MINISTRY FOR DEVELOPMENT OF INFORMATION TECHNOLOGIES AND COMMUNICATIONS OF THE REPUBLIC OF UZBEKISTAN

TASHKENT UNIVERSITY OF INFORMATION TECHNOLOGIES

«APPROVED »

Head of department: Mukhamadiev. A.SH

«____»_____2016

GRADUATE QUALIFICATION WORK

Theme: Analysis of two popular standalone rendering software: Vray and Maxwell

Graduating student	_____ (signature)	Shoraimov.X (surname)
Supervisor	_____ (signature)	_____ (surname)
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Consultant on safety	_____ (signature)	_____ (surname)

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TASHKENT 2016

MINISTRY FOR DEVELOPMENT OF INFORMATION TECHNOLOGIES AND COMMUNICATIONS OF THE REPUBLIC OF UZBEKISTAN

TASHKENT UNIVERSITY OF INFORMATION TECHNOLOGIES

Faculty: Television technologies

Department: Audiovisual technologies

Direction (specialty): 5330400 Computer graphics

«CONFIRM»

Head of department: Mukhamadiev. A.SH

«____»_____2016

TASK

On final qualifying work

_____

(surname, name, patronize)

1. Theme: Analysis of two popular standalone rendering software: Vray and Maxwell

2. Confirmed by University order. № 60 - 18 on the 19th of January 2016 year.

3. Deadline for finishing work: 05.06.2016

4. Source data to work: Literature on corresponding subjects, surveys International practice and Rendering software.

5. Contents and explanations of work (executive section): Introduction, The State of Rendering, Major players, Comparison of rendering software Vray and Maxwell Practical work, Life safety issues, Conclusions, References.

6. List of graphic materials: Presentation slides of Microsoft PowerPoint program.

7. Date of task issue: 20.01.2016

Scientific adviser _____ (signature) _____ (surname)

Task receiver _____ (signature) _____ (surname)

8. Consultants on separate parts of final qualifying work

№	Units	Name of instructor	Deadline	
			Task given	Task received
1	Introduction		20.01.2016	10.03.2016
2	The State of Rendering		11.03.2016	29.03.2016
3	Major players		01.04.2016	18.04.2016
4	Using software Vray software Maxwell		20.04.2016	08.05.2016
5	Comparison Vray and Maxwell		11.05.2016	25.05.2016
	Life safety issues		26.05.2016	28.05.2016
7	Conclusion		01.06.2016	04.06.2016

9. Schedule of work implementation

№	Title	Deadline	Mark of instructor
1	Introduction	20.01-10.03.2016	
2	The State of Rendering	11.03-29.03.2016	
3	Major players	01.04-18.04.2016	
4	Using software Vray software Maxwell	20.04-08.05.2016	
5	Comparison Vray and Maxwell	11.05-25.05.2016	
6	Life safety issues	26.05-28.05.2016	
7	Conclusion	01.06-04.06.2016	

Graduater _____ _____ «_____»_____ 2016
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Scientific adviser _____ _____ «_____»_____ 2016
(signature) (surname)

Annotation

The graduate qualification work is dedicated to analyze and solve actual problems rendering objects, details, animations and so on, which were created by using different programs. There is spoken about rendering states, and today's popular rendering software and their advantages and disadvantages. In the graduate qualification work. There is shown differences between **Maxwell** and **Vray** and analyzes as a schedule in the main part of this graduate qualification work.

Mazmunnoma

Ushbu bituruv malakaviy ishi turli dasturiy vositalar yordamida yasalgan obyektlar,detallar, animatsiyalar v.k.z larni render qilishning dolzarb muammolari va ularning maqbul yechimlariga bag'ishlangan.Bitiruv malakaviy ishida render jarayoning o'ziga xos va umumiy hususiyatlari,hozirgi kundagi eng ommabop render dasturlari va ularning afzalliklari haqida so'z ketadi. BMIning asosiy bo'limida hozirgi kunda eng ommabop bolgan render dasturlari **Maxwell** va **Vray** ning o'zaro farqlari tahliliy shaklda taqdim etilgan.

Аннотация

Данная выпускная квалификационная работа посвящена актуальным проблемам рендера объектов, деталей, анимации и.т.д которые были созданы с помощью разных программных средств. В этой работе говорится

об особенностях настроек рендера, их достоинствах и недостатках. В главной части ВКР приведен анализ популярных на данный момент программных средств рендеринга как **Maxwell** и **Vray**.

CONTENTS

Introduction

Legislative documents of the Republic of Uzbekistan Informatization, computerization and communication technologies.

The Government of the Republic of Uzbekistan Islam Karimov and President pays great attention to the development of informatization computerization and information and communication technologies in our republic. This is evidenced by laws and Resolutions adopted on these issues in recent years.

In May 2001 speaking at the fifth session of the Oliy Majlis, President Islam Karimov set specific targets to achieve Uzbekistan to introduce high levels of computerization and information technology in the production of programs and schools Universities, in people's daily lives.

To solve the problems on the computerization of society development Information Technology May 30, 2002 adopted a decree President of the Republic of Uzbekistan "On further development computerization and introduction of information and communication technologies. "

Implementation of the measures identified by the Decree, will establish national informatization conditions for mass introduction to the economy and the life of every member of society computing and information technology, increase competitiveness of the national economy on the world market.

Pursuant to the Decree of the President of the Cabinet of Ministers adopted 6 June 2002 decree "On Measures for Further Development computerization and the introduction of information and communication technologies. " Approved program of computerization and ICT for 2002-2010, in which sets targets for Telecommunications Development and data transmission, use of resources, create your own Internet sites.

Basis for making these important decisions was needs of national economy and society in rapid exchange information, access to global information resources, the need for computerization of educational processes.

Program was provided for the construction of new facilities Telecommunications; by 2005 the number of international channels at the regional level should rise to 50,000. By 2010 the number of schools with Internet acces increase in 10-15 times Among the priorities identified measures to develop software, development of domestic production computer technology.

To perform these tasks was formed special Coordination Council for development of computerization and information and communication technologies. The Council was requested to prepare a program for the period up to 2010: on development of a national network of telecommunications and data transmission; introduction of electronic technologies in public administration; development of electronic commerce. In order to develop the necessary legal acts for development of information Service Centre was established development and introduction of computer and information technology.

These measures will be enhanced active role telecommunications, computer and information technology increase efficiency in the economy of the republic, to equip activity and life of people committed technical views facilities and services in the successful integration of the country into the world processes.

The need to ensure the safety of information and database data was the basis for the adoption of December 12, 2002 Law "On the principles and guarantees of freedom of information." Law consists of 16 articles. The main objectives of the Law – Enforcement principles and guarantees of freedom of information, the right of every receive, distribute, and store information and ensuring information security and information security of the individual, society and state.

December 11, 2003, the Law of the Republic of Uzbekistan "On informatization". The law includes 23 articles. The purpose of the law - regulation of relations in the field of information, use of information resources and information systems. Article 3 of the Act provides the basic concepts of information, information resource, information technology, information system.

The Act is the State policy information, which is aimed at creating a national information system, implementation of constitutional rights every member of society access to information resources, creating a unified information space of the Republic Uzbekistan, the formation of the state information resources, etc.

The law defines what is included in the national information system and thereby it is created.

Individual articles are devoted to the organization of the Law protection of information resources and information systems.

President Islam Karimov in his writings and speeches repeatedly points to the need to develop computerization and introduction of information and communication technologies in all spheres of activity. In the preface of his book "The global financial-economic crisis, ways and measures to overcome in Uzbekistan, "he writes:" ... support banking system, modernization, maintenance and update diversification of production, widespread adoption of innovative technologies - a reliable way to overcome the crisis and Uzbekistan to the new frontiers of the world market ".

In his report "Our main task - further development the country and the welfare of the people "29 January 2010 on meeting of the Cabinet of Ministers of Uzbekistan Islam Karimov said: **"Talking about development of communication systems, particularly noteworthy that strategic importance, which has for its development high-tech telecommunications industry. Today it is impossible to imagine life without computers, information technology, the Internet, cellular telephone Communications "**. Under the conditions of Uzbekistan advanced industries and productions certainly should have priority development branch of modern information technologies and systems telecommunications.

Report of the President of Uzbekistan Islam Karimov at a meeting of the government on the basis of socio-economic development of the country in 2010 and the main priorities for 2011 "All of our programs and aspirations - for the

further development Country and welfare of the people "a lot of attention also paid to the development and implementation of information technologies in educational process. In particular, states that: "In to implementation of the learning process and communication networks Internet technologies .... to complete the construction of a national network "Electronic Education" ... to provide connectivity in 2011 to integrated computer information network of all higher education institutions of the Republic, and in the future - and academic lyceums professional colleges. " "Currently prepared and will soon be adopted by the Program development of higher education institutions in 2011-2016. The most important objective of the program - further strengthening the material and technical equipment base and higher school with modern teaching, Laboratory and scientific equipment, eventually – in improving training programs, implementing quality new approaches and training to meet the increased requirements of time ".

Finally on the 4th of february in 2016 there was the next law by the President on changing " THE STATE COMMITTEE FOR COMMUNICATION, INFORMATIZATION AND TELECOMMUNICATION TECHNOLOGIES OF THE REPUBLIC OF UZBEKISTAN" **to** THE MINISTRY FOR DEVELOPMENT OF INFORMATION TECHNOLOGIES AND COMMUNICATIONS OF THE REPUBLIC OF UZBEKISTAN."

If you're new to 3D, you might have wondered ***what exactly is rendering?.*** To casual fans and folks who are new to 3D production, the concept can initially seem as cryptic and unapproachable as hieroglyphics. While the sophisticated math

and science behind rendering is far beyond the scope of this article, the process plays a crucial role in the ***computer graphics development*** cycle. I will not go into too much depth here, but no discussion of the CG pipeline would be complete without at least mentioning the tools and methods for rendering 3D images.Rendering is the most technically complex aspect of 3D production, but it can actually be understood quite easily in the context of an analogy: Much like a film photographer must develop and print his photos before they can be displayed, computer graphics professionals are burdened a similar necessity.When an artist is working ***on a 3D scene,*** the models he manipulates are actually a mathematical representation of points and surfaces (more specifically, vertices and polygons) in three-dimensional space.The term ***rendering*** refers to the calculations performed by a ***3D software package's*** render engine to translate the scene from a mathematical approximation to a finalized 2D image. During the process, the entire scene's spatial, textural, and lighting information are combined to determine the color value of each pixel in the flattened image.

Two Types of Rendering: There are two major types of rendering, their chief difference being the speed at which images are computed and finalized.***Real-Time Rendering:*** Real-Time Rendering is used most prominently in gaming and interactive graphics, where images must be computed from 3D information at an incredibly rapid pace.

Interactivity: Because it is impossible to predict exactly how a player will interact with the game environment, images must be rendered in "real-time" as the action unfolds.

Speed Matters: In order for motion to appear fluid, a minimum of 18 - 20 frames per second must be rendered to the screen. Anything less than this and action will appear choppy. The methods:

Real-time rendering is drastically improved by ***dedicated graphics hardware*** (GPUs), and by pre-compiling as much information as possible. A great deal of a game environment's lighting information is pre-computed and "baked" directly into the environment's texture files to improve render speed.

Offline or Pre-Rendering: Offline rendering is used in situations where speed is less of an issue, with calculations typically performed using multi-core CPUs rather than dedicated graphics hardware. Predictability: Offline rendering is seen most frequently in animation and effects work where visual complexity and photorealism are held to a much higher standard. Since there is no unpredictability as to what will appear in each frame, large studios have been known to dedicate up to ***90 hours render time*** to individual frames. **Photorealism:** Because offline rendering occurs within an open-ended time frame, higher levels of photorealism can be achieved than with real-time rendering. Characters, environments, and their associated textures and lights are typically allowed higher polygon counts, and 4k (or higher) resolution texture files.

Rendering Techniques: There are three major computational techniques used for most rendering. Each has its own set of advantages and disadvantages, making all three viable options in certain situations.

Scanline (or rasterization): Scanline rendering is used when speed is a necessity, which makes it the technique of choice for real-time rendering and interactive graphics. Instead of rendering an image pixel-by-pixel, scanline renderers compute on a polygon-by-polygon basis. Scanline techniques used in conjunction with precomputed (baked) lighting can achieve speeds of 60 frames per second or better on a high-end graphics card.

Raytracing: In raytracing, for every pixel in the scene, one (or more) ray(s) of light are traced from the camera to the nearest 3D object. The light ray is then passed through a set number of "bounces", which can include reflection or

refraction depending on the materials in the 3D scene. The color of each pixel is computed algorithmically based on the light ray's interaction with objects in its traced path. Raytracing is capable of greater photorealism than scanline, but is exponentially slower.***Radiosity*:** Unlike raytracing, radiosity is calculated independent of the camera, and is surface oriented rather than pixel-by-pixel. The primary function of radiosity is to more accurately simulate surface color by accounting for indirect illumination (bounced diffuse light). Radiosity is typically characterized by soft graduated shadows and color bleeding, where light from brightly colored objects "bleeds" onto nearby surfaces.In practice, radiosity and raytracing are often used in conjunction with one another, using the advantages of each system to achieve impressive levels of photorealism.

Rendering Software Although rendering relies on incredibly sophisticated calculations, today’s software provides easy to understand parameters that make it so an artist never needs to deal with the underlying mathematics. A render engine is included with every major 3D software suite, and most of them include material and lighting packages that make it possible to achieve stunning levels of photorealism.

The two most common render engines: *Mental* – Packaged with Autodesk Maya. *Mental Ray* is incredibly versatile, relatively fast, and probably the most competent renderer for character images that need ***subsurface scattering***. Mental ray uses a combination of ray tracing and "global illumination" ***(radiosity).***

So I am going to explain the comparison and make clear of two rendering software Vray and Maxwell in my graduate qualification work. I will try to show which of them are useful in particular fields.

I. The State of Rendering

1. Issues of the day

Rendering often comes up in conversations. While that may not be a topic most directors focus on, it is these people and their respective leads on projects who must decide how they will achieve the incredible shots they bid, often with unparalleled realism on ever-tighter budgets.

In this graduate qualification work - a follow-up to fix guide's extraordinarily popular Art of Rendering piece - we explore the state of play with renderers in the visual effects and animation fields. Part 1 provides background on the issues of the day, while Part 2 highlights each major renderer in some detail based on interviews done exclusively with each company. I also take a brief look at the future and question if the whole approach is not flawed?

"Each pixel is just a single color but to come up with that color you have to look at the entirety of the environment."In this first section I highlight the primary issues in the area of rendering. "Each pixel (on the screen) is just a single color but to come up with that color you have to look at the entirety of the environment inside that pixel."

The rendering equation was presented by James Kajiya in 1986. Path tracing was introduced as an algorithm to find a numerical solution or approximation to the integral of the rendering equation. A decade later, Lafortune suggested many refinements, including bidirectional path tracing. Metropolis light transport, a method of perturbing previously found paths in order to increase performance for difficult scenes, was introduced in 1997 by Eric Veach and Leonidas J. Guibas.

The original rendering equation of Kajiya adheres to three particular principles of optics:

1. the principle of global illumination,
2. the principle of equivalence (reflected light is equivalent to emitted light), and
3. the principle of direction (reflected light and scattered light have a direction).

From informally surveying the industry, fxguide has identified some of the key trends in the following areas:

GI:While there is a great amount of work being done in non-realistic rendering, especially in Japan, the overwhelming trend is to more realistic rendering. This means rendering with global illumination and providing images with bounce light, color bleeding, real world light samples, and - increasingly - the use of physically plausible shaders and lights.The most widely used methods for GI are distribution ray tracing, path tracing, and point-based global illumination. Each of these has their advantages and limitations, both from a technical point of view and from the complexity, they force upon the lighting artist or TD setting up the shot.

The first use of global illumination as noted in a recent paper (*Multiresolution Radiosity Caching for Efficient Preview and Final Quality Global Illumination in Movies* 2012 Per H. Christensen et al.) in a feature-length movie was for the movie *Shrek 2*. Here, PDI/DreamWorks computed direct illumination and stored it as 2D texture maps on the surfaces, and then used distribution ray tracing to compute single-bounce global illumination.As the paper points out the use of 2D textures requires the various surfaces in the scene to be parameterized. "The irradiance atlas method is similar, but uses 3D texture maps (“brick maps”) so the surfaces do not need a 2D parameterization. Both methods use two passes: one pass to compute the direct illumination and store it (as 2D or 3D texture maps), and one pass for final rendering." Irradiance maps are baked and not generated per frame as Sam Assadian from Clarisse iFX points out. "Irradiance maps flicker with

low frequency noise - the worse kind." By rendering once and storing the value, rendering is faster overall and consistent over time (temporally stable).

Path tracing is a form of ray tracing and it is a brute-force unbiased global illumination method that was first seen via the Arnold render in *Monster House* from Sony Pictures Animation. The advantages of path tracing are that it does not use complex shaders nearly as much as a biased or point cloud approach. Given the way a path tracer renders it can provide fast feedback during interactive lighting design. The problem with all ray tracers is noise. At the basic level to halve the noise you need to quadruple the number of rays. The promise, mathematically, of unbiased ray tracing is that given enough rays it will converge to a correct solution. Ray tracing is built on probability and if you fire enough rays, instead of sampling and estimating the result, the variance is reduced to 0, and the solution converges to the correct result. Of course, firing an infinite or extremely large number of complex rays is not viable especially with the nonlinear noise curve, so one has only three options:

• use a different clever solution - like brick maps and say a scan line renderer or a partial ray tracing solution

• write really fast and clever code that renders very quickly i.e. fast clever rays

• aim the majority of your rays where they matter the most i.e. aim those fast clever rays better

At the core of the ray tracing scheme is the notion of solving a lighting problem using samples, normally random samples decided by a probability distribution function, but to get GI, you also need to think about what other rays are fired off due to the material (the shader/BRDF etc) and how you sample the lights, or rather things that will contribute light. From on set we all know you can light with a bounce card, so to catch every object in a scene bounce light, and the biggest example of this is lighting with a giant light dome or what is known as

image based lighting. In image based lighting a dome or sphere is mapped with an image, normally a HDR image. The whole dome or sphere contributes light to everything inside it, which is again why sampling this giant massive spherical light sensibly is important. After all we are trying to do nothing less than recreate the world in all its lighting complexity and how every part of it affects every other part of it.

Like any sphere it is easy to think that there is energy bouncing around in the form of light, which should all add up. In other words if a light bounces off a table the bounce light would never be more than the light coming from the light source, and if one moves the light further away, then the bounce would not only seem less strong, it would actually reduce according to the inverse square law. We all know this from moving any light in the real world. This idea of correct light behavior and correct material behavior is what is being referred to in "physically plausible lighting and shaders". (For this article we will use the more relaxed term physical lighting and physical shaders, but they are of course nearly always just a very close approximation).Millions of frames of animation and effects have been produced without either, but the trend is towards both, not for everything, but in the world of VFX and animation it is the dominant trend. We will try and highlight non-ray tracing solutions, and there are many, but the state of the art today is centered around a "rays race" to produce better results, that are easier to light and yet do not explode memory and render budgets.

One of the biggest disadvantages of ray tracing is its memory requirements. We will cover some of that history below but today RenderMan stands alongside Arnold, V-Ray, Maxwell, and newer programs like the cloud based Lagoa and the GPU Octance renderers as a program that is trying to render faster and more accurate ray traced images to an ever competitive environment.How competitive? Since we wrote the first Art of Rendering story, just 18 months ago, the landscape has changed dramatically. New renderers and whole new approaches have been

released. There have been dramatic improvements, renderers have died, others have been bought, and there is no sense that the process is anywhere near over. Rendering, once a fairly predictable evolutionary space, has become like a quickly moving landscape. For this story alone we have done over 20 interviews and we will be covering 14 major production rendering platforms. We have aimed to focus on production renderers for animation and VFX and not even really touch on game engine rendering, GPU rendering and mobile offerings. Art of Rendering saw many compliments but also a host of complaints. To paraphrase a quote from the first article, "rendering is now a bit like a religion."

Ray tracing vs point solutions: Ray tracing is only one approach to GI and its main rival is point-based global illumination. Actually the terms are confusing as strictly speaking one can have a non-fully ray traced solution that still involves some firing of rays. But for now let's consider 'ray tracing' to mean fully unbiased ray tracing or path tracing.

Before discussing ray tracing it is important to understand how point based GI works, as many solutions in the real world use a combination of results. For example, in Pixar's latest feature *Monsters University*, the film moved to primarily ray tracing and physically based lighting and shading, but still for the sub surface scattering (SSS) it used a point based solution (although that will not be true of the next Pixar feature). SSS is the way light softens beneath the skin as especially the red light wavelengths scatter and produce the waxy look of skin vs the flat look of plastic. SSS is key to character animation and is not new - for example, Joe Letteri (senior VFX supervisor Weta Digital) used it extensively in the original Lord of the Rings films (see this 2004 fxg interview) and it was key to the original ground breaking look of Gollum. But SSS is very expensive and hard to achieve in a brute force ray tracer, but very achievable using a point source solution.

1.1. Physically Plausible Lighting and Shading

Figure 1.1

The overriding trend at the moment is to move to a physically based shading and lighting model. Marcos Fajardo of Solid Angle - the company behind Arnold - remarked that every (production) studio in the world has moved over to being able to work this way or is in the process of moving now. "That is happening right across the industry, ever single company you talk to is either in the middle of it or has already moved, and this is something I have been working towards for the last ten years or so, so I am really happy to see that happening - finally." Fajardo should be credited as one of the greatest advocates and enablers of this massive shift in the industry. Solid Angle is very much at the forefront of the industry-wide move to path traced GI with physically plausible lighting and shading in a production environment (meaning in a cost effective way with ever tighter schedules).Central to the popularity of path traced unbiased ray tracing is the desire

to just make life similar for the lighting artists while making the pictures even more realistic.

