Illustrative Visualization for Medicine and Science
SIGGRAPH 2006

This course presents important research and developments in computer generated illustration techniques within the area of non-photorealistic rendering (NPR). We present material not covered by previous NPR courses and concentrate specifically in the subfield of illustration techniques for data, including methods for computer-generated technical, scientific and medical illustration, as well as interactive illustrations of both surface and volumetric data. We also present both the perspective of the role of illustration in medicine from a medical illustrator, as well as the perspective of the use of computer generated illustrations in medical training and surgical simulation from a traditionally trained medical illustrator. Topics are presented with a balanced description of traditional methods and practices and a how-to approach, including detailed descriptions and analysis of the basic and latest state-of-the-art techniques and algorithms which can utilize commodity graphics boards for interactive illustration effects.

Course organizers

David S. Ebert, Purdue University
Mario Costa Sousa, University of Calgary

Speakers

In alphabetical order:	Affiliation:
Bill Andrews	*Medical College of Georgia*
Stefan Bruckner	*Vienna University of Technology*
David S. Ebert	*Purdue University*
Bruce Gooch	*Northwestern University*
Mario Costa Sousa	*University of Calgary*
Nikolai Svakhine	*Purdue University*
Don Stredney	*Ohio Supercomputer Center*
Ivan Viola	*Vienna University of Technology*

Expanded statement

This course presents recent and important research and developments from academia in illustrative, non-photorealistic rendering (NPR) focusing on its use for medical/science subjects. Lectures are organized within a comprehensive illustration framework, focusing on three main components:

- Traditional and computerized illustration techniques and principles for Technical and Science Subjects (2 lecture)
- Evaluation and Practical Use (2 lectures)
- Viewing & Rendering (3 lectures)

Presentation of topics is balanced between descriptions of traditional methods and practices, practical implementation motivated approaches and evaluation, and detailed descriptions and analysis of NPR techniques and algorithms.
We begin in the morning with a lecture presenting an overview of traditional illustration in technical, science, and medical subjects followed by a description of the main components in a NPR pipeline for developing systems to help technical and science illustrators with their work. The course progresses with an overview of the NPR used in illustration as well as approaches to evaluate their use and effectiveness. The morning concludes with the start of the "viewing and rendering" section. The three lectures in this section describe the latest techniques in computerized illustration algorithms for scientific and medical data for both surface and volumetric data, covering techniques from silhouette enhancement to stippling, to cut-away viewing, labeling, and focus+context rendering. Each of the lectures also discusses practical issues in making these techniques interactive and their use for different application domains. We conclude the course with a trained medical illustrator discussing the principles/caveats/issues in using illustration techniques in real-world medical applications. This lecture will also describe an evaluation, from an illustrator's point of view, of the use and quality of the techniques presented throughout the day.

List of prerequisites

Required: intermediate knowledge level of 3D computer graphics and scientific visualization algorithms. Programming experience using a 3D library for interactive graphics and some awareness of existing NPR techniques may be helpful. Not required: prior knowledge of or background in artistic techniques, traditional scientific illustration, or perceptual psychology.

List of topics beyond the prerequisites

The course covers principles of traditional illustration, algorithms and numerical methods for interpreting form (silhouettes and shape features), aspects of the viewing & rendering pipeline (texturing, algorithms for scientific illustration, ink-based rendering solutions for meshes and volumetric representations), evaluation of techniques in medical applications.

Course Syllabus

http://www.cpsc.ucalgary.ca/~mario/webpage/publ/2006/course-6-siggraph-06/

Topics	Speaker(s)	Time
Introduction/history/needs of medical illustration	Andrews, B.	60 min (08:30 – 09:30)
Overview of NPR for Computerized Illustration	Sousa, M.C.	45 min (9:30 – 10:15)
-- Break		
Perception and Evaluation: Optimizing Computer Imagery for Communication	Gooch, B.	60 min (10:30 – 11:30)
Volume Illustration for Medicine and Flows (Part 1)	Ebert, D.	45 min (11:30 – 12:15)
-- Lunch		
Volume Illustration for Medicine and Flows (Part 2)	Ebert, D., Svakhine, N.	45 min (1:30 – 2:15)
Focus of Attention+Context and Smart Visibility in Visualization	Viola, I. Sousa, M.C.	60 min (2:15 – 3:15)
-- Break		
Interactive Illustrative Volume Visualization Techniques for Exploration and Communication	Bruckner, S.	45 min (3:30 – 4:15)
Illustrative Visualization: Implications to Interactive Medical Simulation and Training	Stredney, D.	60 min (4:15 – 5:15)

