Research Statement

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Motivation. Research in an academic environment provides a unique opportunity to solve problems and vision the technology of the future. My current research interests are concerned with the development of methods and algorithms for image synthesis and generation. Computer generated imagery is becoming ubiquitous in all segments of life ranging from entertainment such feature films and computer games to more serious applications like medical and scientific data visualization. In the past two decades there have been many advances in the field of computer graphics and visualization. Despite numerous technological advances in both graphics hardware as well as algorithms, there are many challenging problems that still limit realism and effectiveness of computer generated imagery. My main research goal is to create tools and algorithms for efficient generation of compelling and effective imagery and animations for a variety of applications.

Research Philosophy. I do believe that a strong understanding of the problem is extremely important. There are numerous fields related to computer graphics that produced a great body of work that could be applied to computer graphics and provide insights on how to improve existing algorithms and design new approaches. While related areas of science may strive for extreme accuracy, the ultimate test of computer generated imagery is plausibility and predictability and rarely accuracy. While vast body of work from related areas could be readily applied to computer graphics problems, they are often too complex, slow and cumbersome to use. A big part of my early research work in simulating natural phenomena and illumination has been studying the problem, trying to understand the physical nature of it and design a model that would either simulate the problem or solve it using mathematical techniques. While this approach has often provided satisfactory solution it still yielded methods that were still hard to use and slow. Understanding the problem and gaining insights has allowed me to made approximations that were more user friendly and faster to compute without sacrificing visual quality. For example, light transport in water is governed by scattering and numerous optical and other physical properties that are hard to control for a non-expert user. However, as a part of that research I encapsulated appearance of water with only a few meaningful and intuitive parameters. This approximation process often involves manipulating underlying mathematical equations and physical model which I greatly enjoy. My dissertation research has involved making approximations to the light transport equation in natural environments and I intend to pursue this methodology further to find more approximate methods to core computer graphics problems such as global illumination and reflectance. Human visual perception is increasingly gaining popularity in graphics community. Human perception and the way our brain processes information should become part of these approximate methods and should play significant role together with mathematics and physics. I also strongly believe that contributions to computer graphics field can often be made without pretty pictures that often obfuscate real research issues. Therefore, I greatly value theoretical work, because theoretical investigations could lead to some very practical suggestion on how to improve existing methods or design yet unexplored methods. Fundamental aspects of image generation and human perception are worth studying because they may provide new insights for problems we are facing now.

Previous Work. My main focus of research has been realistic image synthesis. This involves several different subjects: global illumination (the propagation of light or energy throughout the environment), local illumination(the way a material or BRDF reflects incident light back into the environment), rendering (the projection of an environment into an image) and visual perception (understanding how the eye/brain perceives an image, what information is important, what can be safely discarded). I have worked on problems in the past that dealt with reflectance models for surfaces (microfacet models) [1] and materials that exhibit significant subsurface or volumetric transport [4, 5] and provide analytic approximations for it. I have also worked on illumination models for volume rendering[2, 5] that can be used for a variety of applications including feature films. Visualization of multifield data is still in not widespread. I collaborated on an interactive algorithm for medical data visualization that employs analytic approximations for computing volume integral[3].

Future Directions. I would like to explore a broad range of topics both within traditional scientific visualizatio and computer graphics as well as interdisciplinary areas that improve efficiency, quality and effectiveness of depiction while exploiting fields ranging from computer science to psychology and perception. I briefly outline some types of research I would like to pursue.

Dealing with Geometric and Illumination Complexity. Most existing rendering algorithms are inadequate when dealing with vast amount of geometric complexity and illumination. When the scene geometry is generated at run-time with procedural methods as opposed to being read from a file, many rendering algorithms and illumination models fail. While on-the-fly generation of geometry enables more geometric complexity in a scene, global illumination algorithms require the entire scene geometry to be in memory. I want to develop global illumination methods and approximations that can handle large geometric and illumination complexity. This entails building some intelligence into the renderer, clever visibility queries and decomposing global illumination problem into something more local yet still plausible and predictable. I have been experimenting with some possible approaches during my dissertation research. I have also been involved with the Real Time Ray Tracing project at the University of Utah that tackles geometric complexity and efficiency issues with carefully chosen data structures and streamlined implementation on a shared memory multiprocessor.