In some old pipelines an artist could be handed a set up with a few hundred lights, plus extremely complex shaders - which are their own C ++ code-style clever box of tricks to pull off what was needed. Lighters would sometimes just have to sit and turn on and off lights to just work out what everything was doing.

Most companies would not claim that implementing physical lights and shaders made the rendering faster per say, but quite a few companies believe it makes the artist's role much easier and frankly artist hours are more expensive than render hours by several orders of magnitude.

The new system uses energy conservation which means that lights behave much more like real world lights. This means that the amount of light that reflects or bounces off a surface can never be more than the amount of light hitting the surface.

For example, in the traditional world of CG the notion of specular highlights and reflection were separate controls and concepts, as were diffuse and ambient light controls. So under the previous model if you had three lights pointing down (three beams one from each spot to a surface below), if the specsize is varied, the specular from the point light doesn’t get darker as the specsize increases. “Indeed this is the specular model we have been using for years at ILM actually gets much brighter with grazing angles so the actual specular values are very hard to predict,” says Snow.

Figure 1.2 Old lighting tool (ILM)

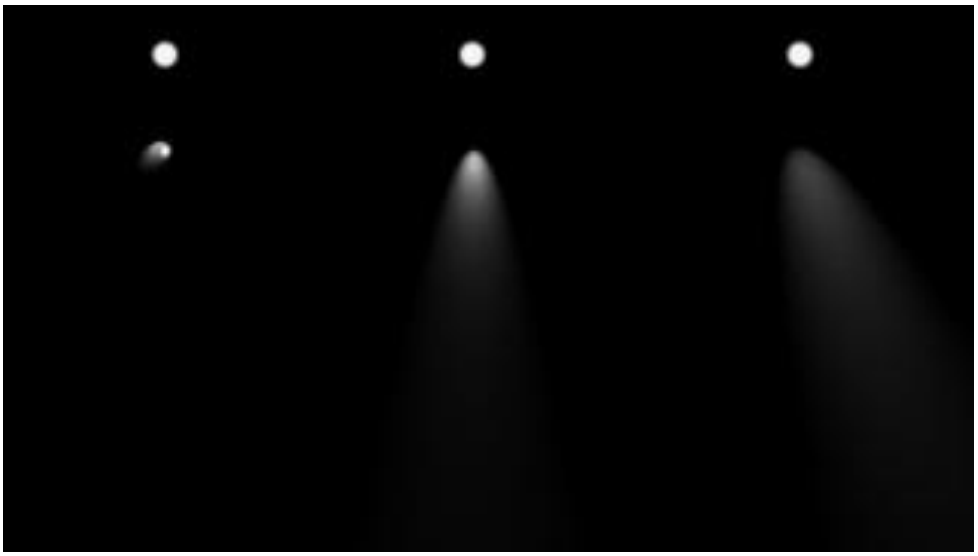


Figure 1.3 Energy conservation tool (ILM)

Under the new energy conservation system, the normalized specular function behaves in the same way that a reflection does. As the specsize increases, the intensity of the specular goes down. Previously the system required the artist to know this and dial down the specular as the highlight got broader. While a good artist would know to do this, it had to be dialed in in look development, but different materials on the same model might behave differently, and of course objects would behave differently in different lighting environments and would have to be hand tweaked in each setup.

This ground breaking work started a fire that has spread throughout the industry. Now entire rendering systems are being set up that allow only for physically based lighting and shading.

But the system did something else, it accelerated the work ILM was doing with IBL. See below.

Importance sampling and multiple importance sampling (MIS):If you do move to a system of ray tracing from above, one of the key things to be doing is as we stated "aiming those fast clever rays better." But what does that mean?

Given that a large number of rays are going to be needed to solve some parts of the scene successfully, it is ideal to increase sampling where and when you need it while not wasting effort where you do not. This is the art of importance sampling, (IS) as the name implies - sampling where it is important.

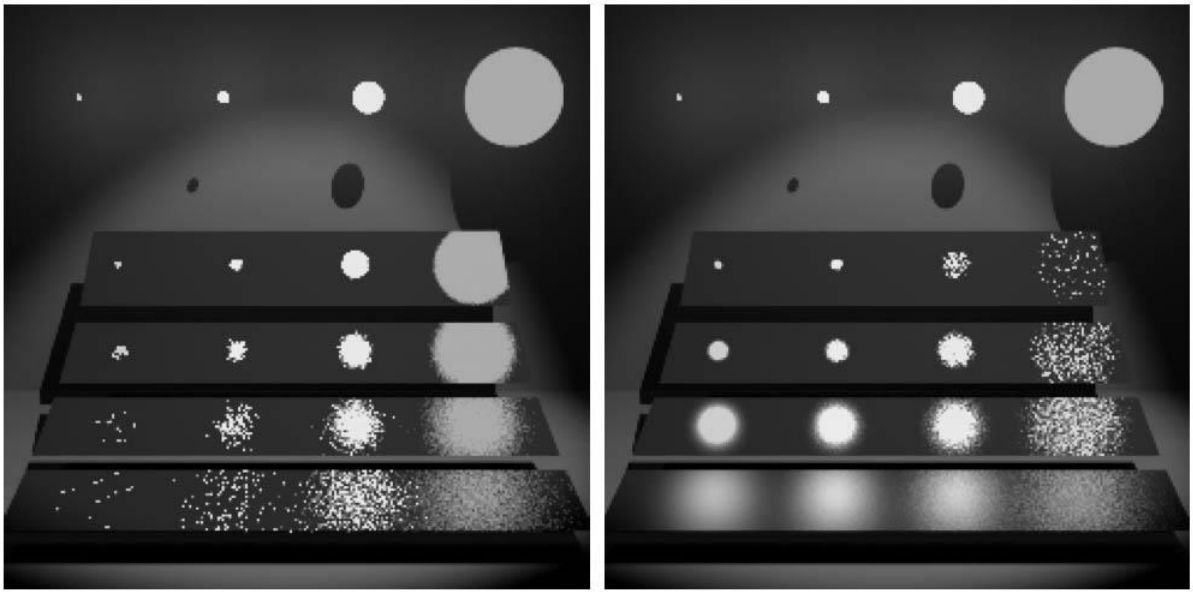
There are four levels of IS at the moment in the industry:

1. undirected brute force renderers which do not have IS
2. renderers that have it for just say environment lights or dome lights: environment sampling eg. Modo
3. renderers that have it for both lights and materials and intelligently balance the two: multiple importance sampling (MIS) - this could arguably be considered 'state of the art', eg RenderMan
4. advanced MIS - applying IS to a range of other solutions as well such as SSS eg. Arnold

Key implementations of this groundbreaking MIS work in the current renderers environment has been done by Christophe Hery while at ILM with Simon Premoze (who was a research engineer at ILM, then at Dneg until recently). Premoze has since done courses at SIGGRAPH and MIS has become a critical part of rendering with ray tracing.

Christophe Hery implemented the MIS used on *MU* and it worked off a Power 2 formula also from Veach's original Ph.D. Interestingly, this is one of the few occasions in recent times where the software used by Pixar was slightly out of step with the public RenderMan. Far from this being a deliberate withholding, it seems Pixar almost over ran the RenderMan team's schedule of implementation, but this is now getting back in sync, such was the dramatic nature of the adjustment to the new approach. (You can learn more about the ***physically plausible shaders in MU in our 2013 fxguide article here).***

To understand the power of MIS one need only refer to the original Veach doctorate which is still as relevant today.Below is a picture from that paper showing on the left the IS favoring the materials of BRDF samples, on the right it favors the lights in terms of sampling. There are 5 lights in both shots which are the same set-up apart from the IS settings. The fire lights are 4 lights at the back of shot and one overhead to just see what is in our space. If we ignore the top light - the back 4 lights are all of equal energy - so as the size of the light gets bigger - it appears to dull from bright white. In front are 4 panels angled to reflect the lights behind. The back panel is glossy, the front panel is much more diffuse.



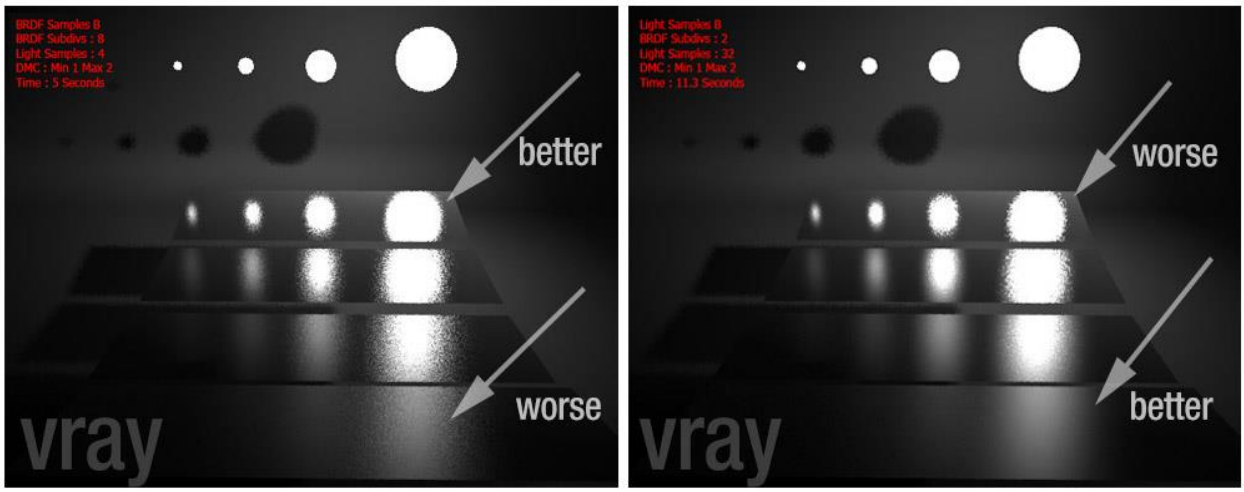
(a) Sampling the BSDF **(b)** Sampling the light sources

Figure 1.4 ***Figure 1.5***

Notice how when favoring the BSDF the tiny point light on the left is poorly sampled and thus on the rough bottom plane on the bottom left it is very noisy, but in the same BSDF the light on the right is reflected well - as it is big and easily reflected from the higher sampling on the material. By contrast, if we favor the light sampling, then the rough surface produces a nice spread out light effect from the hot tiny light, but the big light on the right is very noisy. Clearly we want to sometimes favor the BRDF (BSDF) and sometimes the lights - it depends on how diffuse the surface is and how big the lights are.

Thankfully this is exactly what MIS does. So much so it is hard to replicate this result with some modern renderers since the latest version of RenderMan virtually restrains one from making the render this bad (by using MIS), similarly in Arnold, but you can get close my manually adjusting setting in V-Ray (this is not to say V-Ray is in any way inferior - far from it - but all renderers aim to not produce such noisy clearly 'wrong' renders).

Amid Rajabi produced this version below for fxguide in V-Ray by manipulating both the light/BRDF samples and V-Ray's adaptive DMC (Deterministic Monte Carlo Sampling).



(a) Sampling the BSDF **(b)** Sampling the light sources

Figure 1.6 ***Figure 1.7***

The results are easy to see in even the small form shown in the article but if you click on the image above and look at the larger version - the difference is even easier to see.(Note: due to the clipping of an 8 bit image the 4 key lights 'appear' to be the same brightness no matter their size but in the floating point render output they fall off in value as they get bigger in size along the back of each of these images.)

Here is an example of the difference using importance sampling inside Otoy's Octane GPU renderer.Rendered in real-time with OctaneRender standalone 1.20 on 1 GTX 680 + 1 GTX Titan using path traced sub surface scattering. Head model scanned with LightStage, containing over 17M triangles.

Image-based lighting:Started a while ago with a combination of new on-set light probe sampling and various dome lights, there has been real growth in the use of IBL with physically based lighting and shading. In *MU*, not only did the animation unit of Pixar move to physical lights and shaders, they also used IBL lighting, which is perhaps odd as it historically has been used for sampling real world 'on location' lighting and using it to match CG elements into that location.

Figure 1.8

On the left is a simple test scene with 2 cats, and a robot. It has soft shapes and hard edged geometry.

On the extreme left there is a chrome sphere at the top, and a diffuse sphere beneath it, for context. At this stage the scene is lit with a single distant light simulating the sun. It has shadows, but it is missing fill light.

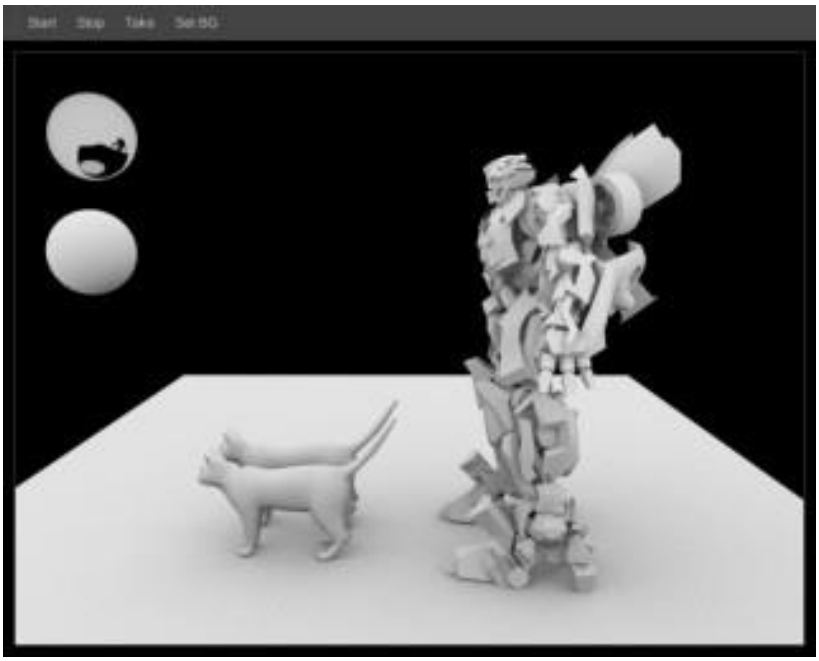


Figure 1.9

If we relight with just effectively a large white environment light (or dome/IBL white ball). The image now becomes effectively an ambient occlusion pass.Note: the single distance light is off from ***Figure 1.8***

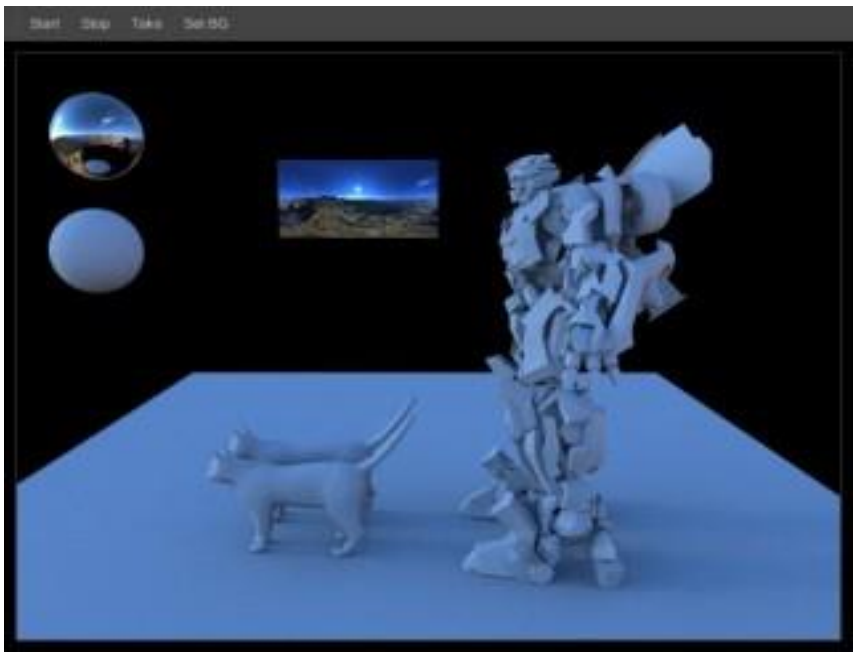


Figure 1.10

The scene is now lit with an example HDRI, and it is mapped into the env light (the photo in the middle is that hdr mapped onto a plane so you can see what the HDR is - as a preview). This is more realistic but not production quality.

Note: the shadows are coming from the 'sun' in the HDR. The environment light is the only light source in this image.

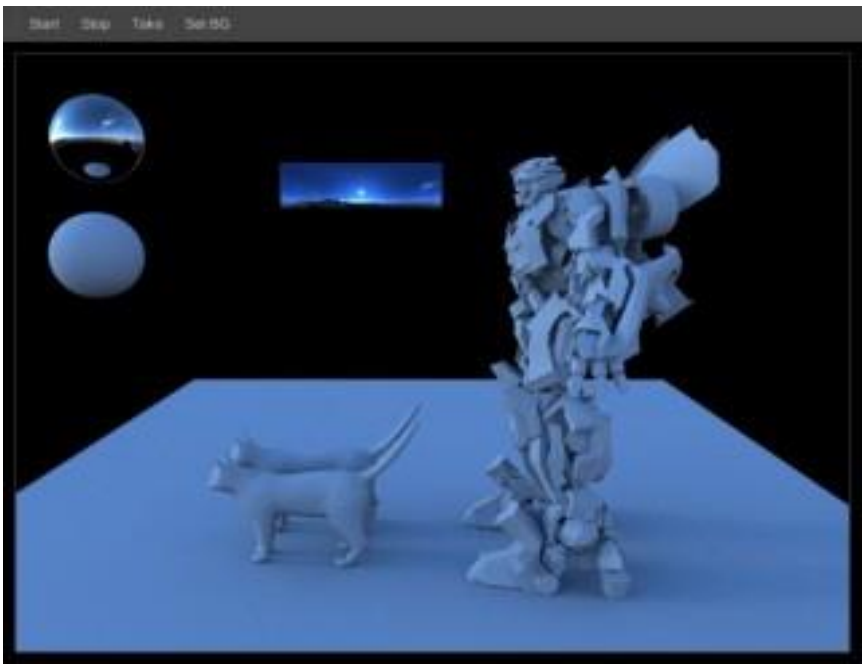


Figure 1.11

`The env light is now edited. Note the brown ground has been painted out. The correct ground bounce light should be from what the figures are standing on. If you compare the last two images you can see some warm bounce on the back of the robots leg, (we need to remove that).

Note: this may not be needed in practice if the env light was just a 180 dome, or the ground plane 3D element they are standing on blocked that light, but here we are painting on the HDR to illustrate the point.

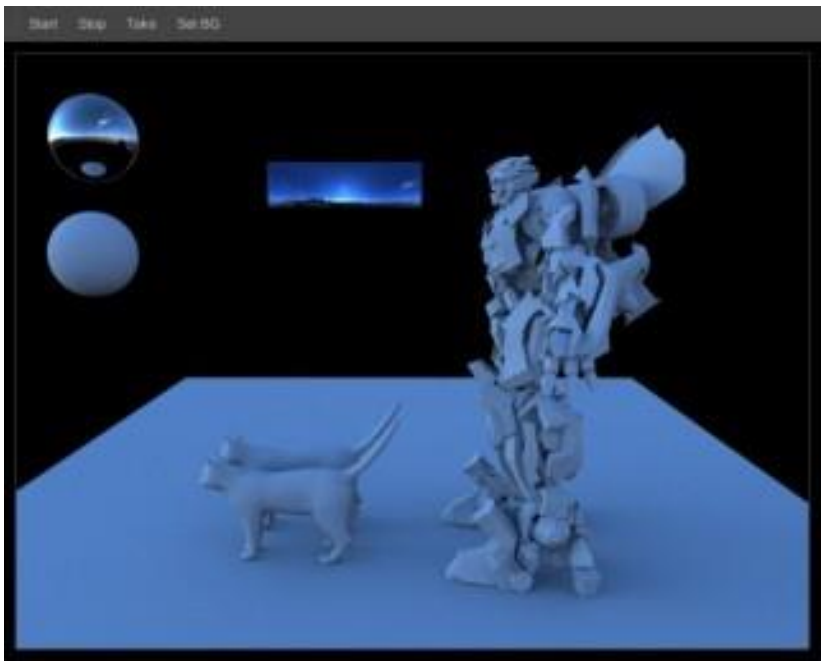


Figure 1.12

The sun is now painted out of the HDR. Unless the HDR is very carefully captured - there will be some clipping on the real sun in the HDR, and some renderers can’t handle that amount of dynamic range in an HDRI without creating noise or fireflies (or black dots). Creatively it is also good to be able to move the sun without rotating the env light.We now we have a basic map to start working with.

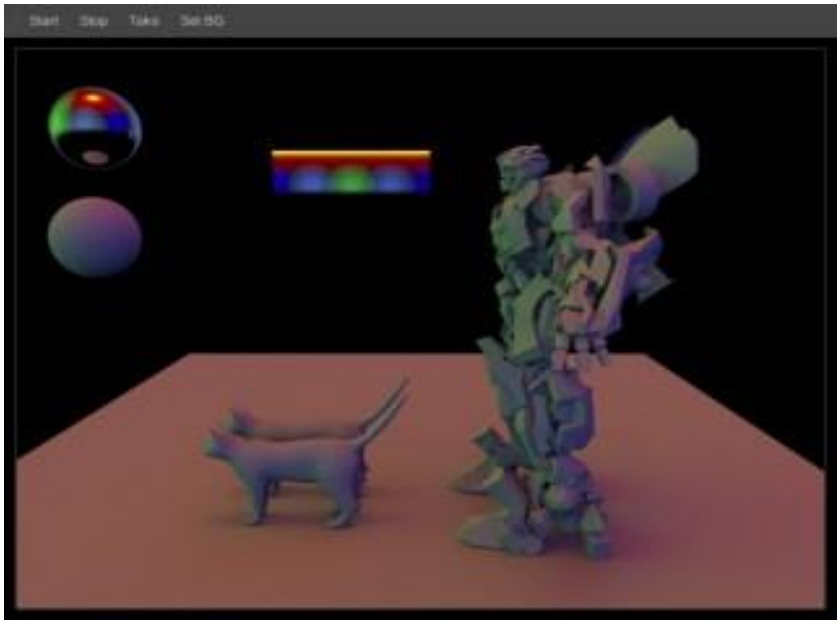


Figure 1.13

Sometimes a temp colour map is used to better understand which are the interesting areas of the HDR. Green is the area around the sun (imagine the hazy light area that extends around the sun on an average sunny day, its usually much MUCH wider than the sun itself), blue to represent the sky low to the horizon, a darker blue at the back of the map for the region facing away from the sun, red for overhead, and yellow for the small area directly overhead. This helps the TD or lighter understand what they are working with.