Descriptions of each lecture

Introduction/History/Needs of Medical Illustration

Bill Andrews, Medical College of Georgia

Abstract

Medical illustrations are in essence drawings/paintings of measured accuracy, depicting subtleties without ambiguities. Though often highly representational (”realistic-looking”), the main purpose of such illustrations is to communicate information and not necessarily to look real.

In medical subjects, there are four instances where good illustration is the best (and possibly the only) medium to use; this is the case where: (1) Areas of reference exist physiologically but not gross anatomically; (2) Superimposing one structure upon another gives related information; (3) Section views show instruments in place in body cavities, etc; (4) Eliminating much visual garbage from a photo can produce a simpler explanation.

In this lecture I will describe current traditional and digital illustration techniques that medical illustrator uses almost everyday to create the feel of traditional imagery in the digital age. Follow a step by step presentation that starts as traditional line art sketch and is then brought to life with color and style on the computer screen using glazes, airbrush, "wet" paintbrush, and more. I will also describe how medical illustrators would benefit from using illustrative visualization systems, including research and development requirements and ongoing collaborations between the computer graphics/visualization and medical illustrators communities.

Outline

- Introduction to medical illustration
- Traditional and digital techniques
- Current communication and production pipeline
- Using illustrative visualization systems: current status, research challenges, collaboration with computer graphics and visualization communities.

Contributions

This lecture contributes the perspective on computer illustration from a faculty member who teaches traditional medical illustration and uses it in practice daily. Therefore, this lecture gives a great historical perspective, as well as a very useful perspective on incorporating and guiding computer-generated illustration techniques and systems in medical applications.

Overview of NPR for Computerized Illustration

Mario Costa Sousa, University of Calgary

Abstract

Current scientific visualization techniques create complex images that may be difficult to interpret and do not have the expressiveness of illustrations. Incorporating traditional scientific illustration techniques into a visualization system enables artists and non-artists to harnesses the power of traditional illustration techniques when visually representing scientific data. In this lecture I will

present an illustrative scientific visualization framework incorporating general illustration principles, as well as NPR techniques and aesthetics of various styles. Such a framework provides a basic foundation for categorizing and communicating research and may stimulate future illustrative visualization systems.

I will also present taxonomies and describe the key techniques behind recent works in applying computer-generated medical and scientific illustration techniques to the problems of depicting shape features, visualizing volumetric datasets, and applying existing tools on different science subjects.

Outline

I. Traditional medical and scientific illustration
II. The illustration production process
III. Hybrid NPR solutions
IV. System components and algorithms
    - Interactive Modeling and Shape Analysis
    - Expressive Rendering and Composition
V. Recent works: taxonomies, techniques, future work

Contributions

This lecture provides a detailed description of a global framework for illustrative scientific visualization which parallels the pipeline used by traditional illustrators. By providing terminology and an order of events for the creation of effective illustrations, we can afford a high-level perspective of the recent technical contributions supplied by researchers and enable further contributions to abstraction and communication of medical and scientific data.

Perception and Evaluation: Optimizing Computer Imagery for Communication

Bruce Gooch, Northwestern University

Abstract

Computers are becoming faster and more interconnected creating a shift in their primary function from computation to communication. While the computer industry has produced faster processors, larger disk drives and higher memory capacity, these advances do little to help people understand the meaning of their data. This lack of understanding stems from the fact that machines process data in numerical form, while humans more easily comprehend visual data. Visualization is the process of using computer graphics to transform numerical data into meaningful imagery, enabling users to observe information. The resulting display allows a viewer to detect and analyze features in numerical data that may not have been recognized otherwise. The transformed data can be represented as a picture, an animation, or an interactive computer application. The art of visualization lies in choosing perceptual representations that maximize human understanding. This talk will demonstrate how perceptual psychology and visual art cognition provide the framework for new visualization methods. This iterative two-part process consists of using artistic computer graphics techniques to enhance the presentation of important data features, then conducting perceptual studies to evaluate the effectiveness of the resulting imagery. The strength of this approach lies in the synergy achieved in the tight coupling of the two research areas.

