Research Statement for Matthew Kaplan, PhD

Academic research is offers a fascinating opportunity to shape the technology of the future. My own research has focused non-photorealistic rendering (NPR). Whereas traditional rendering attempts to photorealistically simulate the world around us, NPR includes many diverse topics such as simulating traditional artistic media for both rendering and user interaction and exploring alternative methods of communicating pictorially or visualizing data. The diversity of these topics promotes the constant exploration of new material and mitigates the urge to confine oneself to a narrow research area. My three primary goals are: First, to quantify and express qualities of the aesthetic and artistic through rendering. Second, to find ways to more effectively communicate through images by optimizing the perceptual qualities of the visualized data. Third, I wish to find new techniques for simulating traditional artistic media and the fine arts.

Artistic and Expressive Rendering

Despite the fact that there are many how-to books describing how to draw and paint, there are very few that attempt to describe technically or algorithmically the aesthetic principles that constitute good art. These concepts are discussed in broad, general or emotional terms in most art books. Therefore, a major goal of my research has been to discover new ways to quantify and recreate aesthetic and artistic principles.

At NPAR 2000 [8], my coworkers and I presented work on a unifying framework for many different interactive artistic effects. Using automatically generated view-dependent runtime geometry, our method was able to encompass oil painting, pen and ink, colored pencil, and included the rendering of artistic primitives in a stylized manner in order to emulate the stylizations of such artists as Dr.Seuss. In 2002 [10], I presented a method that used wavelets to analyze images in order to derive an economical set of multiresolution brush strokes. At CA 2005 [3], I presented a method for producing expressive, stylized renderings automatically. This method quantifies aesthetic principles and optimizes the lighting configuration of a scene in order to best match those principles. This allows the production of predictable stylizations automatically and allows the user to more easily communicate based on specific style decisions.

Media Simulation

Simulating artistic media, such as pen and ink, pencils and paints is a major component of most NPR rendering systems. The quality of the simulation is an aid to the sense of fidelity to the target art form. In 1999, I collaborated on a project that developed one of the first haptic painting simulations, which was published at VR '99 [8]. At CA 2005 [4], I presented a program that simulated the construction of canvas and paper models.

Animating 3D scenes with 2D media presents a unique problem since there is always an inherent contradiction between the fact that media is created in 2D and the motion fields describing the camera and object transformations exist in 3D. I addressed this briefly in [7] and at length in [4]. There, my dynamic canvas model was an attempt to solve the “shower door” problem using a new texture synthesis technique. I extended this paradigm in 2006 during collaboration of interactive watercolor rendering, where we showed how to recreate noise and turbulence textures whose features existed in 2D yet whose motion matched the 3D motion fields of the scene exactly.

It has previously been noticed that most NPR research does not contribute to canon in the way that, for example, ray tracing research contributes to a large, single body of work. In 2003, I developed a media simulation package that is used for NPR programs in-house at the University of Utah. In 2006, I developed a large system whose goal was to integrate many NPR techniques within a single framework known as NPRlib. The intermediate purpose of this system was to explore the possibilities that occur when mixing NPR styles to visualize speculative versus concrete data, such as in architectural and medical rendering. The results of which are to be published next year. We intend to make this project open source. Currently, we are preparing a book describing all of the techniques and code presented. This is intended as a “NPR recipes in C++” style book.

Patterns, Tilings and Ornament

Object decoration based on tilings and patterns has had an enormous influence in the history of art. It is found frequently on decorative objects, buildings and in books, yet the research into this area has not been proportional to its influence. At the Rendering Workshop 2003 [6], I presented a paper on automating computer generated Celtic decoration. This allowed the user to quickly create complex Celtic artwork with minimal input and design time. My coworkers and I extended this work and presented a paper at Pacific Graphics 2004 [5] that described a method for tiling 3D meshes with consistent low distortion patterns of Celtic knots using geometry images.

Sketching based Modeling and Interfaces

Illustration is a widely used form of communication and sketching is the preferred form of initial design in many important fields (such as architecture). Sketches are quick to create, and most people have an intuitive, natural facility with basic drawing. Furthermore, drawing comprehension seems to be inherent to human perception and some types of information may be more easily conveyed or emphasized with drawings. I have explored sketch rendering techniques frequently over the years, and presented a new method for producing drawings in my dissertation [9]. In 2006, I presented a paper at SBIM on creating models automatically from input drawings using minimal user intervention. This problem is underconstrained, since input drawings essentially lack an entire dimension of data, and the field crosses the boundaries of computational geometry and modeling, visual perception, user interfaces, and NPR. This was given one of the Best Paper awards for the conference. An expanded version will be published in Computer Graphics monthly next year.

Future Work

I would like to explore a broad range of topics in NPR and traditional graphics. Here I outline several avenues for future research projects, several of which are suitable for PhD topics. Effective visualization of data has been a perennially hot topic in scientific visualization, architectural rendering and other fields. NPR has shown itself to be an effective alternative to photorealistic pictorial communication and the NSF, DARPA and NIH have given many grants supporting research into NPR visualization, animation and modeling techniques (For example, NSF MIP-9420352, DARPA F33615-96-C-5621).

A theoretical and practical framework for determining the effectiveness of aesthetic and expressive renderings should be developed, taking into account visual perception and classical artistic literature. This would provide a basis for exploring the effectiveness of mixing NPR techniques. One of the key goals of such research is to provide a concrete analysis, quantification and expression of the notion of *style*, as I briefly discuss in [3].

Texture synthesis for 3D->2D motion field matching has been explored for specific applications [2,4]. I intend to develop a general theory of all such mappings for any dimension, along with a practical synthesis algorithm and analysis of what types of textures can be effectively modeled with such techniques and in what instances these algorithms apply. Such a theory would be useful for animating a wide range of media simulations.

GPUs offer a new ability for data visualization and interactive geometry creation (as seen in [7] as well as traditional rendering. New techniques are required not only for transferring classic NPR algorithms to the GPU but also for new innovations.

At the moment, model interpretation from sketches requires a human operator for analysis and verification. Efforts to minimize the amount of user interaction required are ongoing. These range from reduction of the effective problem range (to normalon or polyhedral) to the use of overly general heuristics which are prone to numerous failure cases. Methods to surmount these obstacles would be invaluable to designers who are already producing sketches in their initial design phase.

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