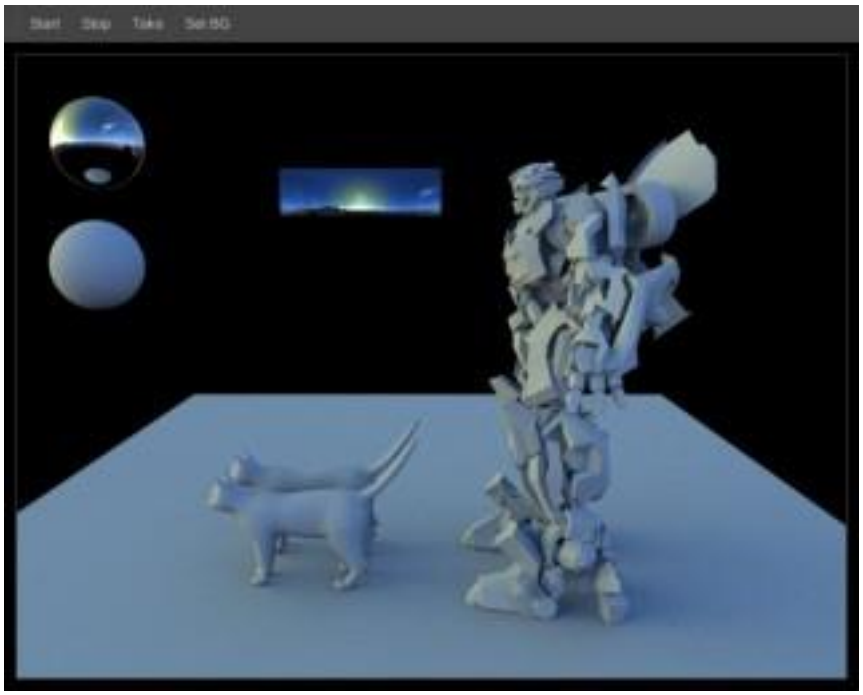


Figure 1.14

In Dailies in production, the issue of ‘shape’ + warm vs cool often comes up in the context of finding nice modelling detail in the assets and wanting to enhance them or possibly avoid the 'hero' from looking 'flat'. Color is used to have a sense of separation. Shapes that face the sun here have warmer tones, while the parts facing away, have cooler tones. Here the green zone from the previous image, has been converted it into a soft sun area, and tinted in that area of the map to a warmer

yellow. This gives the warm/cool separation often desired, & a more interesting shape.

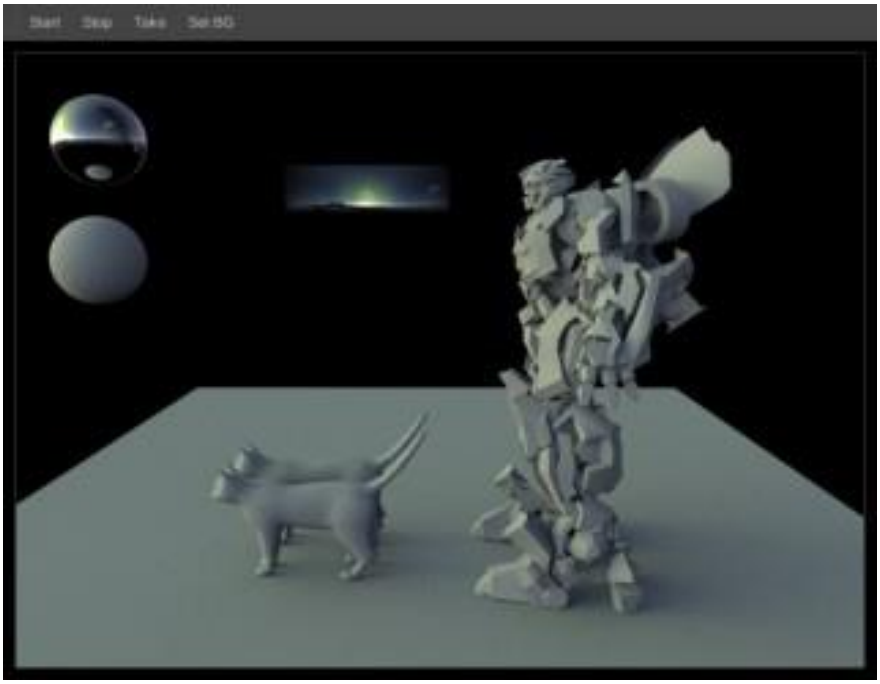


Figure 1.15

Here I've used the blue and red zones (blue being sky near the horizon, red being the sky region a big higher), and set my sky colour to a more desaturated blue. A clear blue sky IS blue, but you rarely perceive gray objects as blue in real life. your eyes naturally white balance to remove the blue cast, and cameras will normally be adjusted to do the same. in a cg lighting context, you'd be looking at neutral objects in the live action plate (or a gray ball that's been shot on location if you're lucky), and making sure your environment light tints your cg objects to match. i've also used the region that faces away from the sun, and exposed it down. comparing to previous, it has the effect of slightly darkening shapes away from the sun, giving a little more shape again.

Here’s a trick from Etienne Marc, one of the senior lighters on *Great Gatsby* at Animal Logic. Here we have added a thin, high intensity stripe of white across the top of the HDR. Here’s a trick from Etienne Marc, one of the senior lighters on *Great Gatsby* at Animal Logic.

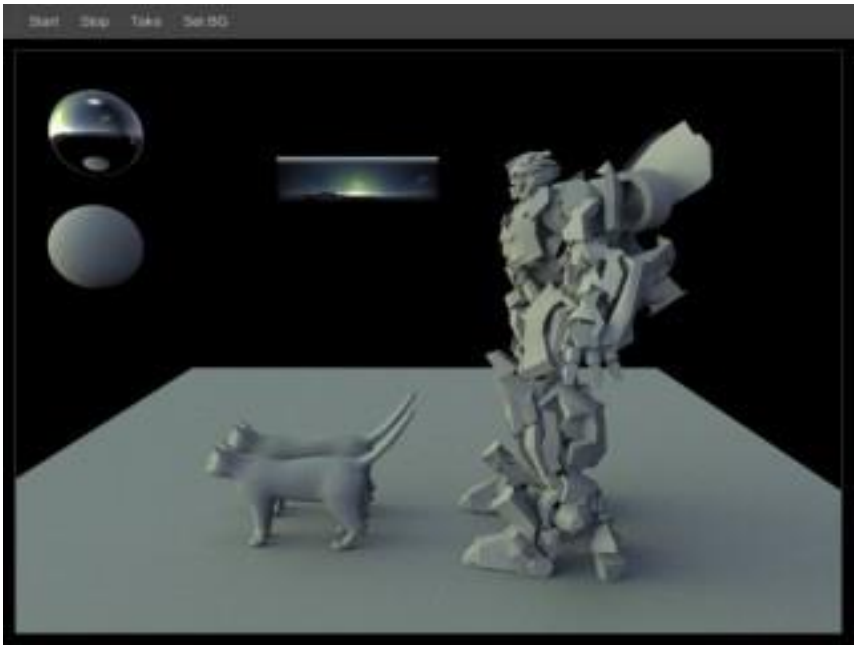


Figure 1.16

. This adds a little more top light across the top of objects, but more usefully, sharpens their contact shadows, making everything feel a little more grounded. If you click on the image and toggle between this and the previous slide, you can see how the ground contact shadows are more defined. "‘The CG feels like it's floating’ is a regular comment in lighting reviews, this helps avoid it."

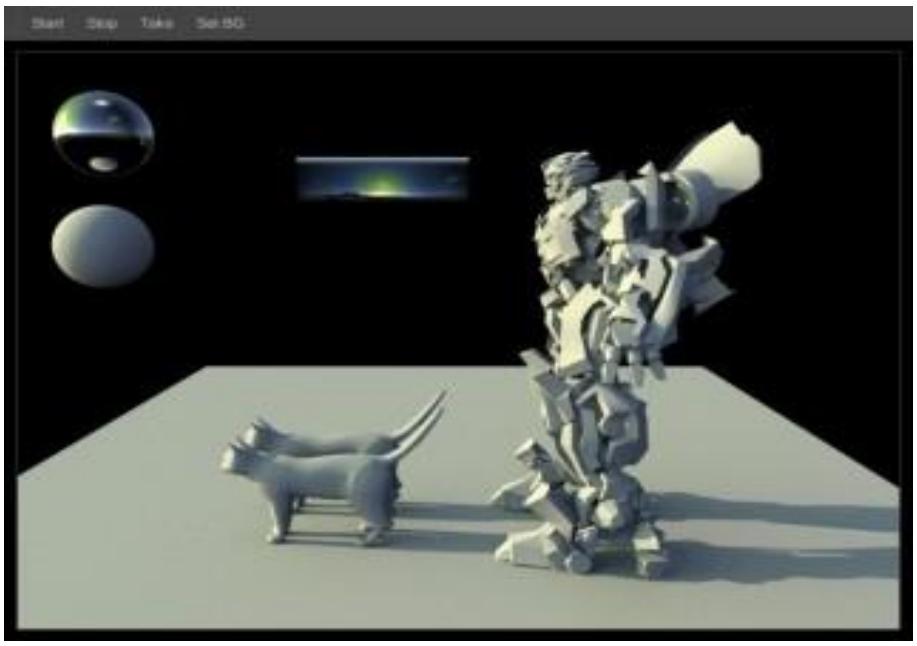


Figure 1.17

Finally the key light is turned back on, and balanced between the key light against the environment light. The shading is now much more interesting, but still grounded in realism. There is a solid base for a keylight now, now with more indirect bounce light form other objects and final materials, the shot is well on the way for a nice looking shot.Below is a before and after reel from *The Great Gatsby*, showing the great work of Animal Logic (primary vendor) in producing realistic and stylized lighting. The other vfx houses involved on the film were Rising Sun Pictures, Iloura, ILM, Prime Focus and Method Vancouver). The overall supervisor was Chris Godfrey.

1.2. Cortex (major support from Image Engine)

Image Engine in collaboration with several other companies has been promoting a new system for visual effects support (C++ and Python modules) that provides a level of common abstraction while unifying a number of ways of rendering a range of common vfx problems in a similar way. Cortex is a suite of open source libraries providing a cross-application framework for computation and rendering. The Cortex group is not new but it has yet to reach critical mass, although as with many successful such projects it comes from being used in production and facing real world tests, particularly inside Image Engine which uses it to tackle problems it sees as normally being much bigger than a company their size could tackle. For example it provides a unified solution to fur/hair, crowds and procedural instancing. Image Engine used it most recently on *Fast and Furious 6* - but it is used extensively inside Image Engine.John Haddon, R&D Programmer at Image Engine: "Cortex's software components have broad applicability to a variety of visual effects development problems. It was developed primarily in-house at Image Engine and initially deployed on District 9. Since then, it has formed the

backbone of the tools for all subsequent Image Engine projects, and has seen some use and development in other facilities around the globe."

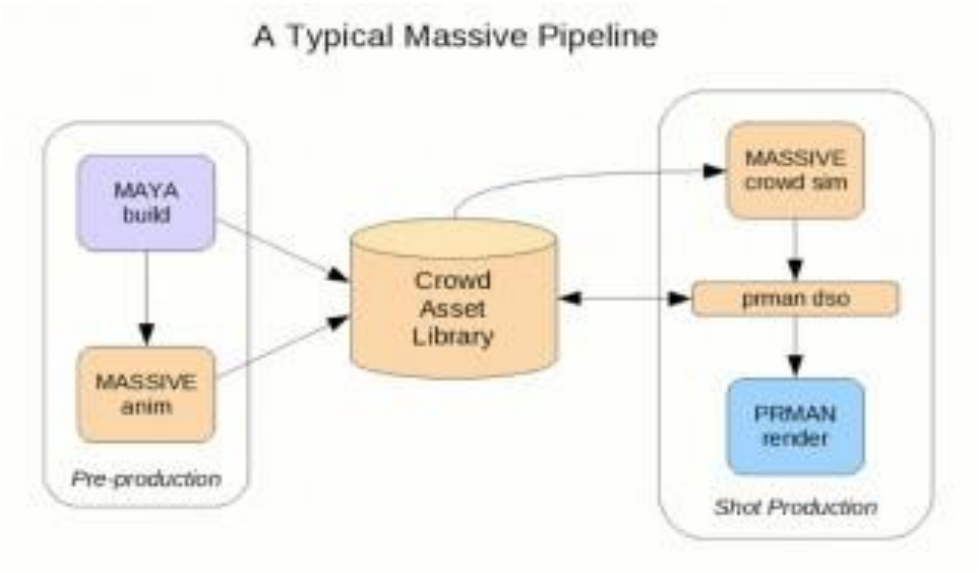


Figure 1.18

An example outside Image Engine was shown by Ollie Rankin, from Method Studios, who presented at an earlier SIGGRAPH Birds of Feather on Cortex and how it can be used in a crowd pipeline. He had used a typical Massive pipeline which involved Massive providing agent motivation, and yet they felt Massive was not ideal for procedural crowd placement. In a hack for the film *Invictus*, they used Houdini to place the Massive agents, and they rendered in Mantra.

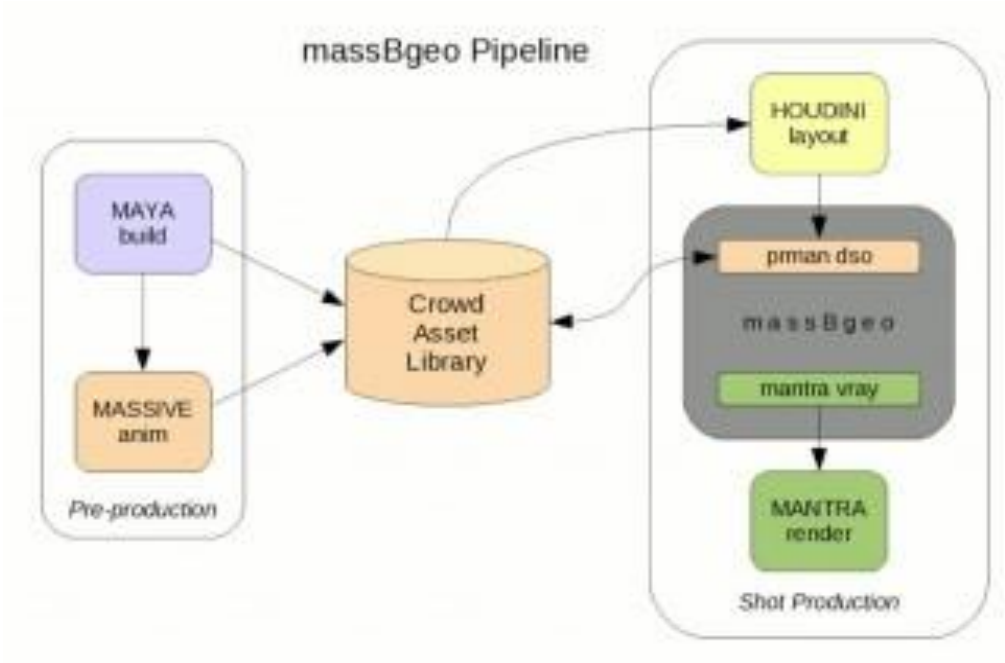


Figure 1.19

Massive exports native RIB files and like RenderMan, Mantra would work with Massive and Mantra is very similar to RenderMan - but it was a hack introducing Houdini to just handle procedural placements and still gain agent animation from Massive. Massive provided just the moving, waving, cheering agents but their placement was all from Houdini as "we didn't need Massive to distribute people into seats in a stadium - we knew exactly where the those seats where - all we needed was to turn those seat positions into people". The rendering did require a bridge between Massive and Mantra, but with a custom memory hack using PRman's dso (Dynamic Shared Object)."While we were happy with the way that Massive manipulates motion capture and happy with the animation it produces, we felt that its layout tools weren't flexible enough for our needs", Rankin told fxguide. "We realised that the challenge of filling a stadium with people essentially amounts to turning the known seat positions into people. We also wanted to be able to change the body type, clothing and behaviour of the people, either en masse or individually, without having to re-cache the whole crowd. We decided that a Houdini point cloud is the ideal metaphor for this type of crowd and set about building a suite of tools to manipulate point attributes that

would represent body type, clothing and behaviour, using weighted random distributions, clumping and individual overrides."They still needed a mechanism to turn points into people and this is where "we had to resort to a monumental hack." Massive ships with a procedural DSO (Dynamic Shared Object) for RenderMan that can be used to inject geometry into a scene at render-time. It does so by calling Massive's own libraries for geometry assignment, skeletal animation and skin deformation on a per-agent basis and delivering the resulting deformed geometry to the renderer. "Our hack was a plugin that would call the procedural, then intercept that geometry, straight out of RAM, and instead deliver it to Mantra," Rankin explained

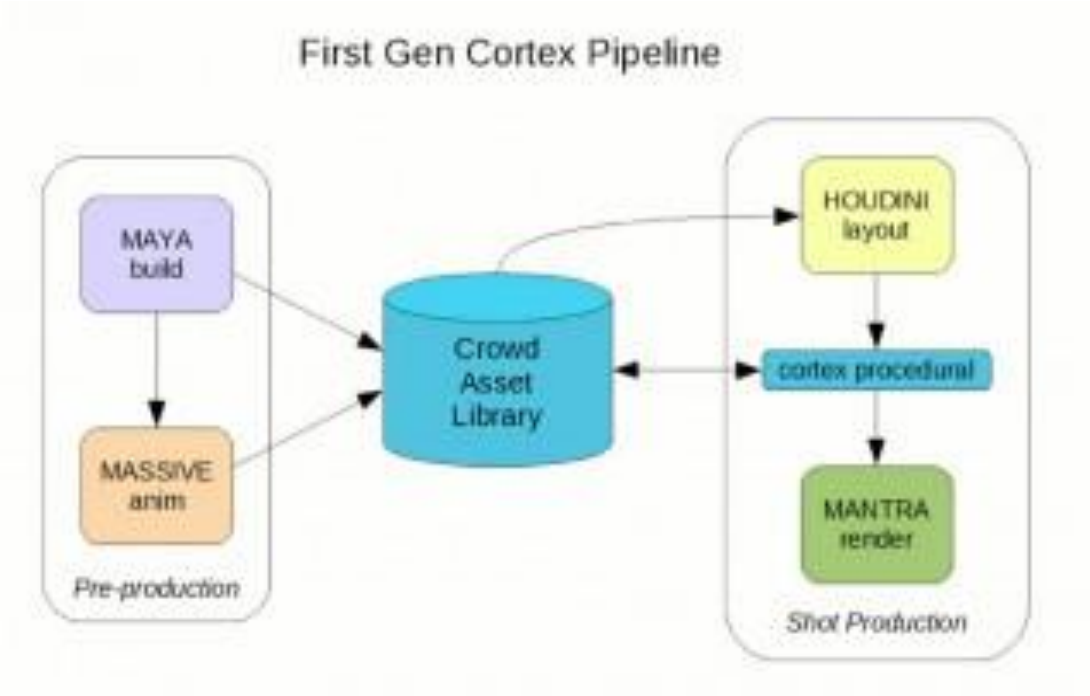


Figure 1.20

By comparison a Cortex solution would allow a layer of Cortex procedural interface between Massive and RenderMan - it would access and query the Massive Crowd assets library and remove the need for the Houdini/PRman dso hack, but still allow Houdini render Massive's agents. But once there is a unified standard cortex procedural hub, it is possible to replace say Houdini or update to a

different renderer all without breaking the custom black box hack that existed before.