Artistic images are often easier to understand than photographs. In their classic 1956 experiment, Ryan and Schwartz demonstrated that line drawings with exaggerated features of interest evoked a more rapid and accurate response than photographs or plain line drawings. More recently Gooch found increased learning speed using computer generated facial illustrations. NPR images convey information more effectively by: omitting extraneous detail; focusing attention on relevant features; and by clarifying, simplifying, and disambiguating shape. Control of detail in an image for the purpose of enhanced communication is becoming the hallmark of NPR. Control of image detail is often combined with stylization to evoke the perception of complexity in an image without explicit representation.

What the eye perceives is not always what the mind comprehends. A general knowledge of perception can guide the creation of a visualization method. However, attempts to understand human cognition are hampered by the fact the workings of the mind cannot be observed. We must rely on external signs of cognition as exemplified in behavior. Therefore, there will always be a need to evaluate the effectiveness of the resulting imagery to insure optimal results. The effectiveness of an image can be evaluated by measuring its ability to communicate. Measuring the communication content of a image can best be performed in an indirect manner: a behavioral study is conducted in which participants perform specific tasks on sets of visual stimuli. If participants are statistically better at performing a task given a certain type of imagery, then that imagery can be said to be more effective for the given task. The ability to measure the communication content of imagery, means that empirical methods can be used to establish principles to validate methods.

Outline

Manipulation of perceptually important artistic parameters (30 minutes)

- Outline
- Texture
- Color
- Using NPR to represent uncertainty
-

Evaluation of the resulting display (30 minutes)

- Task based evaluation
- Cognitive walkthroughs
- Reasoning with uncertainty

Contributions

This lecture will round out the course by providing evaluation techniques specifically designed for visualization. While the perceptual evaluation of computer generated imagery has been to topic of several SIGGRAPH courses in the past this will be the first to specifically address illustrative visualization. This lecture will also address the cognitive aspects of decision making based on the presentation of visual data. This is also a first for the SIGGRAPH audience.

Volume Illustration for Medicine and Flows

David Ebert, Purdue University
Nikolai Svakhine, Purdue University

Abstract

This talk will start by describing general techniques and principles for effective computer-generated illustrations of volumetric datasets and review the state-of-the-art of volume illustration. It will then describe unique techniques and problems of both medical and flow data and discuss specific solution techniques for each class of data. An in-depth presentation of the work by Ebert's group in this area will be discussed next, including work on interactive stipple rendering, example-based volume illustration, and then Svakhine's system for interactive medical and flow illustration. The talk will conclude with a discussion of implementation and optimization techniques for interactive volume illustration by Svakhine as well as an interactive demonstration of the use of the system for medical education illustration, surgical simulation training, and analyzing three-dimensional fluid flow datasets, such as flow past spacecraft and convective flows.

Outline

Part 1 – 45 min (11:30 - 12:15)

I. Need and Motivation
II. Principles for Effective Volume Illustration
III. Common Techniques and Domain-specific Techniques
    a) Medical and biological visualization data
    b) Experimental and computation flow data

IIII. Interactive Volume Stippling and Example-based Illustration
    a) System overview and features
    b) Techniques for stippling
    c) An Example-based illustration system
IV. Interactive Volumetric Illustration System
    a) System architecture
    b) Specification of illustration styles
    c) Tools and Techniques

Part 2 – 45 min (1:30 - 2:15)

V. Interactive Volumetric Illustration System Details and Demonstration
    a) Implementation Details
    b) Interactive Demonstration
    c) Use for temporal bone surgery training, medical illustration
    d) Use for flow visualization

Contributions

The lecture presents the foundations as well as recent work in illustrative volume visualization for both medical and scientific datasets. Not only are techniques and approaches presented, but system implementation details, interactive demonstrations, and discussion of use in both medical and fluid dynamics research are presented.

