Eurographics Symposium on Rendering (2004)
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Rendering Evolution at Industrial Light & Magic

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Abstract

From Jurassic Park to Van Helsing, the rendering technologies at ILM have evolved over the last 10 years, both to satisfy the high demands of our clients and also those of the general public. State-of-the-art rendering techniques such as volume rendering, ambient occlusion, image-based rendering, sub-surface scattering and global illumination are now in common use. This summary will give a brief history of how rendering schemes came to be deployed (and fairly often pioneered) at our facility and the challenges they brought with them.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Methodology and Techniques

1. Introduction

Since its creation by George Lucas in 1979, the Computer Division of Industrial Light & Magic is responsible for not only some of the most stunning images in motion pictures, but also of some major technical breakthroughs. In section 2, we give a brief account of some of the now famous technical results that the company has accomplished. Then, in section 3, we look towards the future of rendering and realize that Global Illumination in itself is not enough.

2. Timeline

The dates mentioned correspond to the beginning of the research, not to the release of the films.

2.1. Paleozoic Era

Eons ago (in the early 80s), Pixar, then part of LucasFilm, develops the Reyes architecture, whose main strengths lie in its ability to support:

- rendering of hundreds of millions of simple geometric primitives making up photo-real scenes [CCC87]
- motion blur and stochastic sampling [Coo86]
- programmable shading [HL90].

This work later leads to the Renderman® product and specification.

2.2. Mesozoic Era

Beginning of the 90s, ILM devises a way to stitch surfaces together in a smooth way. This process is called "socking" and is exhibited to great effect in *Terminator 2*. Also on this show, to help "stick" the projections during the 3d morphs, ILM makes heavy use of "Pref reference geometries", an association of static variables for each vertex P (Pref being in essence an extra set of coordinates, that the renderer can interpolate alongside P).

Enveloping comes to *Jurassic Park*'s dinosaurs, as a means to create some skin deformation. Organic and photo-realistic creatures also require the development of large, complex shaders. These shaders are controlled primarily through painted layers (which rely on a novel tool for 3d texture creation called "viewpaint"). They contain a lot of procedural noise for bump and/or wetness simulation. Displacement is employed, with great fear of the "Cracking God", for improving the geometric details. At this stage, the illumination model is mainly Cook and Torrance [CT82].

2.3. Cenozoic Era

Fur. After some brute force instantiation of 4×2 patches for "Kitty" in *The Flintstones* (1993), a dedicated hair primitive renderer is written for *Jumanji* (1994). Still in use today, "prender" works by procedurally generating curve splines from some dedicated shaders, maps and/or guide hairs, that the artist controls. Key to the look of the Lion and

later *Mighty Joe Young* (1997) is the development of volume shadows. "Fake" fur comes as a natural optimization of our hair rendering technique for *101 Dalmatians* (1995) [Gol97].

In parallel, "prender" is equipped with more primitives like particles and "blobbies", again with the idea that the data amplification should happen procedurally at rendering time. This way we are able to generate such complex phenomena as the tornadoes in *Twister* (1995) and the underwater events of *Daylight* (1995).

Rendering, materials and light properties are becoming canonized. We devise a whole new way of dealing with intensities and grey scales, which allow better prediction of image densities on film. Light probes (grey spheres and chrome spheres) also become mandatory on location as reference elements.

2.4. Industrial Age

A long time ago (1998), in a galaxy far far away™, ILM is forced to revise its overall pipeline in order to produce more than 1800 shots, some of them entirely computer generated, for *Star Wars Episode 1: The Phantom Menace*. Some notable new rendering advances (besides throughput) include:

- terrain rendering for the "Pod Race" sequence
- crowd rendering (procedural primitives and level of detail) for the ground battle sequence [HS01]
- a brand new job scheduler to take better advantage of our growing render farm.

Water suddenly becomes a new topic for us with *The Perfect Storm* (1999). A variety of techniques are thrown together to render the ocean surface. For *Mission to Mars* (1999), some volume rendering techniques are perfected to achieve the "burning bush" finale of the movie.

2.5. Modern Age

The new millenium marks the advent of image based rendering with the development of the ambient occlusion technique for *Pearl Harbor* and *Jurassic Park 3* (2000) [Lan02]. Also key to this development is the creation of a new high dynamic range file format called OpenEXR (www.openexr.com).

The following year sees some major effort applied to incorporation of sub-surface scattering techniques within our pipeline, resulting in "Dobby"'s skin for *Harry Potter and the Chamber of Secrets* (2001). Some time later, during the production of *Terminator 3* (2002) and *Van Helsing* (2003), the method is perfected [Her03].

We are now incorporating area lighting and global illumination into our bag of tricks.

3. Challenges with Global Illumination

Lighting Technical Directors have been used to working around the limitations of the existing illumination models for so long that it is very hard for them to employ more "natural" tools. For instance, when sub-surface scattering was introduced, the artists would still tend to place rim lights on the side of the subject (as opposed to the back of it), just at they would when the bleeding of light was impossible. A new concern of ours is (re)training.

Algorithmically, global illumination (in the broad sense of the term) tends to be fairly expensive if one wants stable (over time) and relatively noise-free images. People have to get used to such things as photon mapping and/or irradiance caching as a means to address those issues. So, even though the light behaviour is more "correct" and artists need spend less time adjusting bounce lights and such, those techniques bring their own collection of idiosyncracies.

Furthermore, over the years, in-house tools have been custom made to work with the idea of shadow buffers and multiple rendering passes. We do not wish to remove any of those features, but it is important to expose ray-tracing concepts with an easy and comprehensible user interface. This leads us to the re-engineering of our lighting tool.

We have to design not only a tool, but a comprehensive new work-flow, spanning all the steps between data capture on location through to film printing in the lab. This is where the gap between theory (the research community) and practice lies. It is our task to adapt these new tricks into an easy set of editable components. Remember here that, even if our Computer Graphics models were able to reproduce fully that which Mother Nature performs, we would not be removed from the need to tweak our renders to satisfy the demands of our clients.

4. Conclusion

Rendering techniques are evolving all the time, and at a very rapid pace. We have shown that, for them to be fully embraced by artists in production, novel and elegant user interfaces need to be introduced.

Acknowledgments

We want to thank ILM's management for nurturing an environment where new computer graphics techniques can be explored. We are also grateful to Miles Perkins and ILM's PR department, for allowing the inclusion of images.

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Figure 1: *Terminator 2 ©1991 Carolco & TriStar.*

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Figure 2: *Jurassic Park ©1993 Amblin Entertainment and Universal Studios.*

Figure 3: *Mighty Joe Young ©1998 Disney.*

Figure 4: *Star Wars Episode 1: The Phantom Menace ©1999 Lucasfilm Ltd. & TM.*

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Figure 5: *Pearl Harbor ©2001 Touchstone Pictures.*