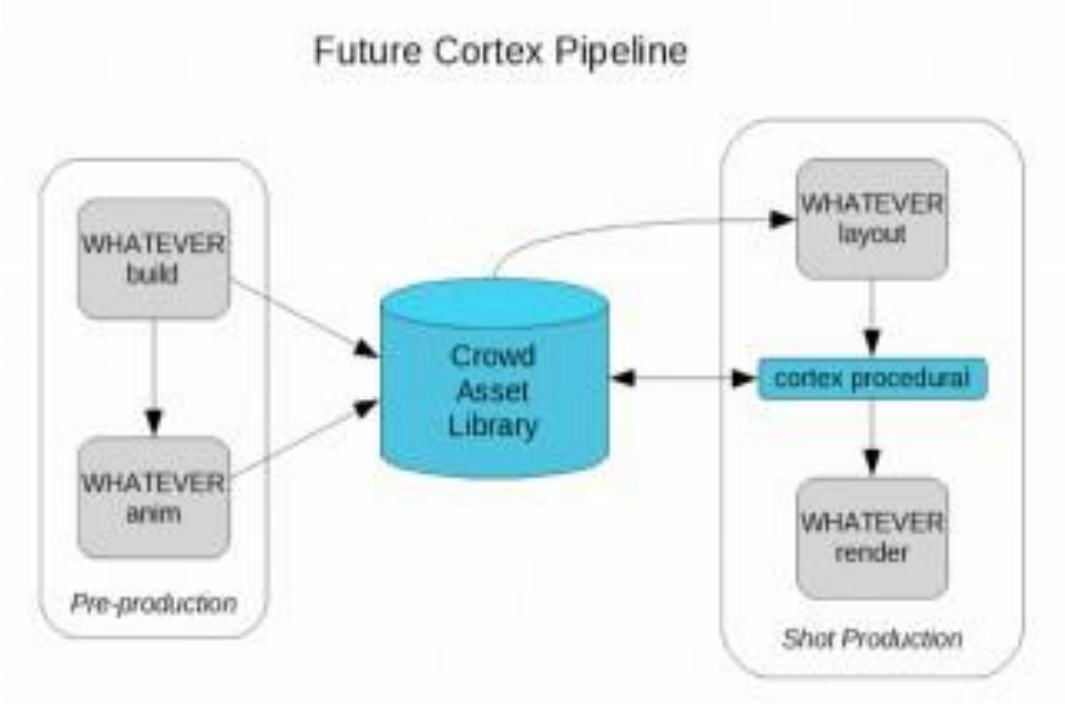


Figure 1.21

The same coding approach and API interface used in this example for solving Massive - Houdini could be used for Maya, Nuke or a range of other applications. By introducing a standardized Cortex layer, geometry say could be generated at Render time in a host of situations but all deploying the same basic structure and not requiring new hacks each time or needing to be redone if a version of software changes or need to be replaced.

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II. Major players

In **Chapter one** of The State of Rendering, we looked at the latest trends in the visual effects industry including the move to physically plausible shading and

lighting. **Chapter Two** explores the major players in the current VFX and animation rendering markets and also looks at the future of rendering tech.There are many renderers, of course, but we have focused below on the primary renderers that have come up during the last 18 months of writing fxguide stories. It is not an exact science but fxguide has a ring side seat on the industry and the list below covers the majority of key visual effects and non-exclusive in house animation renderers. We have excluded gaming engines and many fine non-vfx applications.

The order is not in terms of market share - in reality the 3ds Max default renderer or Mental Ray would swamp many others due to the market share of Autodesk with Max, Maya and XSI. But the order does indicate a subjective rough grouping based on our feedback with major studios and artists around the world.

2. RenderMan - Pixar

In those interviews and podcasts you can hear first hand about the evolution of the product and spec, but you will also hear about the leadership of Dana Batali. While RenderMan has many contributors and excellent researchers, Ed Catmull, President of Disney and Pixar, points out that one thing that has always been true behind the scenes and screens of RenderMan has been the lack of committee thinking. At the start, Catmull points out that, "we had Pat Hanahan as the lead architect on the design of RenderMan, and Pat is a remarkable person. I set up the structure so Pat made all the final calls, at the same time we involved as many companies as we could, 19 if I recall...and of those 6 or 7 were really heavy participants, but that being said, we gave the complete authority to make the final choice to a single person. And I think that was part of the success - that it has the integrity of the architecture that comes from a single person, while listening to everyone else."

Today there is also one man responsible for guiding the product, Dana Batali VP of RenderMan Products at Pixar. Ed Catmull explains: "The way it has developed is that we have given Dana a free hand in how the product develops, it isn't as if he comes to me and says is it OK for us to put the following features in - he never asks. The charter is that he is meant to respond to what is needed. We set it up so they make changes to what is needed, they never ask me what should go in - they just do what the right thing is and we have doing that for many years." In this respect today there is still one person with a single vision of what should be developed for RenderMan's worldwide clients, including Disney/Pixar. "Yes, that is the set up and one I believe strongly in," reinforces Catmull.Dana Batali in turn sees his role as just focusing the intense collaboration of the incredible team of scientists and researchers inside Pixar's RenderMan development team based in Seattle. There is no doubt that team is exceptional, something easily judged by the volume of papers and published articles that has flowed from the team since it's inception, much of it published at Siggraph as they will do again next week.fxguide has recently covered the advances in RenderMan's use in *Monsters*

University and the move to ray tracing with physically based shading and lighting, so for this article we decided to get very technical on the implications and implementations of the ray tracing framework in the current release and the upcoming new RPS18 release with Dana Batali.

RenderMan supports two means for computing area light shadows and both reside behind the RSL function: areashadow. The simplest solution is to ray trace the shadows and this is the preferred solution as long as the shadow casting geometry can fit in memory. But with hundreds of hairy creatures in an Monster University (MU) shot all the shadow-casting geometry can't fit in memory. Our hybrid solution allows us to produce a "deep shadow map" in a reyes-only (memory efficient) pre-pass that can be used by the areashadow function to produce realistic shadows during the beauty pass. RenderMan can combine the tracing of rays against real geometry with the evaluation of area shadow maps (which might only contain shadow information for hair) to produce a hybrid shadowing solution.

Finally, getting back to the topic of GI: with the widespread adoption of physically plausible (area) lights, it became feasible, even necessary, to consolidate the code and the parameters that control the integration of direct illumination with controls for indirect illumination. In practice this simply means: there should really be no difference between a reflection and a "specular highlight". A photon arriving at a surface directly from a luminaire doesn't behave any differently than a photon that arrived by a more indirect path. Prior to the consolidation, shaders would have two shader parameters to express the specular color and reflection color. While certainly offering lots of artistic control, this isn't physically plausible. Only a single specular color should be needed. But the idea of taking away artistic controls can be very contentious and part of the significance of the success of "the GI efforts" on MU was the fact that a lot of lookdev and lighting artists had to be convinced that the benefits of physical plausibility outweigh the potential for

artistic control that these traditional parameters represented. Christophe is a driving force of this message at

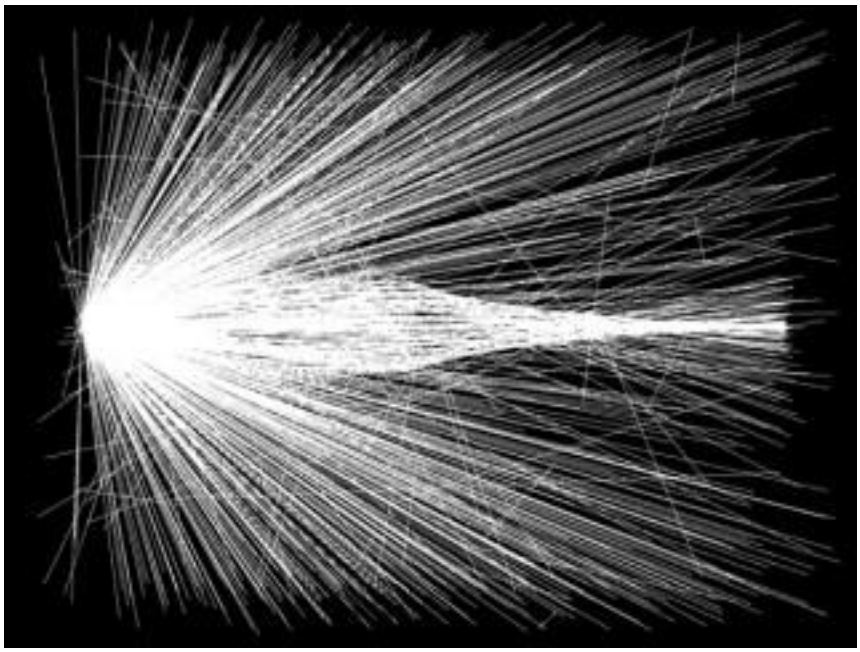


Figure 2.1 *Photon beams for caustics - Pixar.*

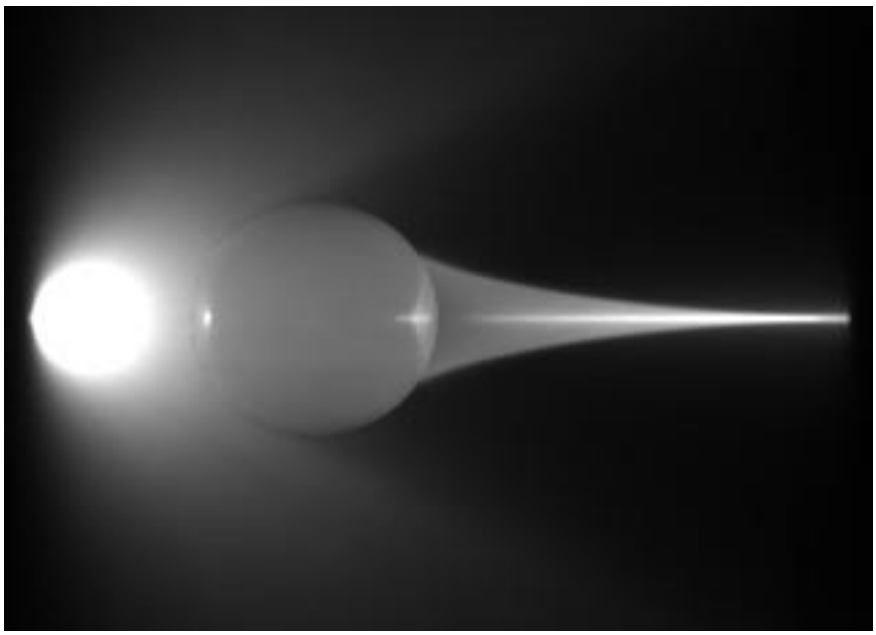


Figure 2.2 *Photon beams for caustics - final render in RenderMan.*

A great example of the flexibility of RenderMan is in the way it is used by Weta Digital for extremely large renders, splitting the rendering problem and using a GPU pre-render using and storing spherical harmonics, with PantaRay pre final render. This robust pre render is very different from the point cloud pre-renders outlined elsewhere in this document and you can read about it here in our fxguide story.

The new approach offered by RenderMan still needs to address the same issue all ray tracers do which is memory limitations, but for most production shots (perhaps not Weta level) the one pass approach offers greater simplicity of lighting control coupled with incredible realism. By moving from very complex shaders to having the renderer understand things such as bxdf, geometric area lights - results in a much better and cleaner rendering model. To some extent the older rendering model has been viable with some ray tracing doing a style of 'what's the value at this hit' type of integration. But that is not powerful enough moving forward into worlds where there are much more complex integration techniques at play. The shader programming models were not geared towards bidirectional or other integration techniques. Nor did they let the renderer help with complex problems (such as sampling geometric lights).

RenderMan still very much supports both models, but recently the team has worked hard to service the trend of heavier and heavier fully ray traced shots. By redoing the shaders and making the system easier to implement at a full energy conserving physically based lighting system, the RenderMan team under Dana Batali's leadership is hoping to secure a strong place in the next 25 years of computer graphics.

2.1. Arnold - Solid Angle

Much of the history of Solid Angle and the development of Arnold by its founder Marcos Fajardo was covered in our previous Art of Rendering piece.Arnold is a path tracer that tries to solve as efficiently as possible ray tracing for film and media production, with as few tricks, hacks and workarounds from the end user as possible. “We are just trying to solve the radiance equation, on the fly without doing any type of per-computation, and pre passes,” explains Fajardo. “So we just trace a lot of rays around and hope to get an accurate answer. The challenge is to design a system that is optimized so that it traces a relatively small number of rays for a given quality and also the ray tracing needs to be very fast. That’s what we do everyday we try and optimize the renderer with both mathematical processes to optimize the Monte Carlo equations and also to make the code very fast – so those two things – the speed of the rays and the number of the rays – that is what we work on everyday."

Latest advances: Solid Angle has achieved remarkable success in producing incredibly powerful ray tracing that balances render time, memory management and image quality. It continues to grow and expand around the world.Arnold remains an incredibly important product, not only is it very fashionable and on most studios' render roaster (or being evaluated for inclusion) but the company has a strong commitment to R&D and like Pixar before them is committed to sharing and publishing their work. As such the company is held in very high regard and there is no doubt their focus on advances inside a production framework is yielding spectacular results but still obtainable inside the budget constraints (time and money) of the real world.

Note: a material definition or BRDF becomes a BSSRDF (Bidirectional surface scattering reflectance distribution function) when considering SSS

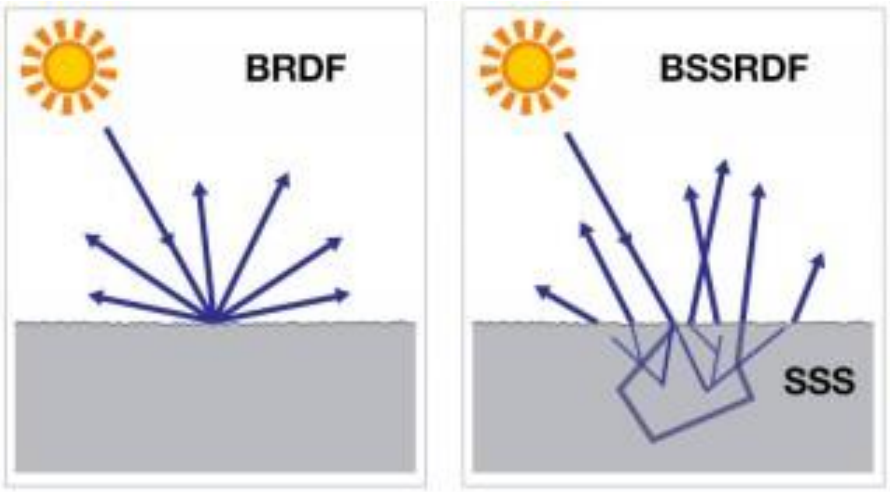


Figure 2.3

Some background first on the state of the art of SSS. Starting with a landmark paper by Jenson (et al Siggraph 2001: A Practical Model for Subsurface Light Transport), much of the Subsurface scattering approaches have been an approximation, normally based on dipoles, a method that approximates the scattering beneath the surface using points and the dipole maths of having a function above and below the surface that gives the control on the amount and distribution of the scattering.

Mis:Arnold was one of the first renderers to deploy MIS back when Fajardo worked at Sony Pictures. Today the implementation at Solid Angle is quite advanced, more than just using it for BRDF and lights. It is "applied to many many places in the renderer, virtually any place in the renderer where there is an integral you can apply IS - and there are many integrals in a renderer," says Fajardo. If you are smart enough to find multiple samplers, most of the time people find just one sampler or method, but if you are smart enough you can find multiple samples for the same task and then combine them." It is for example used for SSS in Arnold.

"The control is hidden from the user," says Fajardo. "The user should never know, they don't need to know. The user should never never know as it is unrelated to the art of using a renderer."

While the user may never need to know directly, MIS is incredibly important to image quality and render speed. IS is being used in the new SSS example above and also with area lights. Area lights are not only great tools for producing very attractive lighting as any DOP knows but it is also key in using IBL with HDR lights in the scene and many other areas of modern production. Another great example of Arnold's research into IS was published at Eurographics Symposium on Rendering last month (2013). The paper was called *An Area-Preserving Parametrization for Spherical Rectangles.* This rather dry sounding paper explains how much more sensibly the lights can be sampled given the spherical projection nature of working in computer graphics.

In this diagram below (left) it can be seen that a rectangular light can appear bowed - in much the same way a real light such as a Kino Flo appears bowed when shot with an 8mm fish eye lens (right). Note this 'appearance to the spot being computed is called the Solid Angle (from where the company takes its name).

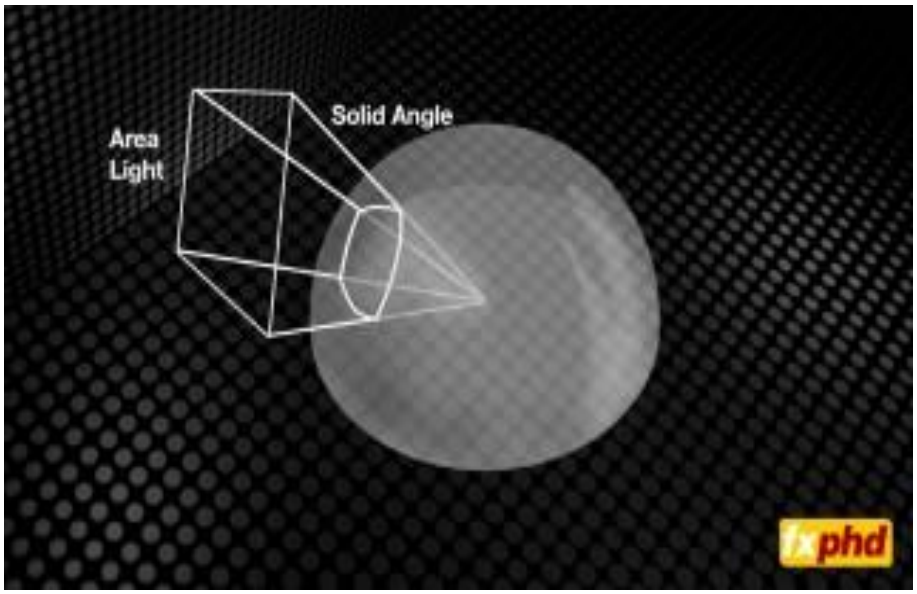
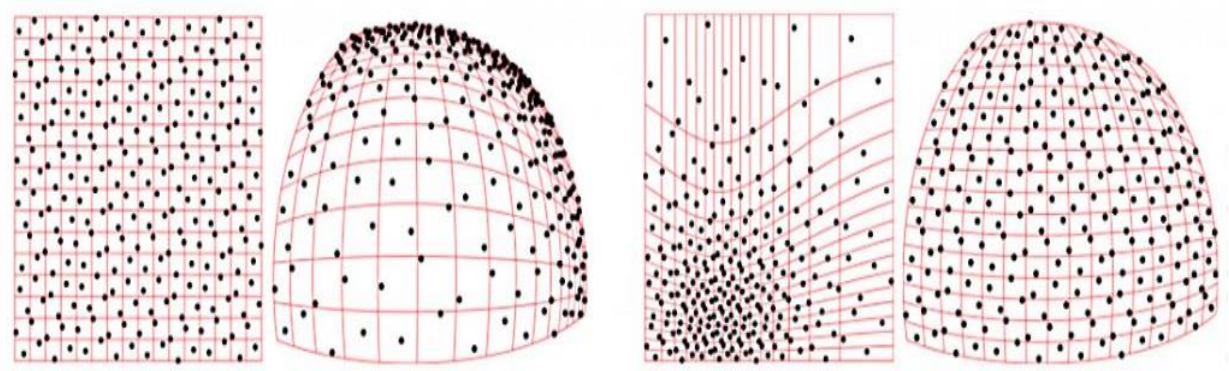


Figure 2.4

The point of IS and the render equation is to estimate the integral via sampling intelligently. "If you project a rectangle onto a hemi-sphere, that covers a certain solid angle - whose shape is spherical rectangle," explains Fajardo, "and we have found a way to sample the solid angle." By sampling the solid angle uniformly, you are sampling the original rectangle not uniformly, and thus much more effectively. "It turns out that doing that cancels out the one of the terms in the rendering equation (the inverse square term or geometric factor) and because it cancels it out, you just have less variation in the integral, which translates to less noise (in the render)."

The company Solid Angle takes the mathematical solid angle into account with its sampling. The problem is when an area light is seen from the computer's point of view via the 'soild angle' maths that is the area light as 'projected' along sight line with the computational 'dome' used in computer graphics, it is now easy to see just how much the samples are all collecting along the edges. So much stronger is this bias or effect than one might imagine - it is worth checking any square for yourself (count in from the left and bottom and you can see that both of the shapes in (A) marked Area sampling are exactly the same. What is needed is to start from a distribution. If one starts with the scattering on the left in (b) Spherical Rectangle sampling, when the 'projection' is taken into account the sample is now more evenly spread. This directed sampling is just a refinement that falls under improved Importance Sampling.



(a) Area sampling (b) Spherical rectangle sampling

Figure 2.5

It is most noticeable closer to the lights. Exclusively, we can show an animation rendered with the normal area sampling and then - with no other change than the new IS - the spherical sampling version. The reduction in noise is dramatic. (note some banding in these videos is from compression NOT rendering)

Muti-Threading performance: It can be argued that with ray tracing there are three primary concerns:

1. render speed
2. noise
3. memory limitations

But Fajardo says he would add a fourth: threading scalability. Today machines can have 32 threads and this is only going to increase. Scalability "is going to be more and more important as Intel and others come out with processors with more and more threads on them," says Fajardo.Arnold has incredible multi-threading performance. "I feel like we have done a tremendous amount of work to make Arnold scale optimally in many-core machines. It's easy to run fast on one thread, but running on 64 threads is a different story, you typically run into all kinds of performance bottlenecks that you have to analyze individually and solve with careful, low level programming or sometimes with better mathematical models."

Fajardo argues that things that one might take for granted, like texture mapping, can become threading bottlenecks unless the renderer and development teams can benchmark, analyze and optimize to a machine with many cores. Currently, as we spoke to Fajardo at Solid Angle, they are evaluating machines graciously donated from Intel with 32 physical cores / 64 threads.

In the case of texture mapping, the problem is that you need a texture cache to hold the hundreds of GB of texture data required to render a complex VFX shot.

"And texture caches require some sort of locking mechanism so that multiple threads can write and read from the cache in parallel without corruption," says Fajardo. "We worked hard with ILM during PacRim (Pacific Rim) to solve that problem and as a result we probably have the most efficient (in terms of threading) texture engine in the industry. It's funny to watch other renderers die at such scenes, renderers that have traditionally had awful threading scalability (like Pixar's PRman), where people have gotten used to such bad scaling that to compensate run such renderers on a small number of threads per job, e.g. run four 2-threaded jobs on a machine with 8 threads, therefore limiting the amount of memory available to each job."