Focus of Attention+Context and Smart Visibility in Visualization

Ivan Viola, Vienna University of Technology
Mario Costa Sousa, University of Calgary

Abstract

In this part of the course we first discuss smart visibility techniques that provide maximal visual information through dynamic change in visual representation. Such techniques originate from technical illustration and are called cut-away views or ghosted views. We discuss basic principles and techniques for automatic generation of cut-away and ghosted visualizations. One approach is importance-driven feature enhancement, where the visibility of a particular feature is determined according to assigned importance information. The most appropriate level of abstraction is specified automatically to unveil the most important information. Additionally we show the applicability of cut-away views on particular visualization examples. The specific application of cut-away views in computer-assisted angiography will be discussed in more detail.

The second category of smart visibility techniques are based on modification of the spatial arrangement of structures. Such techniques are closely related to exploded views, often used for assembly instructions. We discuss visualization techniques that separate context information to unveil the inner focus information by splitting the context into parts and moving them apart. Another visualization technique enables browsing within the data by applying deformations like leafing, peeling, or spreading. In the case of time-varying data we present another visualization technique which is related to exploded views and is denoted as fanning in time.

Outline

1. Visual modifications
   1.1 Traditional Illustration
   1.3 Importance-Driven Volume Visualization
   1.2 Cut-Away Views and Ghosted Views Visualizations
   1.4 VesselGlyph: Focus+Context for Angiography

2. Exploded Views and Deformations
   2.1 Traditional Illustration
   2.2 Deformation in Information Visualization
   2.3 Spatial Explosion in the Scientific Visualization
   2.4 Temporal Explosion in the Scientific Visualization

Contributions

The lecture provides an overview on the latest expressive visualization techniques inspired by traditional illustration. Illustration techniques such as cut-aways or exploded views are realized in scientific visualization through smart visibility techniques. The discussion on latest smart visibility techniques is the contribution of the lecture.

Interactive Illustrative Volume Visualization Techniques for Exploration and Communication

Stefan Bruckner, Vienna University of Technology

Abstract

Illustrative visualization deals with computer supported interactive and expressive visualizations through abstractions which are inspired by traditional illustrations. The first part of the lecture discusses illustrative techniques for the exploration of volume data with limited or no prior knowledge about the nature and/or structure of the data. Conventional techniques, such as clipping planes, suffer from the drawback of missing context information. Context-preserving volume rendering uses a function of shading intensity, gradient magnitude, distance to the eye point, and previously accumulated opacity to selectively reduce the opacity in less important data regions while still preserving landmark features. The second part of the lecture deals with illustrative volume visualization in the context of communication where traditional illustrations play a major role. Whether used to teach a surgical or radiological procedure, to illustrate normal or aberrant anatomy, or to explain the functioning of a technical device, illustration is an important tool in communicating complex structures or relationships. Although many specimens are readily available as volumetric data sets, particularly in medicine, illustrations are commonly produced manually as static images in a time-consuming process. The lecture covers methods to realize an interactive system for creating illustrations directly from volume data combining artistic visual styles and expressive visualization techniques.

Outline

I) Context-Preserving Exploration of Volume Data
   1) Conventional approaches and their drawbacks
   2) Artistically inspired volume exploration

II) Interactive Generation of Illustrations with VolumeShop
   1) Overview of abstraction techniques
   2) Design of a Direct Volume Illustration system
   3) Multi-object volume rendering
   4) Illustrative enhancement
   5) Selective illustration

Contributions

The lecture presents recent work in illustrative volume visualization as well as a conceptual overview of existing approaches. The material has not been part of any previous SIGGRAPH course.

Illustrative Visualization: Implications to Interactive Medical Simulation and Training

Don Stredney, Ohio Supercomputer Center

Abstract

In this lecture, I will present how current NPR techniques and illustrative visualizations are being used in projects funded from a variety of sources, including the National Science Foundation and the National Institutes of Health. Included in this presentation will be current efforts to obtain medical data using multimodal (i.e., CT, MR, optical) and multi-scale acquisitions (macro/micro/cellular) as repositories that support systematic studies of biomedical phenomenon.

This discussion will also include how representational techniques can be used to facilitate the level of expertise of the user, and later used to provide a more comprehensive methodology for demonstrating expertise and understanding of complex biomedical phenomenon.

