Recent Advances in Non-Photorealistic Rendering for Art and Visualization

Course Notes for SIGGRAPH 2002

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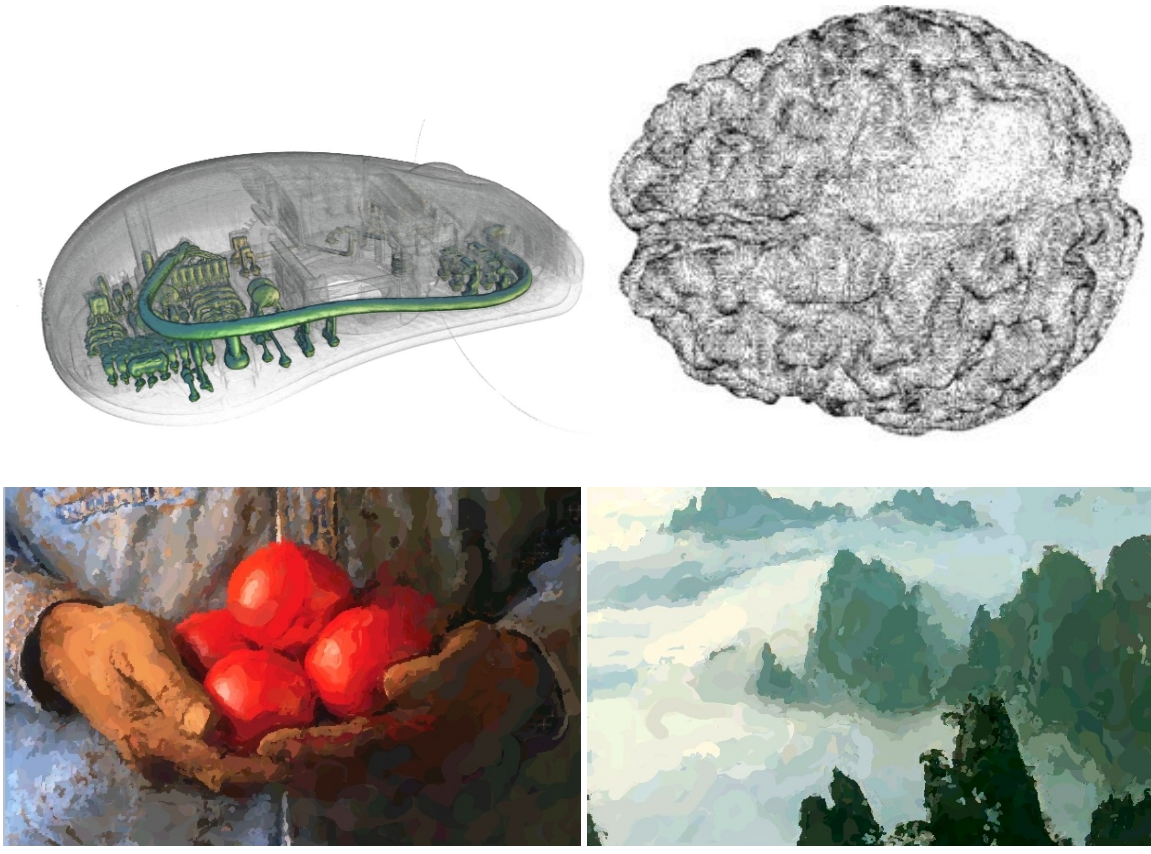

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BIOGRAPHIES

Aaron Hertzmann received his BA in Computer Science and Art & Art History from Rice University in 1996, and his MS and Ph.D. in Computer Science from New York University, in 1998 and 2001, respectively. In 2003, he will join the faculty of the University of Toronto computer science department. His research interests include non-photorealistic rendering and machine learning for computer graphics.

Aaron has worked at Microsoft Research, Mitsubishi Electric Research Lab, Interval Research Corporation and at NEC Research Institute. He is currently serving on the program committee for NPAR 2002, the second International Symposium on Non-Photorealistic Animation and Rendering.

Aaron has presented four papers at SIGGRAPH, including three on non-photorealistic rendering. He spoke in the SIGGRAPH 1999 course on Non-Photorealistic Rendering.

Victoria Interrante received her PhD in 1996 from the University of North Carolina at Chapel Hill, where she studied under the joint direction of Dr. Henry Fuchs and Dr. Stephen Pizer. From 1996-1998 she worked as a staff scientist at ICASE, a non-profit research center operated by the Universities Space Research Association at NASA Langley.

Her research focuses on the application of insights from perceptual psychophysics, art, and illustration to the design of more effective techniques for visualizing data. Some of her current projects include: the study of texture's effect on shape perception and texture synthesis for shape representation, the study of texture perception and classification for texture synthesis in multivariate data visualization and uncertainty representation, the segmentation and tracking of vortical structures in turbulent boundary layer data, and feature identification for gaze direction determination from uncalibrated photographs. Her work involves collaborations with researchers from a variety of departments at the University of Minnesota, including Electrical Engineering, Aerospace Engineering, Architecture, Mechanical Engineering, and Child Development. In 1999, she received a Presidential Early Career Award for Scientists and Engineers (PECASE) for her work on perceptual issues in data visualization.