With Arnold, one can be sure "you are making full use of all of those 16, 24 or even 32 cores in your machine while using all of the available memory," argues Farjardo. This becomes increasingly important of course as artists do lighting work on increasingly complex scenes, in their powerful workstations with an ever increasing number of CPU cores.

"You would be surprised", explained Fajardo, "even Disney's almighty Ptex library, which caused so many ripples in the industry, is not threaded well and destroys the performance of your renders. Which is probably OK for Disney as they use PRman therefore running it on very few threads. But run it on all the threads of a powerful machine, as we did, on a simple scene with a single Ptex-textured polygon, and the results are abysmal." Here are the results Solid Angle provided to support this claim:

threads	pixel rendering time	**speedup**
1	18.94s	1x
2	11.91s	1.6x
4	7.23s	2.6x
8	9.44s	2.0x
16	12.37s	1.5x
32	13.39s	1.4x
64	14.65	1.3x

In this test case, instead of 32x faster with 32 threads, it's only 1.3x faster. "Which means that 30 of the cores are idle and you are wasting your money," he adds. "I could give you more examples. Katana has never been thread-safe and therefore forced single-threaded loading of geometry (though I imagine they will fix this eventually). Most hair-generation pipelines are ancient and therefore not ready for multi-threading. All of which are reasons why big studios don't fully take advantage of threading and would run multiple single-threaded jobs on the same machine. It's an embarrassing fact that most studios hide, and if you ask them they'll give you all kinds of hand wavy explanations as to why running single-threaded jobs is more "efficient", Fajardo points out passionately.

2.2. Mantra - Side Effects Software

Side Effects Software's Houdini product is incredibly successful. In countless films now it seems a Houdini component exists helping with either fluid effects, destruction sequences, smoke, flames or just procedural implementations of complex animation.Andrew Lowell, Senior FX Artist and Houdini trainer at fxphd.com, has used Houdini on films like *Jack the Giant Slayer, Ender's Game, Transformers 3, Thor, Sucker Punch, Invictus, Mummy 3* and *Aliens in Attic*. "Like most things in the Houdini universe, Mantra will deliver everything you ask of it and more as long as the user commits to learning the science of what they're doing," says Lowell. "It doesn't hold anything back or make anything easier.

Like many people the first time I fired up a Mantra render I was thoroughly disappointed by the lack of prettiness, a clunky speed, and having to go to a few different places in the software to get in and start adjusting things. But, when it came time to get the job done, Mantra has never let me down. It's enough to make any lighting department struggling with heavy renders, envious. What at first seems like a slow render on a sphere manifests itself in production as a highly efficient render of millions of particles with full motion blur. What seems like a lot of work to set up a shader ends up being that life-saving modification at a low level to easily give the compositor the AOV's they need. And what seems like a lack of user interface with ease concerning lighting and submission turn into highly automated and dependent systems in the latter stages of production."

Mantra as a renderer in it's own right can also be optimized for almost any render or situation, such as large crowds, or very large volume renders, "and it has the flexibility to achieve any look on any project," adds Lowell. "I remember a bit of render engine snobbery from a vfx supervisor saying he would only accept renders from a certain engine and Mantra was the worst you could get (!). We

didn't have time for the lighting department to do look development on the fx so, I simply took the time and textured/lit the elements myself, and mimicked the properties of the other engine. I submitted my final elements as lighting elements. Everyone was on board thinking how well we had lit elements except for the compositing department, who wanted to know why the motion blur was of higher quality."

Of course, Houdini could be used for any 3D animation, but it is known for its effects animation more than anything else today. Mantra is included with Houdini. In 2012 fxguide celebrated the 25th anniversary of the company. In that story we wrote:

According to Nick Van Zutphen, who helped us compile this story, in 1988 a guy in a big wool sweater showed up at the Side Effects office, 'sheepishly' looking for a job. That person was Mark Elendt, who at the time was working for an insurance company. The insurance company part didn't really impress Kim Davidson and Greg Hermanovic, but what they did notice were some photographs Elendt showed taken from an Amiga 1000 screen (with 512kb RAM). It displayed renders of a typical late 80′s ray-traced sphere. "He had written a ray-tracer as a hobby," says Van Zutphen. "This was the prototype of Mantra, which is Houdini's native renderer."

Mantra is still to this day the Side Effects Houdini packaged renderer. It is very similar in many ways to Pixar's RenderMan, a renderer that many Houdini customers also use.

Today Mantra is very much a powerful solid option for rendering, offering one of the best known in-house renderers from any any of the primary 3D vendors. It is very much a tool that could be marketed separately but has always been part of Houdini. Mantra's micropolygon rendering is based on the REYES algorithm. It is a *divide and conquer* algorithm, a strategy whereby a difficult problem is divided

and sub-divided into smaller and smaller problems until it is decomposed into a large number of simple problems. For micropolygon rendering, this takes the form of *refinement*.

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and sub-divided into smaller and smaller problems until it is decomposed into a large number of simple problems. For micropolygon rendering, this takes the form of *refinement*.

Figure 2.6 *Mantra looks very much like RenderMan:*

With raytracing, mantra does not refine geometry *if it knows how to ray trace it natively*.The raytracing engine has algorithms to do efficient raytracing of points, circles, spheres, tubes, polygons, and mesh geometry.

"These days it has shifted very much towards the ray tracing approach, we don't have too many people using micropolygons anymore, unless they are rendering something that can not fit in memory, but the amount of memory on processes these days is quite high, you fit a lot of geometry in memory and use the ray tracer for pretty much anything," explains Side Effects' Andrew Clinton, 3D graphics programmer. "There are a lot of techniques handled more efficiently with ray tracing than with micropolygons, like instancing, you can keep a single copy of an object in memory and just trace rays with different transforms whereas with micropolygons you would need to create new shading grids for that object for each instance, which is a lot slower. The other advantage is that if you have polygons

smaller than a pixel, you spend a lot of time breaking up objects that are already smaller than a pixel. In ray tracing you just keep the geometry as is and you don't need to create any additional geometry or data structures so it is efficient memory wise."

VEX is a high-performance expression language used in many places in Houdini. VEX evaluation is typically very efficient giving performance close to compiled C/C++ code.

VEX is loosely based on the C language, but takes ideas from C++ as well as the RenderMan shading language.Mantra uses VEX for all shading computation. This includes light, surface, displacement and fog shaders.

Mantra has at the kernel of the renderer both the micropolygon renderer and a ray tracing engine, but "there are different renderers built on top of that, we have a pure ray tracer but we also have a physically based rendering system that is built on top of that and it is built using the VEX shading language," points out Side Effects senior mathematician Mark Elendt.The core ray tracer could have a biased or unbiased renderer written on top of it thanks to the flexibility of VEX. "Our physically based renderer is pretty much completely unbiased and it is written in that shading language," adds Clinton.

In the physically based renderer the team use MIS for the direct lighting, and the BRDF in the scene. Side Effects has experienced a lot of interest, but actually they built it some time ago, before there was as much interest. And it was "a bit like: if we build it - they will come," says Elendt, referring to their 2008 initial implementation. Today there is much more interest in physical plausible pipelines, something that has validated a lot of the early work Side Effects did in this area.

Mantra and Houdini are known for their volumetric work, having won technical Oscars in this general area of research (Micro-voxels). Side Effects was one of the first companies to work with Dreamworks on OpenVDB, partnering with them to

help make it open source. The new OpenVDB allows the volumes to cope with very sparse spaces, which really expands Houdini's Mantra to efficiently render huge spare volumes without huge memory hits. Side Effects really supports open source, also very actively supporting Alembic for example. "One thing we did in 12.5 with Alembic and our own geometry is that we implemented a really efficent polygonal mesh that uses pretty much the minium amount of memory possible, and this really helped with our big fluid sims such as oceans," explains Clinton.They have also done serious work in volumetric lighting, providing say fire as a lighting source, which was a generalization of their area lights to handle volumes as well as surfaces as volumes. "If you have parts like the center of the fire, that are really bright then it was really good from a perspective of sampling, to be able to focus your ray tracing on those parts of the volume, to be able to direct your sample there, it results in really low noise in the render."

The next release not only will have improved Alembic support, but new lighting tools for Houdini and Mantra interaction. But as the next release is not until later in the year Side Effects may release support before the next release for OpenEXR 2.0 deep compositing. Mantra has had its own format for some time for deep data but this would be that output in the new OpenEXR 2.0 deep data standard. "The advantage of OpenEXR 2.0 is that you can bring it into Nuke and do compositing there", says Clinton.Mantra supports SSS using a point cloud approach with an irradiance cache, it is based on a Jenson dipole model. There is a ray tracing and path tracing approach in the lab, but many to have a ground truth to compare the point cloud to. Research is continuing but there are no immediate plans to change the system or approach.

Mantra continues to improve its speed, this is especially true of the ray tracer. Clinton joked that some work is new algorithms and some stuff is more dumb stuff that was broken. In one isolated case a simple fix on opacity made a huge difference to fur rendering - literally one tweak yielded a render several

orders of magnitude faster on complex fur for one client. It is not this simple but "we just played with a constant and got huge improvements!," joked the team quick to point out that was an unusual "edge case".

2.3. CINEMA 4D - Maxon

Oliver Meiseberg, product manager, Maxon Computer GmbH told fxguide: "CINEMA4D supports other renderers very well, we cover almost any renderer out there in our software. It is up to the user to choose whichever renderer they feel comfortable with and is the best for the project."

Figure 2.7

While most renderers are available, Meiseberg estimates the most popular is easily V-Ray, "but a bunch also use Mental Ray and the large houses use RenderMan." A new version of CINEMA 4D is expected to be at SIGGRAPH 2013. According to some sources, a third party made bridge to Arnold and support for Krakatoa may be previewed at SIGGRAPH. Thinkbox Software's Krakatoa is a production-proven volumetric particle rendering and manipulation Toolkit. There

may also be a V-Ray update which will be coming. The key area to watch out for with V-Ray is support of light mapping.

Light mapping (also called light caching) is a technique for approximating GI in a scene. This method was developed by Chaos Group and will be in R15 to be announced on July 23rd. It is very similar to photon mapping, but without many of its limitations. The light cache or map is built by tracing many eye paths from the camera. Each of the bounces in the path stores the illumination from the rest of the path into a 3d structure, very similar to the photon map. But in a sense the exact opposite of the photon map, which traces paths from the lights, and stores the accumulated energy from the beginning of the path into the photon map.

CINEMA 4D offers two render options. After version 13 there has been a second physical renderer. The light mapping is in the physical renderer for example. "Most people love the physical renderer - the feedback has been awesome, but with tight deadlines - most people go back to the advanced renderer but if you want physically accurate use the new renderer."

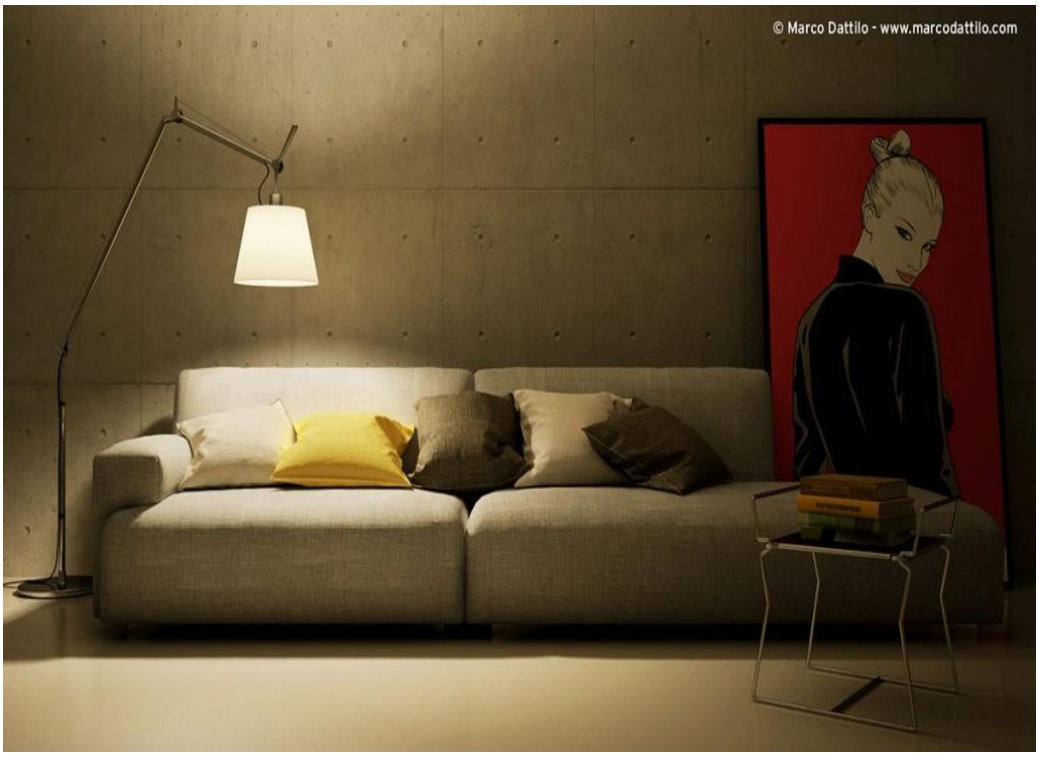


Figure 2.8

The SSS shader was completely rewritten from scratch for version 13, and thus is fairly new. The standard set in SSS with its varying wavelength adjustments has proven popular with customers. Like many users there is a desire amongst C4D users to move to a simpler lighting model, with no loss in quality but with an easier more natural lighting setup phase that behaves more like one might expect and involves less hack and tricks.

The product is the leading application for motion graphics but it is more and more used in visual effects, and while it is not a primary focus for the company, they are happy with the growth the product has experienced in both the entertainment space and the product visualisation community. Maxon has customers in the automotive industry and many other major product design companies. The main goal remains the motion graphics industry. "It is great to see the product entering other markets - even if we don't target them," says Meiseberg.

One of the biggest coups of the last 6 months is the link between Maxon C4D and Adobe's After Effects. While not a rendering issue directly it has helped to bring the product to an even wider audience and given the brand vast extra international exposure. You can link from AE to the CINEMA 4D render engine, the render engine is based on the R14 advanced renderer, and not the new physical renderer, but this is coming, says Meiseberg. There is also a live or dynamic link from Premiere to AE which allows teams to work more effectively in a production concurrently. This places C4D renders back into AE and then automatically into Premiere.

"Cinema 4D entered a new era with the introduction of the physical renderer," says C4D user and fxphd Prof. Tim Clapham. "Allowing us to use real world camera attributes such as aperture and shutter speed in conjunction with true

3D motion blur and depth of field. This combined with a central location to control global samples for blurry effects, area shadows, sub-surface scattering and occlusion shaders results in enhanced workflow with more realistic renders."

2.4. Modo - The Foundry

Modo from Luxology, now at The Foundry, is expanding on several fronts. Firstly, as a part of The Foundry it is more exposed to the high end effects market, but also because independently key supervisors such as John Knoll, senior visual effects supervisor and now chief creative officer at ILM, have been forthcoming in saying how much they like the clean and fresh user experience of Modo and its renderer. For example, inside Modo there is a spherical projection type for camera item that allows the creation of spherical environment maps, including export of MODO-created panoramic HDRI's. John Knoll rendered 360 spherical *Pacific Rim* set images out to his iPad for the film and then he could interactively look around the real set on seeing in real time where the giant Pac Rim machines and bases, cranes etc would be thanks to an app that detects tilt and shift and displays the window onto the Modo rendered 'set' interactively. This allowed actors to know where to look and for anyone to judge what the framing should allow for - in effect it was a virtual set - on set - via Modo and an iPad.John Knoll (an Oscar winner whose films include but are not limited to *Pacific Rim, Mission Impossible: Ghost Protocol, Avatar, Pirates of the Caribbean I, II, III,* and *Star Wars I,II,III* etc) has used Modo since version 201. ILM uses a variety of renderers and Knoll is no different but he seems to genuinely like the Modo tools and renderer for certain projects or tasks.

Modo is a hybrid renderer, if one keeps an eye on setting it is able to be run as a physically plausible, unbiased way. "In that sense I think it is more like V-Ray, when Allen (Hastings) was writing it (in 2002) he was looking at how we can

make it have the scalability that something like RenderMan is known for, but also take advantage of some of the new technologies that were coming out around then," says co-founder Brad Peebler. Through the use of both biased and unbiased approaches Modo's renderer includes features like caustics, dispersion, stereoscopic rendering, fresnel effects, subsurface scattering, blurry refractions (e.g. frosted glass), volumetric lighting (smokey bar effect), and Pixar-patented deep shadows.

The render is not as mature as some, for example its EIS Environment importance Sampling does not yet provide IS on directional lights nor full MIS covering materials, but the EIS does work well for both Monte Carlo and irradiance caching approaches and produces greater realism from HDR light probe captures or approaches. Furthermore the team plan to expand IS throughout the product.

Peebler points out that every renderer makes pretty pictures and can render photorealistic images, but the key now is getting there faster. "There are two ways you can do that, one is making your rendering engine faster and the other is making it so users don't have to fiddle with so many values and tweak so many settings."

Figure 2.9 *Visual effects by Light VFX from The Butterfly's Dream.*

Some renderers, he states, take the approach that everything is physically based and "you have to just render with the real world settings regardless, and others tilt the other direction, more human time to set it up but it renders it faster, inside Modo. EIS is one of those things that does both - and there aren't too many of those (!) - it is something Allan has wanted to do for a long time. Allen was actually inspired into the implementation after a conversation we had with Kim Libreri (senior VFX supervisor), John Knoll (ILM chief creative officer) and Hilmar Koch, (head of computer graphics at ILM) about importance sampling."

EIS is an aspect of the entertainment industry providing a new tool that has been appreciated by Modo's architectural clients, and that has been a two way street. In reverse the design and architectural clients requested embedded python, which has been a big boost to many effects and animation customers.

Modo is one of the companies focused on a variety of markets, pointing out some of their design companies are doing vfx work, but vfx companies like Pixomondo are doing design work to even out production cycles. For Peebler they believe they can cover multiple markets with the same core product, without the need to bifurcate to address them individually. And it is not even just something The Foundry is seeing just with Modo, Apple Inc. owns Nuke licenses, points out Peebler. For Luxology's R&D team it is key that their render technology cover a range of needs both photoreal rendering and more stylized solutions in a range of markets and countries around the world. "I was at a client - a design client who had a real time visualisation they have a set of screens making up a 15m x 10m LED wall - powered by a 500 cluster render farm - for real time interaction for their car design reviews, it was phenomenal, and from a budget point of view, the design space is vastly larger than the entertainment space," notes Peebler.The Modo renderer is provided as both a final render engine and as an optimized preview

renderer that updates as you model, paint or change any item property within Modo.

The Modo renderer uses high dynamic range radiance units throughout its calculations for accuracy and quality. The renderer is highly scalable on multi-core systems, delivering nearly linear speedups as more processors/cores are added. The renderer's performance is a combination of tight code and a "unique front-end that decouples many key computations, allowing for a finely tuned balance between memory requirements, speed, and final image quality," explains Peebler. "A client sent me an image that was about 6 trillion polygons that rendered in about 10 minutes, now those are of course a combination of multi-resolution sculpted micro-polys and a ton of instancing but the renderer is not the bottleneck." Modo 701 now scales better than 601 and "Modo continues to expand in this area of scalability."

One very exciting trend is the possibility of Modo and Nuke working more closely together. Nuke deploys only a scanline renderer as standard. Modo's renderer does not currently support deep compositing, but, says Peebler, "as a company that has the industry's leading comp system supporting deep compositing, you can imagine we would be 'interested' in getting the Modo renderer to support that as well."

Exclusive Nuke-Modo Tech Experiment: What makes Modo's renderer incredibly interesting is its sister applications at The Foundry. Connecting Modo to Mari, Katana both makes 3D sense, but the team is exploring much more than that. The Foundry is doing incredible work in exploring Modo, or more specifically Modo's renderer, with Nuke. This one, complex series of possible connections and interfaces could cause Modo's renderer to be elevated faster and more significantly than anything in recent times. Nuke is the dominant compositor in high end film and effects. Below is a video showing a test running in R&D. In the video Modo is automatically updating 3D renders in a Nuke setup. Of course it is possible to

render a number of passes that would allow Nuke to manipulate a render that has been imported but this is a live connection between the two applications. This was recorded on a laptop running 2.8ghz i7.

Peebler commented, "This is a "technical sketch" showing what we think workflows might look like in the future. This is not indicative of an intended shipping product. We like to "doodle" a bit with our vast body of combined technologies and we hope that this will spark a conversation with users to help guide us on what users would like to see, and what might be possible."

2.5. Lightwave - Newtek

Lightwave is very strong in a few markets including the television episodic effects market where sci-fi scripts have called for more and more visual effects.

Figure 2.10 *Eugenio Garcia Villareal*

Historically, the company has strong user groups in markets outside our scope, but it does influence its approaches to rendering. The company has roots in scanline rendering but since 2006 it has had a fully ray traced solution. Newtek's Rob Powers (President, NewTek LightWave Group) feels that many smaller

companies are keen to use new tools such as are discussed above but found it difficult: "I feel today with the struggles some studios are having to possibly use or adopt the same workflows that possibly highlighted at the very sexy ILM and Weta Digital project level, what I have seen is that a lot of studios are struggling trying to replicate that. We know that a company at the 40 or more staff members is the norm." And Powers feels LightWave is well positioned to help people and companies in that position.

While the renderer today supports ray tracing it also supports some of the other features and more traditional approaches. The software has both a nodal based and layered based shader system. "It is kind of like a Lego block system for people who don't know how to write shaders, and it ships with a bunch of predefined shaders like the skin shader or car paint shader," says Powers.

On the whole the ray tracer is a biased approach - a general radiosity solution designed for production, supporting a wide variety of approaches. It is designed to be quick which is more important than 'correct' according to NewTek. You can do a brute force approach but it is not normally used that way. It is a tool aimed to be quick and fast and not optically accurate to the extent of other high end renderers.