Outline

1. Current efforts to obtain data
    - 1.a multi-modal data
    - 1.b multi-scale data

2. Efforts to process the data for use
    - 2.a registration
    - 2.b segmentation
        - 2.b.1 structural
        - 2.b.2 functional

3. Overview of current efforts in medical education and training environments
    - 3.a Desktop Environments
        - 3.a.1 Medical Educational
        - 3.a.2 Clinical Research
        - 3.a.3 Surgical Simulation and Training
    - 3.b. Shared Virtual Environments

4. How NPR and other representational techniques are being exploited for these applications

5. Conclusion and Q& A

Contributions

The perspective of this presentation is from an applications researcher who is involved in translating emerging techniques in representation and applying them to actual projects, including projects that involve validation and dissemination. This perspective is from a classically trained medical illustrator who adopted computer graphics techniques in his graduate studies in the late ‘70’s and has since employed synthetic representations for a wide variety of biomedical simulations. Examples from current projects using these techniques will be demonstrated.

Description of the course notes

The course notes will include a written overview of the material covered in each talk, including specific technical details, a copy of each presenter s slides, a complete bibliography for each of the topic areas, and reprints of selected publications that describe in more specific detail some of the particular applications described in our lectures. Publications will also be carefully selected among those that are "hard to get" (such as tech reports) and "the classic" publications about a topic collected in one place.

Course notes updates and new material can also be downloaded from:
http://www.cpsc.ucalgary.ca/~mario/webpage/publ/2006/course-6-siggraph-06/

Course presenter information

(In alphabetical order):

Bill Andrews
Medical College of Georgia

Bill Andrews received his BA in Art in 1978 from the University of Texas at Austin and his MA in Biomedical Communications in 1980 from the University of Texas Health Science Center at Dallas. He is currently pursuing a PhD in Health Promotion, Education and Behavior at the University of South Carolina, Columbia. Bill began his professional career as a medical illustrator at the University of Arizona Health Science Center at Tucson before moving to Houston, Texas in 1981. He worked in varying capacities in the Texas Medical Center, including as Art Director for the Texas Heart Institute and as Manager of Medical Illustration & Graphic Design Services at the University of Texas M.D. Anderson Cancer Center. He was honored to join the MCG faculty in 1999. He currently serves as Education Program Coordinator, Gallery Director and Webmaster.

Bill has won numerous professional awards and has had works included in juried exhibits around the world. Bill has presented numerous seminars and workshops across the United States and in Canada, France, Italy and the Netherlands. He has been an active Professional member of the Association of Medical Illustrators since 1982. He has served as President of the AMI and on the Board of Governors, and is a Fellow of the AMI. Bill has been Editor of the national newsletter and is currently the Editor for the Source Book of Medical Illustration. He has been recognized as a Certified Medical Illustrator since 1993. In 1988, Bill became the founding President of the Vesalius Trust, an educational foundation supporting research and education in visual communications for the health sciences.

Stefan Bruckner
Vienna University of Technology

Stefan Bruckner is a research assistant and PhD candidate at the Institute of Computer Graphics and Algorithms, Vienna University of Technology, Austria. He received his master's degree in 2004 from the same University. His work was focused on volume rendering of large medical data sets. His current research is involved with interactive techniques for illustrative visualization, in particular in the context of volume visualization.

David S. Ebert
Purdue University

David Ebert is an Associate Professor in the School of Electrical and Computer Engineering at Purdue University and directs both the Purdue University Rendering and Perceptualization Lab and the Purdue University Regional Visualization and Analytics Center. His research interests are scientific, medical, and information visualization, computer graphics, animation, and procedural techniques. Dr. Ebert performs research in volume rendering, illustrative visualization, realistic rendering, procedural texturing, modeling, and animation, and modeling natural phenomena. Ebert was one of creators of the subfield of illustrative visualization, applying the principles of illustration to the problem of visualizing scientific data. Ebert has been very active in the graphics community, teaching courses, presenting papers, serving on and co-chairing many conference program committees, serving on the ACM SIGGRAPH Executive Committee and serving as Editor in Chief for *IEEE Transactions on Visualization and Computer Graphics.* Ebert is also editor and co-author of the seminal text on procedural techniques in computer graphics, *Texturing and Modeling: A Procedural Approach,* whose third edition was published in December 2003.