She has participated in SIGGRAPH courses in 1997, 1998, 1999, and 2001 with a focus on the fundamental issues of visual perception for image synthesis and visualization.

Eric Lum received a B.S. and an M.S. both in Electrical Engineering from UCLA in 1997 and 1999, respectively. He is currently pursuing a Doctorate in Computer Science at the University of California at Davis. His research interests include non-photorealistic rendering and visualization, interactive visualization, and animation.

Eric has developed several rendering algorithms with the aim to enhance perception of subtle information for better understanding shape, structure and relationship. One algorithm is inspired by watercolor paintings and the other makes extensive use of motion cues. He recently presented his research results on interactive NPR at NPAR 2002. Eric has also participated in a joint effort between UC Davis and two Japanese research institutions for the development of a volume graphics cluster project.

Kwan-Liu Ma received his Ph.D. from the University of Utah in 1993. His research interests includes large-scale data visualization, user interface designs, and high performance computing. One of his current research projects is in NPR with a focus on hardware-assisted techniques. The excellent high performance and quality results he and his students have obtained motivates him to organize this course.

Kwan-Liu organized and taught courses for SIGGRAPH ’97, ’98, and ’99. The SIGGRAPH ’97 course’s contribution to CAL was selected as the most outstanding contribution.

He served as co-chair for the 1997 IEEE Symposium on Parallel Rendering, Case Studies of the IEEE Visualization Conference in both 1998 and 1999, and the first NSF/DOE Workshop on Large-Scale Data Visualization (May 1999). He also served as the guest editor for a theme issue (July 2001) of IEEE CG&A on Large-Scale Data Visualization. Presently, he serves as the secretary of the IEEE Technical Committee on Visualization and Graphics. In October 2000, Kwan-Liu received the PECASE (Presidential Early Career Award for Scientists and Engineers) award. In July 2001, he received the Schlumberger Foundation Technical Award.

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1. "*Texture Synthesis for 3D Shape Representation*", G. Gorla, V. Interrante, and G. Sapiro, (to appear) IEEE Transactions on Visualization and Computer Graphics, 2002.

2. "*Line Direction Matters: An Argument for the Use of Principal Direction in 3D Line Drawing*", A. Girshick, V. Interrante, S. Haker, and T. Lemoine, in Proceedings of the First International Symposium on Non-Photorealistic Animation and Rendering (NPAR 2000), Annecy, France,

June 5-7, 2000, pages 43-52.

3. "*Understanding Errors in Approximating Principal Direction Vectors*", J. Goldfcather and V. Interrante, (to appear) ACM Transactions on Graphics, 2003.

4. "*Paint By Numbers: Abstract Image Representations*", P. Haeberli, in SIGGRAPH '90 Conference Proceedings, August 1990, pages 207-214.

5. "*Image Analogies*", A. Hertzmann, C. E. Jacobs, N. Oliver, B. Curless, and D. H. Salesin, in SIGGRAPH 2001 Conference Proceedings, August 12-17, 2001, pages 327-340.

6. "*Illustrating Smooth Surfaces*", A. Hertzmann and D. Zorin, in SIGGRAPH 2000 Conference Proceedings, July 23-28, 2000, pages 517-526.

7. "*Fast Computation of Generalized Voronoi Diagrams Using Graphics Hardware*", K. Hoff III, T. Culver, J. Keyser, M. Lin, and D. Manocha, in SIGGRAPH '99 Conference Proceedings, August 8-13, 1999, pages 277-286.

8. "*Harnessing Natural Textures for Multivariate Visualization*", V. Interrante, Visualization Viewpoints, Editors: Theresa-Marie Rhyne and Lloyd Treinish, IEEE Computer Graphics and Applications, November/December 2000, pages 6-11.

9. "*Creating Evenly-Spaced Streamlines of Arbitrary Density*", B. Jobard and W. Lefer, in Proceedings of the 8th Eurographics Workshop on Visualization in Scientific Computing, 1997, pages 45-55.

10. "*Interactive Artistic Rendering*", M. Kaplan, B. Gooch, and E. Cohen, in Proceedings of the First International Symposium on Non-Photorealistic Animation and Rendering (NPAR 2000), Annecy, France, June 5-7, 2002. pages 67-74.

11. "*Art-Based Rendering of Fur, Grass, and Trees*", M. A. Kowalski, L. Markosian, J. D. Northrup, and L. Bourdev, R. Barzel, L. S. Holden, J. F. Hughes, in SIGGRAPH '99 Conference Proceedings, Augst 8-13, 1999, pages 433-438.

12. "*Artistic Silhouettes: A Hybrid Approach*", J. D. Northrup and L. Markosian, in Proceedings of the First International Symposium on Non-Photorealistic Animation and Rendering (NPAR 2000), Annecy, France, June 5-7, 2000, pages 31-37.