Figure 2.11 *Naoya Kurisu*

LW has an interactive window in the viewport (VPR). The first VPR was scanline, the next version was a ray tracer (LW 8.6/9), now there is a new version which is very fast and really a third whole approach. It is backward compatible, but the new VPR is really quite impressive. It no longer renders just polygons but it can render lines and other primitives. It also has a new instancing system that is extremely fast.

2.6. Mental Ray - Nvidia

Mental Ray is a ray tracer with MIS, but as a shader allows so much C++, it is hard to say it is unbiased or baised since you can use Mental Ray as just a thing that shoots rays but everything is then done by the shaders. But to be efficient is hard, it is the cost of Mental Ray's massive flexibility. There is so much legacy code around the code base. It may be that Mental Ray never transitions to a new hybrid efficient renderer. Today, one can run Mental Ray with BRDFs but only the

ones provided by the Mental Ray advanced rendering team. Depending on your point of view, Mental Ray is great platform for its flexibility or too code focused for a modern pipeline. The problem is really not if it *can* render it, but what it takes to set up that render, and maintain that as a modern physically based energy conserving rendering environment (should you choose to want to do that). Most people who want to set up modern new rendering pipelines for large scale production environments are simply not doing that in Mental Ray. At the other end of the massive pipeline production render environment are individuals who know how to use it and are keen to just get shots delivered. Lucas Martell is a director and animator who has made some hugely successful short film projects as well as working professionally for many years. "I've worked with Mental Ray for years and it's served our needs very well. A lot of the complaints about Mental Ray come down to its complexity. I feel like it has gotten much simpler in the past few years, but more importantly, those settings do give you some very granular control over the rendering quality/efficiency. Because we already know those settings inside and out, we've never run into something that we couldn't do in MR." "Granted we are a small shop, so the scale we deal with doesn't come close to the big animation studios, but the integration with Softimage is so great that we haven't hit the tipping point where investing in a lot of 3rd party licenses makes sense. Plus we have a lot of custom code written to optimize shaders, set up our passes, etc. Renderers are just tools. The best one is the tool you know inside and out."

2.7. 3Delight - DNA Research

3Delight is a RenderMan compliant renderer, and is used by companies such as Image Engine in Canada. They have been a customer since 2007. They have used it extensively with Cortex (see part 1) and they are one of the renderers' highest profile customers. Image Engine is always evaluating its rendering options moving forward, but for now it is very happy with the close working relationship it has with DNA Research.

Figure 2.12 *Zero Dark Thirty - VFX by Image Engine.*

Like many other companies they are looking at more physically based lighting and shaders with ray tracing. "Coming off the last few shows we have been reviewing our pipeline and thinking about how we might generally be more efficient and one of those things is simplifying the lighting workflow," says Image Engine CG supervisor Ben Toogood.

The notion of moving to new tools that are more physically accurate but also simpler from an artist point of view is a common desire in the industry. Image Engine does a lot of creature work, which often involves a lot of passes, baked textures and complex pipelines, so a high quality realistic but simpler process to lighting is very attractive. The less work in data management the more iterations and actual lighting the team can do. The team is in the middle of re-writing their shader library right now and re-examining some of those complex shader networks that have gone up in production over time. "For a lot of work and especially for background elements - hard surface props etc - we can move to using ready made shaders that have a lot of the physically plausible shading built in," says Toogood, "and having that base will hopefully make their behaviors more predictable for the artists. But whether that will be run through ray tracing or not is something we will have to look at. We need to be flexible and quite responsive, we have to be a bit

more clever than most in spending our computational budget, we are not a huge mega studio."

2.8. FinalRender - Cebas (GPU + CPU)

FinalRender was the first renderer to practically apply true global illumination rendering to the largescale vfx movie production with the film *2012*. The movie's bigger scenes used finalRender's advanced global illumination algorithms to render the vast photoreal disasters. The product is about to completely change with a new approach, and virtually all new code.

Figure 2.13 *An older render pre-4 from Makoto (Pasadena).*

There is a new version of FinalRender 4GPU that will be launched at SIGGRAPH and as the name implies it will have GPU support, and be a normal upgrade to 3.5 users. "We have been working for a long time now," says Edwin Braun, CEO at Cebas Visual Technology Inc, "the next step is really a new product, and with the changes in CUDA (5.5) - it will be a CUDA product - we have had to do so many new changes - it is really a new renderer - there is not much left from 3.5 - other than the name!" It is part of a wave of new GPU products, but significantly different as it is also CPU. There will now be "no difference between a GPU rendering and a CPU rendering and that is a hard thing to do," says Braun, "we are getting really close to this goal we have set for ourselves."The newest version is finalRender 4 GPU which is a hardware accelerated (GPU) rendering approach with a rather unique balance between GPU and CPU balancing. Unlike many other GPU-only renderers, finalRender 4 GPU "will always be faster" with newer hardware even when upgrading the workstation alone and still keeping the GPU card. It will use all available rendering cores and not only one type of processor.

Figure 2.14 *Living room interior rendered in finalRender by Doni Sudarmawan.*

In contrast to other renderers, Cebas uses a hardware acceleration approach that will not favour CPU over GPU or vice versa. In fact, cebas' trueHybrid technology will leverage the full potential of existing CPU cores as well as, simultaneously, using all existing GPU cores and memory. Maintaining full accessibility to features and functionality of the core raytracing system, trueHybridTM will not sacrifice quality for speed. Unlimited Render Elements (layers), Volumetric Shaders, complex Blend Materials and layered OpenEXR image file export along with hundreds of 3rd Party plugins; are a few of the features made possible by finalRender 4 GPU that were otherwise unattainable with a GPUonly rendering system.

finalRender 4 GPU provides some shading and rendering flexibility to GPU rendering. Offering an advanced new material shading core provides finalRender with the advantage of representing nearly every material effect in the form of a highly optimized native GPU shader. It supports the car shader the skin shader, and many other shaders from 3DMax. "If you have a Mental Ray scene and you use the

Mental Ray architectural materials from Mental Ray, you can just render it with our GPU renderer," says Braun.

Rendering Core and Integration finalRender 4 GPU is a fully integrated 3ds Max renderer with the key benefit of being compatible with existing 3ds Max workflows that usually include support of third party plugins. The following three rendering methods are all available with finalRender 4 GPU:

- GPU Only Rendering Mode (full path rendering like Octane, or V-RayRT)
- CPU Only Rendering Mode (like the old 3.5 used to run)
- CPU + GPU (trueHybrid) Rendering Mode

The last mode "uses the GPU for your CPU rendering." What does that mean? If you render with Fume FX, this is a CPU plugin, but in hybrid mode it will pass off some internal calculations to the GPU, in effect it is a GPU turbo charger on the CPU, even if the plugin should only be a CPU option. In tests this hybrid mode has shown 2x up to 5x speed improvements over just CPU alone. This hybrid mode is different from where a CPU may help a GPU. As the Cebas model works the other way, all the CPU plugins will be able to get GPU acceleration. "We can use all 3DStudio Max plugins as we were able to use them in our sw renderer, and the user will have no problem running 3D Max plugins and use their GPU if it is available," explains Braun. This will work well for farm rendering when the farm machines may have no GPU cards.

finalRender 4 GPU is aiming for a really high goal of providing a continuous GPU/CPU rendering workflow for 3ds Max users. trueHybrid is a novel approach. It was developed to allow co-operative hardware rendering by leveraging different types of processors at the same time in one workstation.

Global Illumination Methods:finalRender offers the benefit of multiple Global Illumination engines for artists to choose from. The newest GI rendering

method offers a unbiased, physically accurate path tracing method; with fast GPU based Global Illumination.

Other options or methods include:

- Irradiance Caching
- Unbiased Rendering
- Light Cache Rendering

Core Render Qualities (Realtime and NonRealtime):

- Newly developed: Content Aware Sampling (CAS)
- Physically Based Wavelength / Spectral Light Transport
- Biased & Unbiased Rendering incl. Direct Lighting / Ambient Occlusion support
- Full physically based IES light support
- Physically Based material shading model
- Highly optimized Geometry Instancing for GPU and CPU

2.9. Octane - OTOY

Octane is one of three new renderers that we have included in the round up. Each is approaching rendering from a new point of view and each has the promise of being impactful in their own right. Ocatne is a powerful GPU render solution that works using both local and cloud based GPUs. fxguide has written about the product when it was launched over a year ago, and was heavily featured at the last

Nvidia GPU conference. At that conference it was announced that it would be used by Josh Trank, director of *The Fantastic Four*, for his in house vfx team. Trank appeared on stage during the keynote speech of Nvidia chief executive Jen-Hsun Huang at the GPU Technology conference in San José. Trank touted how his special effects team will be able to tap cloud-rendering technology from OTOY to create the movie at a much lower cost.

As we pointed out at when it came out of Beta, Octane Render is a real-time 3D unbiased rendering application that was started by the New Zealand company Refractive Software. OTOY is now developing the program. It is the first commercially available unbiased renderer to work exclusively on the GPU, and runs exclusively on Nvidia's CUDA technology. OTOY sells Octane as a stand alone renderer as well as a plugin to popular 3D applications such as Max and Maya. The company has strong links to cloud computing and graphics research. OTOY also owns LightStage, LLC in Burbank which did the facial scanning for *The Avengers*, among other films, and Paul Debevec is their "chief scientific consultant". They also have a special relationship with Autodesk, who are an investor, and its tools can be integrated as a plugin for almost all the major 3D art tools on the market today.

The base Octane is still very young, but it has such strong partners in Nvidia and Autodesk alone that it demands attention. But the primary aspect of Octane is its promise to bridge the divide with high end production rendering on GPUs.

Figure 2.15 *God rays using Octane with transmissive fog.*

The company also has Brigade which is not yet a shipping product, but aims to deliver GPU ray tracing at game rendering speed. Brigade is a different code base from Octane and the two products are sharing algorithms and innovations moving forward but Brigade is not yet a shipping product. It is however one of leading realtime path tracing games speed rendering products and tests have shown exceptional rendering speed, but at the cost of classic ray tracing noise, that while fine in real time would naturally need to be rendered longer in a production pipeline.

The whole area of real time ray tracing is about to have another major boost from SIGGRAPH 2013 Realtime Live! event. Once again this year at SIGGRAPH there is a special session showcasing the latest research and in particular games development for realtime rendering. Real-Time Live! is perhaps the world's premier showcase for the latest trends and techniques for pushing the boundaries of interactive rendering. As part of the Computer Animation Festival, an international jury selects submissions from a diverse array of industries to create a fast-paced, 90-minute show of cutting-edge, aesthetically stimulating real-time work.

2.10. Clarisse iFX - Isotropix

Clarisse iFX is included as one of our three new renderers as it seeks to not fit into a pipeline in a traditional sense. The team lead by founder Sam Assadian wants to merge the product into a pipeline not as an end renderer but starting further back up the pipeline. While solving the render equation quickly is important, it is changing the workflow itself that interests him.

Clarisse iFX is a new style of high-end 2D/3D animation software. Isotropix is a privately owned France company and has been working on Clarisse iFX now for several years. It has been designed to simplify the workflow of professional CG artists to let them work directly on final images while alleviating the complexity of 3D creation and rendering out as many separate layers and passes. Clarisse iFX is a fusion of a compositing software, a 3D rendering engine and an animation package. Its workflow has been designed from scratch to be ‘image-centric’ so that artists can work constantly while visualizing their final image with full effects on. It wants artists to see the final as much and as constantly as possible.

At its core, Clarisse iFX has a renderer that is primed and ready to start final renderings within milliseconds of your finger touching something requiring a re-render. It provides a lot more, but this central mantra means that the program feels remarkably fast, insanely faster than it should given that the program is rendering on CPUs and not GPUs.

The renderer is different from some listed here in that it is very tied to the front end, but unlike native renderers of animation and modelling packages, Clarisse iFX can't model. It is designed to import and do some animation, although not character animation.

Figure 2.16 *Screenshot of Cube Creative's assets from the Kaeloo french TV show, featuring characters rendered with 3D DOF and motion blur.*

Since launching a year ago it has been developing new versions of the software but also working extremely closely with several key players to integrate Clarisse into other OEM products. At SIGGRAPH 2013 it will launch the new v 1.5 with major improvements, but one senses the real action will be in these OEM deals. The interest from other companies comes from the lighting fast render times and the data management that focuses not just on fast rendering but changing the relationship between the renderer and the rest of the modeling and animation software. Company founder Sam Assadian explains this conceptually by drawing a picture of the current industry workflow as having "dinosaur, 20 year old code passing along this tiny wire to modern rendering engine - that just does not work." What this means in practical terms, according to Assadian, is that when production shots are ready to be handled over to rendering, just loading the files can take, say, 45 mins to open and then even longer to see the first renders appearing. The pipeline may then render efficiently but this lack of integration and legacy code from generalist old software means the artist has no sense of immediate rendering on large scenes. For Clarisse iFX he claims the same production shots in their

pipeline would open almost straight away and then start rendering almost immediately - "we cut the wire". His approach is to therefore tackle not so much just fast rendering but integrate the renderer further up the pipeline so the traditional divides are gone but so too are the vast load times and poor interactivity.n The actual renderer is a single path tracing solution but after the new V1.5 to be launched at SIGGRAPH they may be introducing irradiance caching. This might seem like an odd move, but the speed of irradiance caching is just too compelling for Assadian to ignore. He feels for some jobs especially stills frames of vast complexity many lighting TDs just want the fastest solution and he is keen to provide whatever it takes to render vast scenes quickly. Actually irradiance caching had been mentioned a year ago when we wrote of the launch of the product, and at that time it was thought to be in beta. As a company they do not do a normal release cycle with major versioning. One gathers that at this early stage custom builds and close integration with their small but important user base does not require or respond to a major/minor release normal schedule. While the company has a range of these key OEM customers, there are few customers using the product in day to day production.

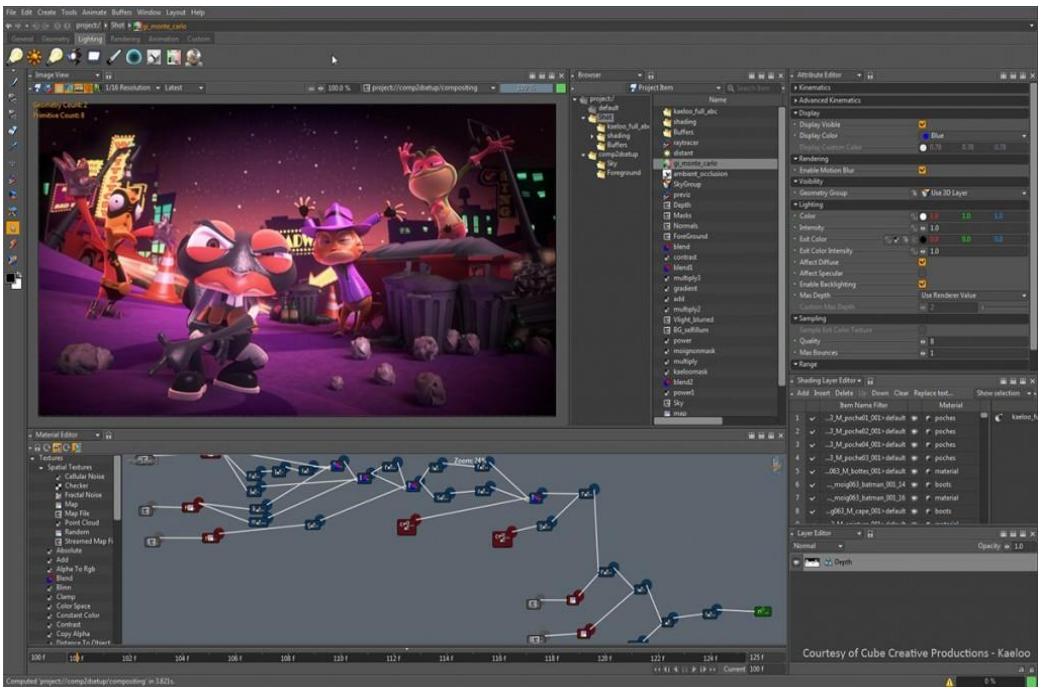


Figure 2.17 *Clarisse screenshot.*

The system is still extremely young, it lacks some features such as caustics and deep color/deep compositing but its multi-treaded rendering approach is fast. The company is keen to embace open source, it is especially keen to embace the new Alembic 1.5 as the company finds the current Alembic file format not suited enough to their multi-threaded approach to not be slowing down the iFX system. The current Alembic is supported but Assadian expects big improvements with the new release 1.5, and he has seen 20x times improvements.

`Similarly they are exploring OpenVDB for post 1.5 and seem certain to adopt it for volumetic work. The shader and material definitions are not currently supporting OSL but Assadian described Open Shader Language as "very sexy" and again something they are very keen to explore later this year.

The company has attracted a lot of early attention for its outrageously fast rendering pipeline (load, interact render). Already it has been working with companies such as ILM and Double Negative. The next 6 months will seem to be critical, if some of these third party companies integrate the product then it could really shake up the industry, if not then its new approach may fail to gain traction and it may need to rethink its new 'string cutting' approach and work more like a traditional renderer. But this second option is clearly not of much interest to the team and founder Sam Assadian in particular. The product is worth checking out at SIGGRAPH 2013 if you are attending, they will have a booth.

2.11. Lagoa

The last of the new renderers is Lagoa. But unlike the others, Lagoa is not GPU based but it is cloud computing only.

Figure 2.18 *Rendered in Lagoa.*

It uses a variety of approaches based on the materials which the company calls Multi-optics. For example, there is a specific approach for hair - optimized for hair, and a different approach for sub-surface scattering, which is a progress non-point based solution - which is again optimized for SSS.

It is a web-based renderer. For almost all other products aiming to be a web tool this would mean it is anything but a production renderer. Most other products fall somewhere between a toy and a light weight educational tool. What makes Lagoa stand out is that the actual renderer is technically cutting edge and has real R&D innovation feeding very high quality results. The company aims to produce production quality rendering in not only render farm free pipeline but to a local render free desktop machie. With modern internet connections Lagoa aims to be taken very seriously in the high end render market and in so doing change the way

people structure companies. The Lagoa SSS is brute force (fully ray traced) and includes both single and multiple scattering. "Consequently, the method does not require any precomputation and works for anything ranging from thin volumetric slabs to an army of volumes with highly detailed surface structure. "The only assumptions we make so far is a specific BRDF at the interface: glossy diffuse ("Rough Volumetric") or pefectly smooth ("Smooth Volumetric"). Moreover, light sources inside a volume is not supported. We also take advantage the path space analysis discussed below (which means that, in the end, we are not fully unbiased)," explains co-founder Arno Zinke.

The ray tracer is uni-driectional but the company does not like working inside labels such as 'biased or unbiased'. "Generally, I think the biased vs. unbiased battle is over - consistency is the key," says Zinke. "We are currently exploring the use of other methods (including fully bidirectional path tracing and a novel progressive consistent method) but the current implementation is uni-directional. On top there is a path space analysis to reduce 'fireflies'. The method goes beyond standard approaches, like clamping or BRDF smoothing and is less aggressive (more selective) when dealing with hard-to-sample paths."

Figure 2.19 *Lagoa Hair Render*

There is extensive use of importance sampling, on materials and light sources and IBL. "We use (multiple) importance (re)sampling for lights (also in spectral domain, when having for example spectrally varying scattering coefficients in case of SSS), image reconstruction filter, phase functions and all other materials," adds Zinke.

The system is expanding with more advanced shaders for plastics and other materials, as part of a realease of an update at SIGGRAPH. Included in this will be a new editing texture pipeline and light projectors are also being added.

One of the great additional services the company offers is to have the exact materials (a 5x5 patch) actually scanned and a real BRDF is then used in the renderer. "Besides classical BSDF and volumes we also support the direct rendering of particle scattering functions, BCSDFs (Bidirectional Curve Scattering Distribution Functions) and BTFs (Bidirectional Texture Functions)," says Zinke.

2.12. V-Ray - Chaos Group

V-Ray from Chaos Group is one of the most successful third party renderers, with wide adoption. Key V-Ray studio users include Digital Domain (*Oblivion*, *Enders Game*) and Pixomondo (*Star Trek: Into Darkness*, *Oblivion*). ILM also used V-Ray heavily for environments on *G.i. Joe: Retaliation, Star Trek: Into Darkness, The Lone Ranger* and *Pacific Rim*. And Scanline VFX is another V-Ray heavy lifter. "In fact I think everything ever rendered on their (Scanline's) showreel is out of V-Ray and they have done tight integration with their Flowline fluid simulations," says Lon Grohs, business development manager of Chaos Group. "This includes work on *Avengers*, *Battleship*, *Iron Man 3*, all kinds of stuff." Stuart White, head of 3D at Fin Design, a boutique high end commercials animation, design and effects company in Sydney, uses V-Ray and finds it a perfect fit, providing high end ray traced accurate results without the pipeline and artist overhead of non-raytraced solutions. "Rendering-wise, we are all about V-Ray here. It makes consistently beautiful images whilst being easy to use, affordable and pretty bullet proof even in the face of some seriously heavy scenes."

