk addresses multimodal interaction in visualization, especially haptics. There are many open questions and issues regarding multimodal interaction. Based on a examples of direct volume haptics issues and future development will be discussed.

*Keywords:* Astronomical visualization, Virtual Autopsies, Multimodal Interactions, Haptics