13. "*Interactive Pen-and-Ink Illustration*", M. P. Salisbury, S. E. Anderson, R. Barzel, and D. H. Salesin, in Proceedings of SIGGRAPH '94, July 24-29, 1994, pages 101-108.

14. "*Orientable Textures for Image-Based Pen-and-Ink Illustration*", M. P. Salisbury, M. T. Wong, J. F. Hushes, and D. H. Salesin, in SIGGRAPH '97 Conference Proceedings, August 1997, pages 401-406.

15. “*Weighted Voronoi Stippling*”, A. Secord, in Proceedings of the Second International Symposium on Non-Photorealistic Animation and Rendering (NPAR 2002), Annecy, France, June 3-5, 2002.

16. “*Fine Tone Control in Hardware Hatching*”, M. Webb, E. Praum, A. Finkelstein, H. Hoppe, in Proceedings of the Second International Symposium on Non-Photorealistic Animation and Rendering (NPAR 2002), Annecy, France, June 3-5, 2002.

17. “*Computer-Generated Pen-and-Ink Illustration*”, G. Winkenbach and D. H. Salesin, in Proceedings of SIGGRAPH ’94, July 24-29, 1994, pages 91-100.

Introduction

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There is a growing interest in Non-Photorealistic Rendering (NPR) methods because of its expressive power for illustrating shapes and spatial relationships as well as for generating artistic drawings and paintings. How we choose to portray a data set can have a significant effect on how accurately and efficiently we communicate with the viewers the information we seek to reveal. In many cases, NPR has been shown to be more effective than photorealistic rendering in communicating subtle information about physical structures or phenomena. We shall see a growing use of NPR for scientific visualization and illustrations as realtime NPR becomes available. Recent advances in painterly rendering have demonstrated that certain artistic styles can be mimicked. The ability to automatically generate arts and illustrations for more effectively communicating with scenes, ideas, or actions would allow content creators for education, films or video games to attain a new level of creativity.

We thus believe a large SIGGRAPH audience will benefit from a course on non-photorealistic approach for scientific visualization and artistic rendering. Courses on NPR related topics have been offered before, two in SIGGRAPH '99 and one in SIGGRAPH 2001. This course is unique since it addresses some of the most relevant aspects of the theoretical basis, software algorithms, hardware-assisted techniques, and applications for NPR. We have designed four concise lectures to motivate the audience, inform them with the state-of-the-art techniques and their applications, and offer them pointers for further research.

In the first lecture, Victoria Interrante will give an overview of the use of NPR rendering techniques in *scientific visualization*, followed by a presentation of the design, implementation and evaluation of several specific NPR methods drawn from her recent research. She will use hand-drawn examples from scientific application areas, such as medical line drawings and archaeological illustrations, as well as some examples from art/illustration to show when and how non-photorealistic representations can be effective in illustrating shapes and structures. She will present mathematical methods for calculating preferred stroke directions over a polygonally-defined mesh, and techniques for synthesizing a high-resolution oriented texture over a surface mesh. She will also discuss results from two controlled observer experiments intended to investigate the effects of surface texture characteristics on 3D shape perception.

In the second lecture, Aaron Hertzmann will describe *stroke-based NPR* methods. This area incorporates a wide variety of methods for pen-and-ink, painterly, and visualization renderings of images, 3D and video, and can be quite challenging to the beginner. In order to help make sense of things, he will present a unified framework for stroke-based NPR and draw attention to the common principles of the area. In particular, stroke-based rendering describes methods where discrete strokes are placed

in order to match some predetermined constraints, such as matching a predetermined image color or intensity. The specific algorithms used depend directly on the form of these constraints.

In the third lecture, Aaron Hertzmann will describe recent advances in *example-based NPR*, where NPR algorithms are designed based on hand-made examples. For example, a painting image filter might be created based on a scanned painting made by a famous artist. This approach is far easier than explicit methods (such as stroke-based rendering), since it is very difficult to write a function that describes the technique of a famous artist; however, only some aspects of a style may be captured. He will survey several recent methods developed in this area, and describe the method of "Image Analogies" in detail.

Finally, Eric Lum will present a suite of *hardware-accelerated NPR* techniques, making extensive use of the advanced features of commodity graphics cards, for interactive visualization of volume data. In addition to the typical view and rendering parameters, each NPR technique adds its own set of parameters that must be specified. Often the user does not know what type of rendering style is desired, only through experimentation can parameters be found suited for their particular application. He will show how *interactive NPR* facilitate this parameter specification process, and how different rendering styles and NPR techniques may be freely mixed with interactive control. Both the benefit and cost of including each NPR technique will be discussed. He will also describe how to use a cluster of PCs to render large-scale volume while maintaining high interactivity and image quality for large-format display.

For the specific approaches covered in the lectures, examples and previous successes, as well as some of their limitations, are discussed. Where techniques are unavailable, or not yet proven, opportunities and promising research directions are offered. In this course notes, each chapter begins with a summary of the corresponding lecture. We also provide comprehensive bibliographies, as well as including a collection of technical reports and previously published papers relevant to the subjects discussed in this course. We hope you find this course notes helpful.

Kwan-Liu Ma
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