Figure 2.20 *Fin Design + Effects, Sydney, use V-Ray for high end TV spots like this Cadbury one.*

As seen above, V-Ray produces excellent images with particluarly good fur, SSS and is used around the world, by large facilities but especially mid-sized companies producing high end work. It is also now available to on several popular cloud services and was used by Atomic Fiction that way for *Flight*. There are various version of V-Ray supporting different products, such as Max, Maya, Rhino, SketchUp and more, but for the purposes of this article we can assume they are the same from a rendering point of view. V-Ray is basically a ray tracer and it does do brute force ray tracing very well, but the team at Chaos Group have added all types of optimizations for architectural visualization and other areas, so the product does have radiance caches and a bunch of other things which would be classed as biased, but it can work very much as an unbiased renderer. It has had physically based material and lights from the the start of the product - "that is what we are from the start" says V-Ray creator and Chaos Group co-founder Vlado Koylazov. V-Ray's workflow is very clean and the artist can work well with data from on set such as HDR image probes and IBL lighting etc. "We hear people like being 90% there and just matched to a plate with just the things they have documented from on set. From there - there is always the artistry. In fact I have only had one client ever come and ask for non-physically based rendering," jokes Lon Grohs.

Figure 2.21 *A scene from Oblivion. VFX by Pixomondo.*

The product has always used MIS since starting. V-Ray is very much the product of being a modern renderer, sampling is often handled for the artist keeping the interface very clean using adaptive sampling. The adaptive sampling both increases based on a noise sampling threshold system. The renderer is checking neighboring pixels and until the noise threshold is reached it can apply more samples.

In the early days of the product the company had to deal with efficient memory use to allow for the scenes to be rendered in what was then very small amounts of RAM. The team deployed a proxy system which was very successful and is still used today. It avoids having to load all the geometry at once.

V-Ray's SSS:

Figure 2.22 *SSS in V-Ray. Dan Roarty*

V-Ray uses a dipole approximation for the VRayFastSSS2 shader. "Some methods are more precise technically speaking, but we've found that the VRayFastSSS2 provides the best balance between quality, speed, and intuitive

controls," says Koylazov. "For V-Ray 3.0, we are considering additional models including a fully ray traced solution. We are also looking to implement a simple skin shader with simple, artist-friendly settings. Some of our customers have written their own SSS shaders for V-Ray including multipole and quantized diffusion." It is possible to render a full brute force solution inside V-Ray but it will naturally be slow. As V-Ray is a production renderer most people use the new and popular VRayFastSSS2, but before the new Fast SSS2, V-Ray was already producing strong SSS images as seen in the Blue Project image left.

Figure 2.23 *Dan Roarty*

Figure 2.24

When Dan Roarty is working he sets up a few area lights behind the head to see how much light passes through the ears. This helps him gauge how thick the SSS should be.

The new 'Nana' was:

- modeled in Maya
- sculpted/textured in Mubox
- hair done in Shave and a Haircut
- all the spec maps in the new SW Knald
- Rendered in V-Ray

"The beauty of V-Ray's SSS2 shader is you don't really need any special techniques to get a great result, the shader behaves like you would expect from a scattering material in real life, so using the SSS2 shader well is mostly a matter of understanding how real world materials like skin behave.

So with that said, there are a couple of specific techniques that some artists might not be aware of. One very useful technique is to use a separate bump map for the specular component. The advantage of this approach is you can introduce an extremely fine bump map that affects only the specular, which is very useful for controlling the microstructure of a surface.

Another useful technique is to use a simple grayscale map to introduce some diffuse shading into the SSS2 shader to simulate dead/dry/flaky skin on top of the scattering surface. A great example of this quality can be seen in something like dry lips, where you have two very distinct materials interacting with each other: the soft, highly scattering skin of the lips as a whole, with the more diffuse, dry skin on top." The next version of the software will be shown at SIGGRAPH 2013, showing 3.0 which is entering Beta. It is expecting to ship V 3.0 in the Fall. V-

RayRT, the real time product, will be supporting new SSS and the team have been working very closely with Nvidia on their CUDA optimizations. Hair and hair rendering should be 10 to 15 times faster in version 3. There will also be a new simplified skin shader in version 3.0 for doing digital double work, and one they hope will be a little more user friendly. Also in version 3 will be open source support as mentioned above, with Alembic and OpenEXR 2 support. Viz maps are being introduced - these are material definitions that will be V-Ray maps which can be common across multiple applications like Max and Maya. Also as mentioned above support for OSL in version 3.0.

The team are also introducing a new "progress production rendering" which is one click path path trace render which will continue to refine and would eventually converge to production final renders.

Figure 2.25 *GI Joe: Retaliation (2013) rendered in V-Ray by ILM.*

Last SIGGRAPH the company announced V-Ray for Katana and V-Ray for Nuke. Both are now at the testing stage. The projects would best be described as 'by invitation'. If you are interested in V-Ray for Foundry products email Chaos

Group directly or find them at SIGGRAPH. Both products are real but will unlikely be shown publicly at their SIGGRAPH booth.

2.13. Maxwell - Next Limit

Maxwell Render is a standalone unbiased renderer designed to replicate light transport using physically accurate models. Maxwell Render 1.0 was first released by Next Limit in 2006, and from the outset it adopted this 'physically correct' approach.

"The main aim of Maxwell is to make the most beautiful images ever," says Juan Cañada, the Head of Maxwell Render Technology. "That's the main idea we had in mind when we started the project. Apart from that we wanted to create a very easy to use tool and make it very compatible, so everybody can use it no matter what platform you wanted to use."

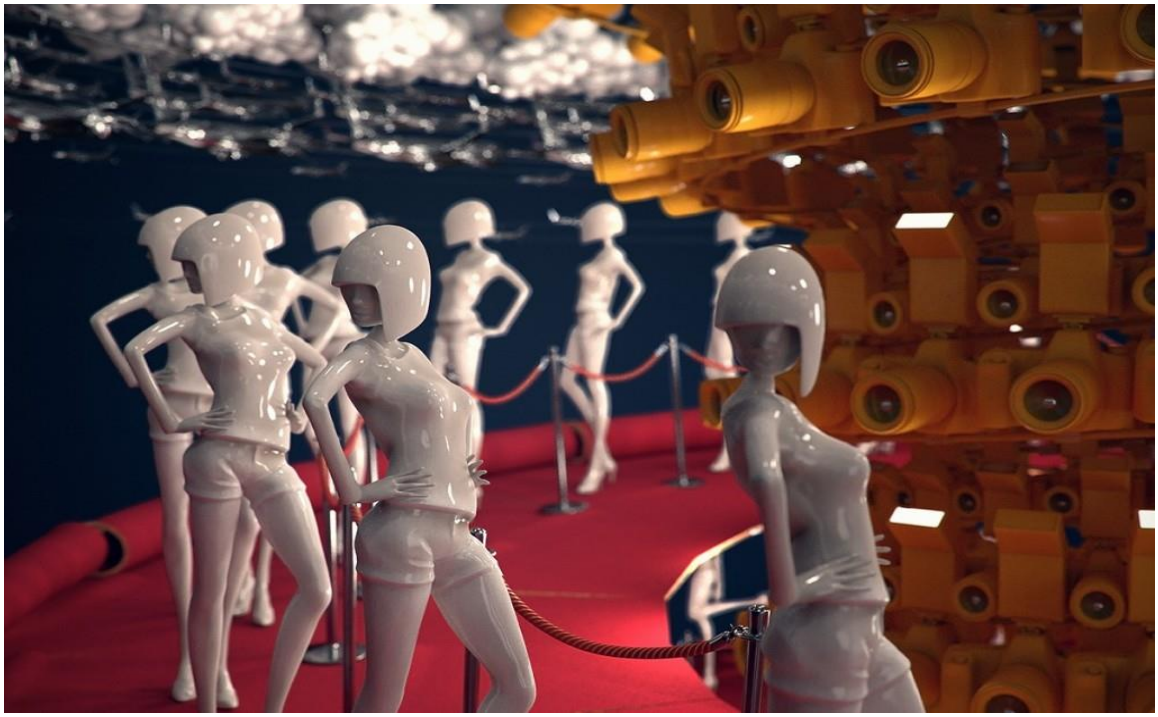


Figure 2.26 *Image from MTV EMA ident rendered in Maxwell Render by Sehsuct Berlin.*

Maxwell Render is unbiased - this means that the render process will always converge to a physically correct result, without the use of tricks. This is very

important both in terms of quality but also ease of use. Maxwell really does mirror the way light works without tricks and hacks. So successful has the Maxwell Render been in replicating real world environments it has become the yard stick by which most other solutions are judged 'correct' or not. It is no accident the renderer is referred to a 'Light Simulator'.

The software can fully capture all light interactions between the elements in a scene, and all lighting calculations are performed using spectral information and high dynamic range data, a good example of this is the sharp caustics which can be rendered using the Maxwell bi-direction ray tracer with some Metropolis Light Transport MLT approach as well.

Figure 2.27 *Grass rendering in Maxwell. Image by Hervé Steff, Meindbender.*

The algorithms of Maxwell use an advanced bi-directional path tracing with a hybrid special Metropolis implementation, that is unique in the industry. Interestingly, in the last few years the whole industry has been moving more towards Maxwell's 'physically based lighting and shading approach', while the Next Limit engineers have been making Maxwell Render faster and better using

key technologies such as M.I.S and multi-core threading to optimize the speed in real world production environments.

Maxwell started out 'correctly' according to Cañada so it has recently been mainly about making Maxwell faster and easier to use, since they have no bias or point cloud approach legacy. The team is focused on issues such as Mutli-threading and other practical issues. "I agree at the beginning Maxwell was almost an experiment - 'lets try and do the most accurate renderer in the world' - once we were happy with the quality we said - 'OK, let's make an interactive renderer - optimize everything'. We have been very focused on Multi-threading so when you had just one or two cores Maxwell might have been slow but now people have 8 or 12 cores. It can even be faster than other solutions in certain situations," says Cañada. It is common now to use Maxwell for animation, something that was fairly unrealistic just four or five years ago. Normal path tracing is slowed or confounded by optical phenomena such as bright caustics; chromatic aberration, fluorescence or iridescence. MLT works very well on some of these shots, while being very complex to implement and Cañada will be giving an advanced talk on lighting rendering techniques at this year's Siggraph 2013 which will cover some of the complexity of attempting a successful MLT implementation and why few people have tried it.

The Next Limit implementation is not a full MLT but a clever hybrid solution. MLT can also be very fast on complex shots and yet more expensive to render on others. For example, its approach of nodally mapping paths bi-directionally helps it focus in on the problem of say light just coming through a keyhole in a door to a darkened room or to produce very accurate caustics. But a full MLT can be slower than other algorithms when rendering simple scenes. "The power of metropolis is in exploring difficult occurrences and its strongest point is sometimes its weakest point when dealing with simple scenes," explains Cañada.

Sometimes with a MLT you can not use all the same sampling techniques you can use with a path tracing system, at least not everywhere in the code. Cañada points out that, "you can not use quasi- Monte Carlo for example in many places - you can of course use some things in some places," but the Maxwell system is very different, for example Next Limit's implementation of Maxwell's MLT, at its core, does not use MIS. There is MIS in Maxwell (extensively) but not in the MLT part of the code.

While pure MLT does not seem to be favored by any part of the industry, Next Limit believes there is a lot to be learnt from MLT and they are constantly exploring how to improve bi-directional path tracing.

Figure 2.28 *Rendering food can be extremely hard. Image by Hervé Steff rendered in Maxwell*

Maxwell Render includes Maxwell FIRE, a fast preview renderer which calculates an image progressively, and so renders can be stopped and resumed at any time. If the renderer is left long it enough it will simply converge to the correct

full final solution. It is very good for preview, but normally once an artist is happy with the look, they switch to the production renderer for the final. This approach means that users can get faster feedback but also know the results won't change in the final render.

"People were used to traditional workflows with old school renderers where they want to render a lot of passes," adds Canada. "You just think of Maxwell as a real camera - so you just focus on lighting, focus on materials. You work like a traditional photo developer and you don't worry too much about the technical details of transport algorithms."

Figure 2.29 *Scandinavian by Alfonso Perez. Rendered in Maxwell.*

One of the most challenging things for an unbiased renderer is SSS. As stated above, many solutions are point based, Cañada explains that "it is one of the biggest challenges for Maxwell in terms of trying to make something accurate and at the same time fast enough to be used in real life production." Most approaches are point based. "In Maxwell we will not apply biased techniques, as it is important

that Maxwell not only be used in effects to create good images but also in a scientific way, producing predictable results to help you with and guide you in making real world design decisions." They have developed their own system, which is fast enough for most applications but it is perhaps the main area of current research and development at Next Limit for Maxwell, and Cañada hopes to make "a large contribution soon, perhaps next year."

Combined with the multi-light feature, advanced ray tracing, massive scene handling, procedural geometry for fur, hair and particles, and a python SDK for custom tools, Maxwell is a production tool today. In the past the 'purist' Maxwell approach could prove too slow for production but with a combination of Moore's Law and Next Limit's engineering efforts, the renderer is becomingly increasingly faster and more popular.

Figure 2.30 Maxwell render by Rudolf Herczog. Rendered in Maxwell

The next release of the product will support new volumetics, alembic, deep compositing and will see Maxwell integrated much more closely with Next Limit's RealFlow with direct Maxwell previewing built into RealFlow. "There will be

between 25 and 30 new features from volumetrics to deep compositing, it is a major release, the biggest release in our history," explains Canada.

III. Comparison of rendering software Vray and Maxwell Practical work

3.1. Comparison Maxwell and Vray with schedules

There are a lot of differences between Maxwell and Vray I just want to show them with this schedule.

RENDERS	Compatibility with 3DS MAX	Compatibility with MAYA	Compatibility with SOFTIMAGE	Compatibility with Houdini	Compatibility with LightWave	Compatibility with blender	Compatibility with SketchUp	Compatibility with CINEMA 4D
V-Ray	YES	YES	NO	NO	NO	NO	YES	YES
Maxwell Render	YES	YES	YES	NO	YES	NO	YES	YES

Figure 2.31

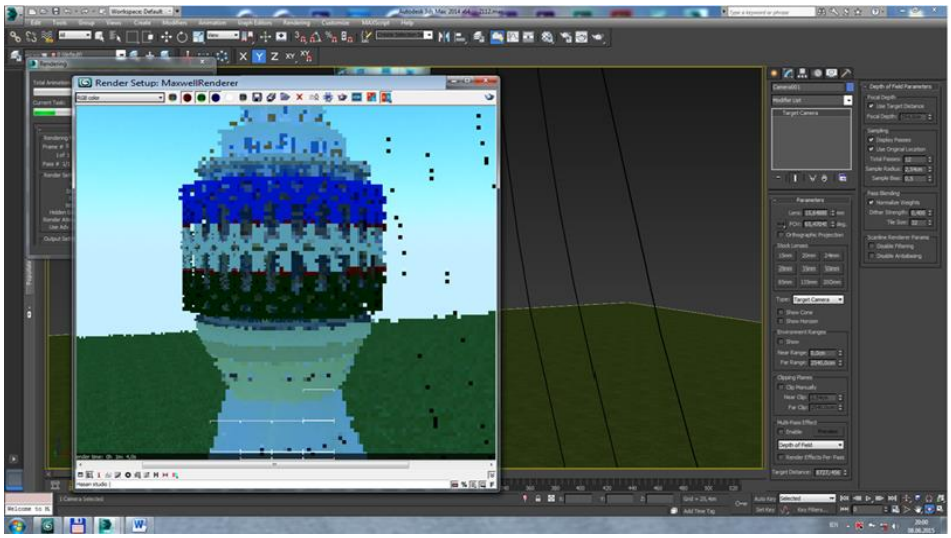
Stand Alone	Current version	SSS	Material library	Area Light	Glossy Reflect/Refract	Official web site	Production country	Producer company
2005 year (crude)	1.5 RC5	+	1300 *vray-materials*	+	+		Belgium	Chaos Group
+	1.61	+	3226 *of site*	+	+	*Maxwell Render*	Spain	Next Limit

Figure 2.32

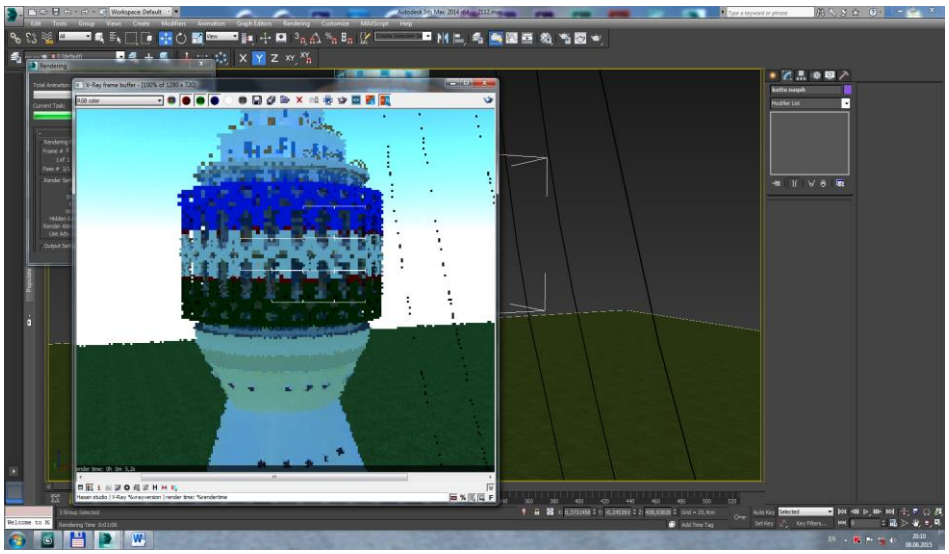
3.2. Comparison Maxwell and Vray on 3D Max

We can experiment these rendering programs on those programs, which are shown in ***Figure 2.31*** but I am going to do that on **3D Max.**