Scientific Visualization with Science in Mind. Too often, visualization algorithms do not consider the data that is being visualized or the underlying science that was used to generate the data. If data visualization is to be a useful tool in real world and not just a collection of pretty pictures, science must be considered in developing visualization algorithms. Effectiveness of visualizations is very rarely considered. Furthermore, visualizations are not very useful if error in the data cannot be properly visualized. I would like to collaborate with scientists and medical doctors in developing algorithms that can alleviate problems with current techniques: quantifying effectiveness of visualizations, representing errors and uncertainties in visualizations.

Time-dependent Multifield Visualization. Currently, most interactive visualization techniques involve static data. The predominant method for visualizing time-dependent data is first to select a viewpoint and then render entire data from the same viewpoint. This severly undermines the effectiveness of exploratory visualization. I want to work on effective and interactive algorithms for visualization of time-varying data. The challenges are numerous due to large amount of data that must be processed at fast rates. Many different approaches could be used to make this possible. First, multicore and distributed computer architectures provide necessary computational power. Second, data structures must be designed such that the computational power is not wasted. Third, data must be analyzed and processed such that redundancies are eliminated and yet no information is discarded. Similar visualization challenges arise in multifield data. Experimental data is often multifield in nature and so is data generated with weather or CFD simulations. The challenges are numerous, but the possibilitis for multidisciplinary collaboration between faculty and students makes this and exciting area of research.

Stylized Rendering And Information Visualization. There are many applications where images do not have look realistic to convey information, mood or emotions. I have always been fascinated by the use of images in science and the methods used for scientific illustration. Stylized rendering has been used by artist for centuries to hide distracting overwhelming detail and guide the viewer towards the important information. It is illusory to expect automatic knowledge transfer and automatic extraction of what is important in a data set and what is not. However, I would like to explore stylized rendering algorithms combined for domain-specific knowledge transfer to depict data in the most informative and visually pleasing way. I have done work in visualizing terrain by creating obliquely viewed panorama maps from human perspective that appeal to a wide range of map-readers. This was done by extracting information from various data sets and allowing user to interactively guide panorama map construction process. I would also like to explore information visualization. For example, data that has many degrees of freedom is hard to visualize. For instance, music or movie recommendation systems relate songs or movies based on many different parameters (artist, genre, language, etc.). Currently, it is very difficult to visualize this high dimensional space and navigate in it. I would like to explore ways to visualize information that would be otherwise hard to understand by enumerating methods used by skilled artists and casting them to stylized rendering approaches.

To conduct productive research I am looking forward to learning much more than I know now. Interaction with peers, students, and learning more about what other research areas have to offer will all contribute to new ideas and exciting research. Computer graphics is the area full of exciting problems and I look forward to working on them.

Further information about my current research and electronic versions of my publications are available at http://www.cs.columbia.edu/˜premoze

References

[1] Michael Ashikhmin, Simon Premože, and Peter Shirley. A microfacet-based brdf generator. In *Proceedings of ACM SIGGRAPH 2000*, pages 65–74, July 2000.

[2] J.M. Kniss, S. Premože, C. Hansen, P. Shirley, and A. McPherson. A model for volume lighting and modeling. *IEEE Transactions on Visualization and Computer Graphics*, 9(2), April - June 2003.

[3] J.M. Kniss, S. Premože, M. Ikits, A. E. Lefohn, C.D. Hansen, and E. Praun. Gaussian transfer functions for multi-field volume visualization. In *IEEE Visualization 2003*, pages 497–504, October 2003.

[4] Simon Premože and Michael Ashikhmin. Rendering natural waters. *Computer Graphics Forum*, 20(4):189–200, 2001.

[5] Simon Premože, Michael Ashikhmin, Jerry Tessendorf, Ravi Ramamoorthi, and Shree Nayar. Practical rendering of multiple scattering effects in participating media. In *Rendering Techniques 2004: 15th Eurographics Workshop on Rendering*, pages 363–374, June 2004.