Bruce Gooch
Northwestern University

Bruce Gooch is a professor of Computer Science and Cognitive Science at Northwestern University. Illustrative Visualization, the research of Professor Gooch, combines computer graphics techniques for creating artistic imagery with the evaluation methods of perceptual psychology to provide effective data visualization. Gooch is the author of over twenty research papers in the areas of computer graphics and visualization. He is also a coauthor of the books "Non Photorealistic Rendering" and "Illustrative Visualization" published by A.K. Peters. Gooch has taught courses at SIGGRAPH 1999, 2002 and 2003 as well as an NPR course for Disney feature films.

Mario Costa Sousa
University of Calgary

Mario Costa Sousa is an Assistant Professor of Computer Science at the University of Calgary and coordinator of the Render Group, the Illustrative Visualization/NPR research wing at the Computer Graphics Lab at the University of Calgary. He holds a M.Sc. (PUC-Rio, Brazil) and a Ph.D. (University of Alberta) both in Computer Science. His current focus is on research and development of techniques to capture the enhancement and expressive capability of traditional illustrations, leading to a comprehensive formal illustrative visualization framework, methodology and software environment for computer-generated medical and scientific illustrations. This work involves topics centered on interactive modeling, shape analysis and expressive rendering for illustrative volume visualization and interactive simulations. Dr. Sousa has active collaborations with illustrative visualization research groups, medical centers, scientific institutes and with illustrators/studios affiliated with the Association of Medical Illustrators and the Guild of Natural Science Illustrators.

Nikolai Svakhine
Purdue University

Nikolai Svakhine is a Ph.D. candidate in Computer Science at Purdue University and will finish his dissertation on interactive medical and flow illustration in December 2006. His research interests include computer graphics and scientific visualization, in application to medical illustration and flow visualization. Svakhine has a BS in computational mathematics from Moscow State University, Russia, and an MS in computer science from Purdue University.

Don Stredney
Ohio Supercomputer Center

Don Stredney is Research Scientist for Biomedical Applications and Director of the Interface Lab at OSC (Ohio Supercomputer Center). In addition, Don is a member of the Experimental Therapeutics Program at the Comprehensive Cancer Center, and a former Associate Member of the Head and Neck Oncology Program at the Arthur G. James Cancer Hospital and Solove Research Institute in Columbus, Ohio. Don is also an adjunct instructor in the Department of Biomedical Informatics at OSU.

Don's research involves the exploration of high performance computing and the application of advanced interface technology for the development of more intuitive methods for interaction with large and complex multimodal data sets. His research interests lie in theories of representation, specifically the representation and interaction with synthesized biomedical phenomena for clinical and biomedical research and education. Don is co-recipient of the Smithsonian Institute/Computerworld 1996 Information Technology Leadership Award sponsored by Cray Research Inc. for the design and implementation of a computer simulation environment for training residents in the delivery of regional anesthesia techniques.

Don currently has funded projects through the National Institutes of Health, the National Science Foundation, the Biomedical Research and Technology Transfer Fund (Ohio) , and the Hayes Investment Fund (Ohio). In addition, Don has been an investigator on projects from the National Institutes of Health/National Library of Medicine, the National Institute for Drug Addiction, National Institute for Deafness and Other Communicative Disorders, National Institute on Occupational Safety and Health, Department of Defense, Medical Army Material Command, Department of Energy, Lockheed Martin, the National Institute for Disability and Rehabilitation Research, Harvard Medical School, Ameritech, the Committee on Institutional Cooperation of the Big Ten and University of Chicago, and Cray Research Inc.

Ivan Viola
Vienna University of Technology

Ivan Viola graduated in 2002 from the Vienna University of Technology, Austria with a MSc in the field of computer graphics and visualization. He received his PhD in 2005 for his thesis "Importance-Driven Expressive Visualization". Currently he is managing the exvisatio research project (www.cg.tuwien.ac.at/research/vis/exvisation) focusing on development of novel methods for automatically generating expressive visualizations of complex data. Viola co-authored several scientific works published on international conferences such as Visualization, EuroVis, and Vision Modeling and Visualization and acted as a reviewer for conferences in the field of computer graphics and visualization.

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