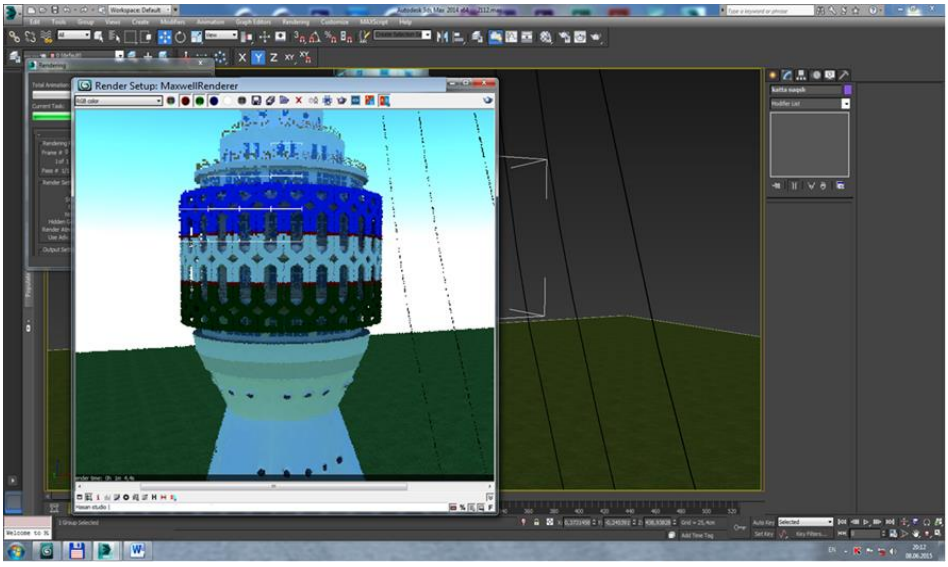
in 20 seconds in **Maxwell**



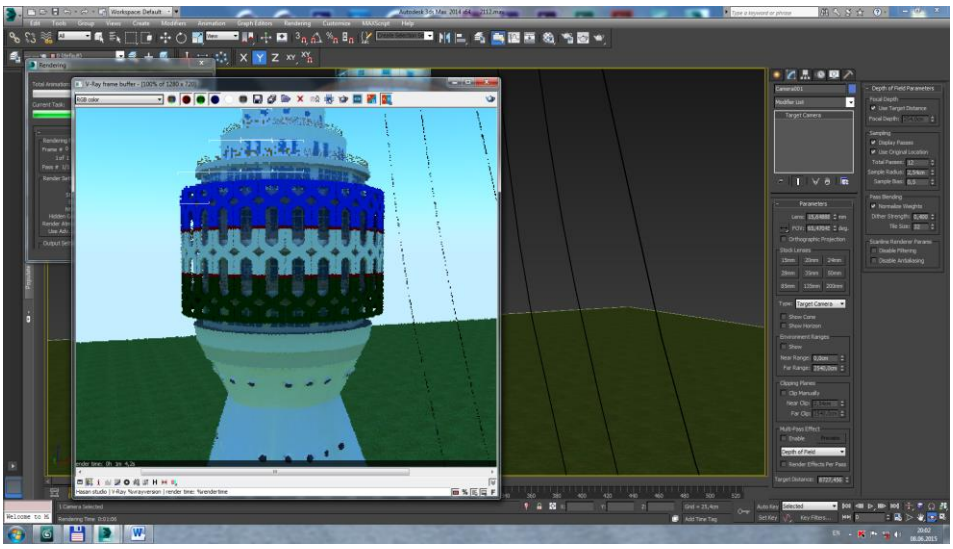
in 15 seconds in **V-Ray**



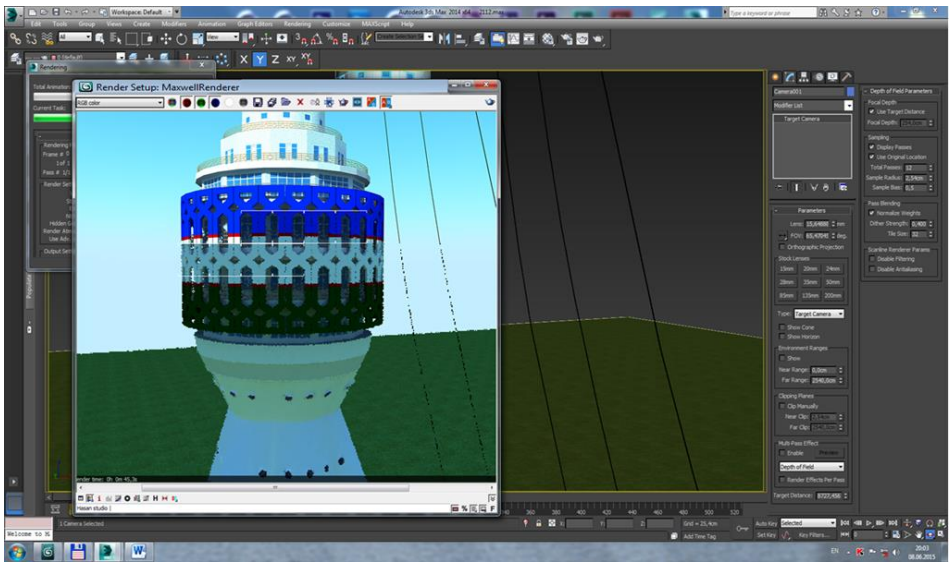
in 40 seconds in **Maxwell**



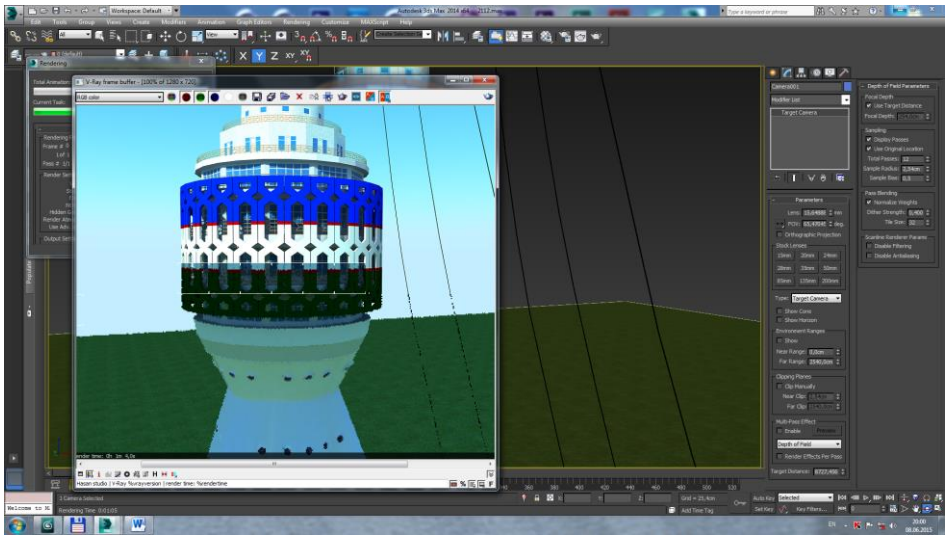
in 30 seconds in **V-Ray**



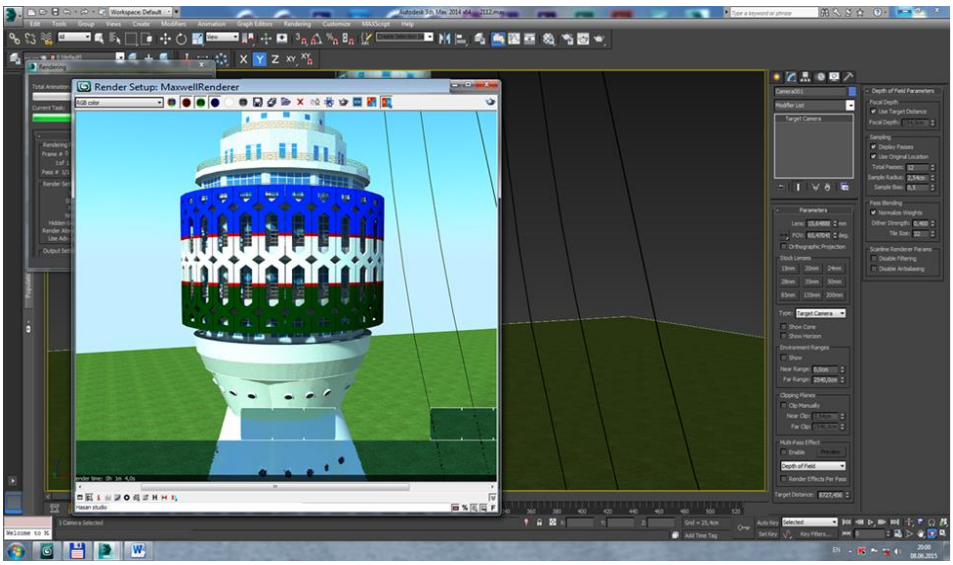
in 50 seconds in **Maxwell**



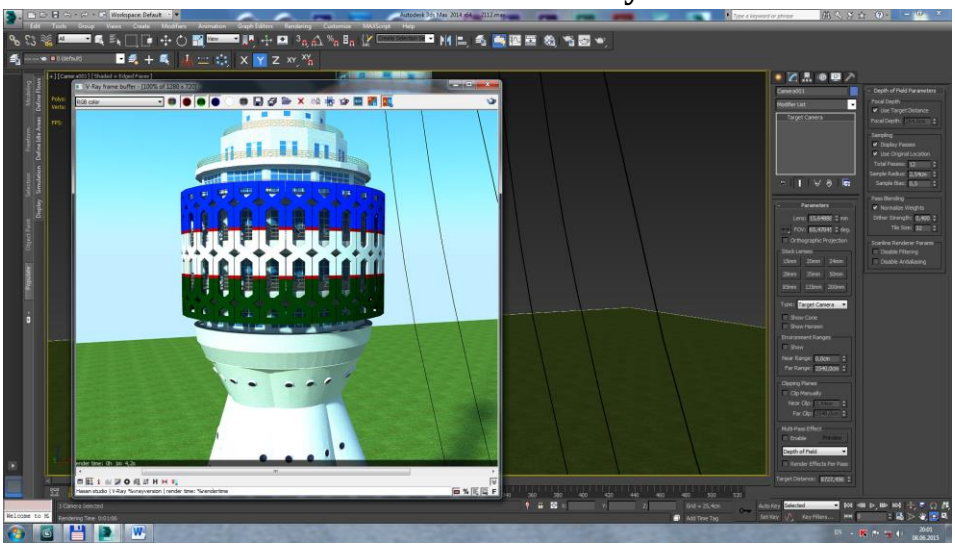
in 45 seconds in **V-Ray**



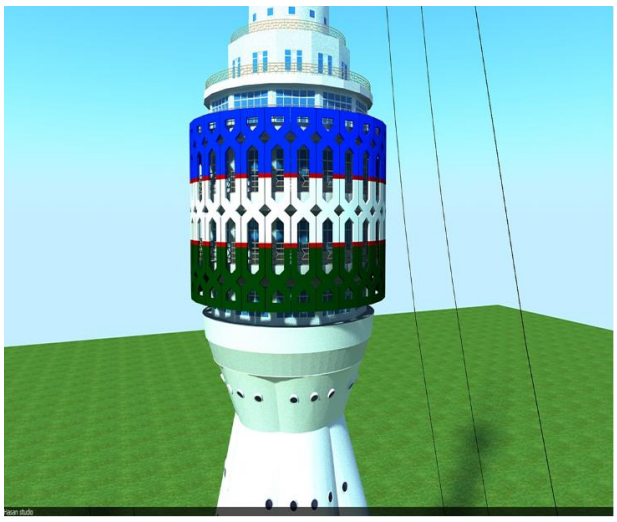
in 00.01.05 in **Maxwell**



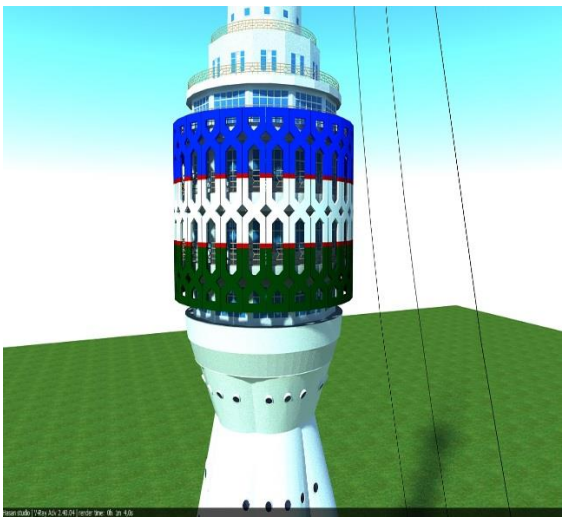
in 00.01.06 in **V-Ray**



The final render in **00.01.18** in **Maxwell**



The final render in **00.01.06** in **V-Ray**



We cannot see big quality differences between them but we can see rather time differences. Therefore, we can use both of them when we need to render our 3D objects. The research shows that we should use Maxwell when we want to work with separate objects.

IV. Life safety issues

This chapter outlines the principles of workplace organization, equipped with a computer. Also discusses issues related to the liquidation of consequences of emergency situations.

4.1 Industrial lighting

Light - is the visible part of the spectrum of electromagnetic radiation with a wavelength of 380-780 nm.

Light values

Basic lighting values: quantitative (sufficiency lighting) and qualitative (comfort).

Basic quantitative values of illumination:

- Luminous flux F, lm (lumen) - part of the radiant energy that is perceived by the eye as light;

- Intensity J, cd (candela) - spatial density of luminous flux

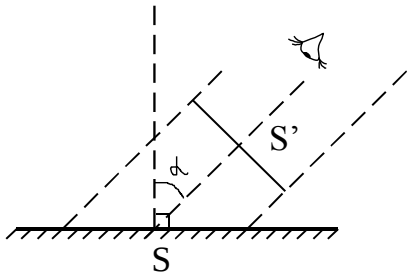
$$J = \frac{F}{\Psi},$$

Where - the solid angle;

- Illuminance E, lx (lux) - surface density of luminous flux

$$E = \frac{F}{S};$$

- Surface brightness L, cd/m2 - intensity of the light reflected from a unit surface area in a given direction;



$$L = \frac{J}{S} = \frac{J}{S \cdot \cos\alpha}$$

- The reflection coefficient, ρ, RLU%.

$$\rho = \frac{\Phi_{отр}}{\Phi_{пад}} \cdot 100\% = \frac{отражённый..световой..поток}{падающий..световой..поток}$$

The main qualitative values:

- Spectral composition;

- Ripple.

Ripple (R) - an indicator of the relative depth of illumination change in time

$$К_П = \frac{E_{max} - E_{min}}{2E_{ср}} \times 100\%$$

Measures for reduction of ripple factor: increased frequency, the connection of luminaires to different phases, changing the solid angle (using capacitors).

Stroboscopic effect - the effect of visual distortion motion that occurs when the frequency of the pulsation frequency of light with moving object (it seems that the object is stationary).

By industrial lighting requirements are as follows: sufficiency, the uniformity in the field of view should be no shade, especially moving, focus, simplicit, reliabilit, low cost, should not create additional dangerous and harmful factors.

Lamps used for lighting are: direct light, reflected light, scattered light. According to the degree of openness: open (unprotected), closed (non-explosive, explosion, dust and water).

Classification of industrial lighting

Industrial lighting is of three kinds: natural, artificial and combined. Natural light is the top and sides. Artificial - total uniform or localized and combined (general and local).

Functional purpose lighting is divided into: working - lighting in the workplace, house - lighting outside working hours, security - lighting protected area boundaries, evacuation - "exit", emergency - for livelihood activities.

Normalization of lighting

Normalization of industrial lighting provided in accordance with SNIP 23-05-95 "Natural and artificial lighting. Design standards. "There is a separate valuation of natural, artificial and combined lighting.

Artificial lighting is normalized according to the characteristics of visual work, discharge of visual work, subclass of visual work and lighting systems.

Characteristics of visual work (accuracy) is determined from the minimum object size discrimination in mm.

Characteristics of visual work

Minimum object size discrimination	0,3 – 0,5 mm	0,5 – 1 mm
Characteristics of visual work	High accuracy	Average accuracy
Discharge of visual work	3	4

Incandescent lamps (IL). Benefits LN: cheapness, simplicity, absence of pulsations, insensitivity to reduce the voltage to be less sensitive to changes in temperature do not cause interference, small size, recycle. Disadvantages LN: short life, low light output.

Discharge lamps. Pros: high efficacy (100 lm / W), high durability, availability of any spectrum. Disadvantages: luminous flux ripple, noise, complexity of operation, loss of luminous flux to the end of life, large size, warm-up time to 15 minutes, in a single lamp to 0.1 grams of mercury.

4.2. Emergency Situations

In theory BDZ disaster - a set of events that result tat occurrence is characterized by one or how many of the following:

a) danger to life and health of a significant number of people ;

b) a material breach of the ecological balance in the area of emergency;

c) failure of the life support systems and management , total or partial cessation of economic activity;

g) significant physical and economic damage ;

d) the need to attract large , usually external to the district emergency forces and equipment to rescue people and mitigation ;

e) psychological discomfort for large groups of people .

Characteristically, the emergency occurs unexpectedly outwardly beyond zapno. Concretization determination is achieved by introducing emergency measures quantitative hazards.

Classifications of Emergency Situations

For reasons of emergencies are natural, man-made, man-made, environmental, social .

The natural (natural) disaster are natural hazards or processes having an extraordinary nature and lead to disruption of daily life style more or less considerable populations kim human casualties, destruction of property . These include earthquakes, floods, tsunamis, volcanic eruptions, mudslides, landslides, hurricanes and death, massive forest and peat fires, snowdrifts and avalanches. Among natural disasters include droughts, prolonged heavy rains, strong frost resistant, epidemic, epizootic epiphytoty, mass distribution of pests in agriculture and forestry.

Disasters can happen: the result would move strictly substance in the process of energy release vnutrizemnoy (tech volcanic activity, earthquakes); with an increase in the general level of rivers, lakes and seas (floods, tsunamis); under the influence quences unusually strong wind (hurricanes, cyclones). not that natural disasters (fires, landslides, mudslides , etc.) may result from actions of the people themselves, but their consequences are always the result of forces at childbirth . For each disaster characterized by inherent factors affecting adversely impact acting on human health .

Natural disasters are a tragedy all state properties , and especially in those areas where they occur. As a result of natural disasters economy suffers, as this destroyed manufacturing enterprises ment and valuable property and, most

importantly, there are casualties among the people killed their homes and property. In addition, natural disasters create extremely unfavorable enabling environment for the population, which may be reason tion of mass outbreaks of infectious diseases. Amount No. of people affected by natural disasters can be very significant and very diverse nature of lesions. Most people suffer from floods (40 % of total damage), hurricanes (20%), earthquakes and droughts (15%). About 10% of the total damage accounts for other types of disasters.

Number of Soviet and foreign specialists, resulting given nye on losses in major disasters, suggest that in the future due to the increasing concentration of population and ana logical strength catastrophe will be accompanied by an increase of the number of victims cheniem tenfold.

Man-made disaster is considered to be a sudden failure of the machines and units during their ekspluatation, accompanied by serious violations of pro production process, explosions, formation of foci by fires, radioactive, chemical or biological in expression of large areas, group lesions (hy underwear) people. By man-made disaster are accidents at industrial facilities, construction, as well as by rail, WHO stuff, roa, pipeline and water trans port, which formed as a result of fires, destruction of civil and industrial building, creating dangerous sion of radioactive contamination chemical and bacterial contamination , was spreading oil products and aggressive (toxic) fluids on the surface of the earth and water, and any other consequences that threaten people and the environment.

Character technogenic disasters depends on the type of accident, its extent and characteristics of the enterprise where the crash occurred (the mode of transport and circum ments in which the accident occurred).

Anthropogenic emergencies are the result of erroneous action quences staff. This class of emergencies can occur at the same sites as the man-made disaster. The only difference is that the man-made disaster is not related to the human factor torus itself.

Disaster on the scale can be divided into five types: local (of the object) local, regional, national and global . For local emergency off-site consequences of limited national economy properties and can be eliminated due to its strength and resources .

Local emergencies are prevalence in Lakh limit settlement, including a large city adminis trative district, multiple district or region and mo Gut be eliminated due to the forces and resources of the region.

In the regional consequences of emergencies outside of a few limited areas or economic region and mo Gut be eliminated due to the forces and resources of the republic. National emergencies have consequences, not covering many economic regions or republics, but without departing dyaschie abroad. Liquidation of Emergency Situations carried is the forces and resources of the state, often attracting tion of foreign aid.

When global disaster the consequences go beyond the country and spread to other states. These effects are eliminated as the forces of each state on its territory and by the international community. The boundaries between all the listed types and class mi disaster to some extent arbitrary. As already noted, some natural disasters - landslides, desertification, in some cases, earthquakes, forest and peat by heat, etc. can have either a purely natural and natural and anthropogenic origin. The same thing can be said to show and systematize disaster on other grounds.

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the republic. National emergencies have consequences, not covering many economic regions or republics, but without departing dyaschie abroad. Liquidation of Emergency Situations carried is the forces and resources of the state, often attracting tion of foreign aid.

Consequences of emergencies can be very diverse. They depend on the type nature of the emergency and SCALE tab dissemination.

The main types of consequences of emergencies are: death , for diseases destruction , contamination , chemical contamination, bacterial contamination. It should be emphasized that people who are in extreme emergency situations, along with various factors affecting ramie act and stressful circumstances, represent a typically complex superstrong irritability teley causing mental impairment in the form of so-called reactive (psychogenic) states. In this psychogenic effects of extreme conditions consists not only of direct, immediate threat to human life, but also indirect, associated with the expectation of its implementation is affected areas. If the radii of impact- tions dangerous and harmful factors disaster can be one way or another, reliably determined by advance payment, the radius of the psychological impact in real tion may actually have very different values of. In some cases, it may be many times greater than the radii of the impact of other factors affecting moat.

Territory, which is affected by the dangerous and harmful factors emergencies, located on it population, stomach GOVERNMENTAL, buildings and structures, engineering services called lesions. Outbreaks tion time to be simple (homogeneous) and complex (combined).

Nidus of simple call center, which arose under the influence of a destructive factor, for exampl, the destruction of the explosion, fire, or chemical tank only ter contamination. Complex lesions arise as a result of several factors affecting emergency. For example, an explosion at a chemical plant entails destruction, fires chemical skoe contamination of the countryside; earthquake and cheers gan besides destruction of installations can cause flooding tion of the coastal strip, fire

damage electrical grids, chemical contamination from leaking tanks SDYAV fracture, etc, etc.

Form lesions depending on the nature of the sources nick hazards can be round - with earth quakes, explosions, lane - when hurricanes, tornadoes, but captivity, mudslides, avalanches, etc., improper form we fires, tsunamis, landslides, etc.

Regardless of the origin and type of development in emergencies, there are four specific steps (phases): birth, initiation, culmination and decay (elimination of the consequences).

At the inception stage of the evolving environment assumption Shortcuts future emergencies : activated when adverse natural processes ; accumulate design and manufacturing defects in structures and numerous technical fault ence; failures occur in the equipment, but engineer and technical personnel, etc etc.

Set the duration of infancy, when than very approximate and can only use regular lar failure statistics, failures, "local" accidents, dan tion of seismic observations, metereologicheskih, mudflow and other stations.

At the initiation stage of emergency events Naib Leia significantly influence the human factor. So, why should stick indicates that over 60 % of accidents occur due to human error.

At the climax stage is the release of energy or substances that adversely impact consequence on the population and the environment, ie, a tively own emergency. Feature extraordinary event - chain nature of the course, when the destroyer tion action triggering event multiple times sometimes hundreds of times is amplified by the involvement in the process of energy- toxic, biologically active com ponents. Figuratively speaking, it's a chain reaction destroyer tion release of energy and matter.

Stage damping emergency time covers the period from the ceiling (limit) hazard - localization of emergency, to the complete elimination of its direct and indirect consequences, including the entire chain secon tion, tertiar, etc. effects. Duration given tion stage may be years, if not decades.

Conclusions

In conclusions, I can say that rendering can be broken down into three fundamental components. Modeling, Materialing, and Lighting. Revit takes care of the modeling. Accurender, Viz, Max, Vray, Maxwell, take care of the rendering. We still need to take care of the materials and to some degree the lighting. A word

of caution before we assume that a good renderer will automatically make good renderings, a good render will highlight bad materials and lighting.

Maxwell's strength is not simply in it's simple interface, but it's simple light setup. Especially for daylight. If you don't know what a space it going to look like, Maxwell will tell you. Vray's claim to fame is speed. It doesn't do everything, but what it does, it does very fast. And most users will probably never run into the things that it doesn't do. Additionally, if your taking the Viz/Max route, the built in rendering engines can do great things (especially Mental Ray) which is almost as fast as Vray and super customizable, and may help you to learn the basics before you purchase another renderer to plug into that. Finally, Maxwell may eventually work directly with Revit, so that you wouldn't need Max or Viz at all, if this were the case you would save yourself the cost of amazing software that you would only be using as a very fancy file converter.

The inverse square law does not apply to every light. The inverse square law applies to omni-directional point sources. With an omni directional point source the photons expand on a sphere and therefore follow the inverse square law. If the photons though are focused in any fashion then they will not follow the inverse square law. For instance if you place a fresnel lens in front of a light or use a reflective half dome you get the traditional ‘par’ light. Moving a par light does not follow the inverse square law.” In other words if a light bounces off a table the bounce light would never be more than the light coming from the light source, and if one moves the light further away, then the bounce would not only seem less strong, it would actually reduce according to the inverse square law. ”

If an omnidirectional point light is a hand grenade going off and the fragments flying out in an even spreading inverse square pattern a focused light is like a shotgun with the density of fragments staying tightly grouped even after long distances depending on the ‘focus’. Similarly photons from an omnidirectional

point light will spread out evenly. Photons from a focused spot light will like a shotgun blast stay in a tight grouping and not reduce in intensity.

We can choose them according to our purposes which of them are suitable for our objects and do we need to save our time or not.

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