PROJECT - I

OBJECTIVE OF THE PROJECT

COMPARATIVE STUDY OF RENDER ENGINES FOR USE IN SIMULATING VARIOUS LIGHTING CONDITIONS

Standard of reference - mental ray
MAJOR RENDER ENGINES:

MENTAL RAY

mental ray® is a high performance, photorealistic rendering software which produces images of unsurpassed realism from computer-aided design and digital content creation data, by relying on patented and proprietary ray tracing algorithms.

Latest version is 3.8

VRAY

V-Ray for Maya is one of the latest developments by Chaos Group. Developed to meet the needs of the most demanding VFX & Film studios around the world, the rendering engine delivers uncompromised stability, interactivity, ease of use and unprecedented speed. The comprehensive list of features provided by V-Ray for Maya includes CarPaint Material, V-Ray Light Select Render Element, PText texture, true 3D Motion Blur, Sun & Sky procedural lighting system, Physical camera for matching live footage, and many others.

Latest version is 2.0 for maya

MAXWELL RENDER

Maxwell Render™ is a rendering engine based on the mathematical equations governing light transport, meaning that all elements, such as emitters, materials and cameras, are derived from physically accurate models. Maxwell Render is unbiased, so no tricks are used to calculate the lighting solution in every pixel of a scene; the result will always be a correct solution, as it would be in the real world.
Maxwell Render does not use abstract lights typically used in traditional 3D applications (distant, point, omni, spotlights). Instead, Maxwell Render uses actual geometry with emitting materials. This approach to simulate lights emulates what happens in the real world and mimics real-world lights, producing a high degree of realism, outputting smooth shadows, providing a natural light distribution in your scene, and increasing the overall quality of your image. Maxwell Render can handle large numbers of lights in a scene without the performance loss sometimes experienced in other applications.

Lights in Maxwell Render™ are created applying an Emitter material to an object. We can adjust the color and intensity of the Emitter using everyday terms like Watts or Efficacy, or you can look into more advanced definitions using Lumens, lux, Kelvin degrees, and RGB

**RENDERMAN**

Pixar's RenderMan has been specifically engineered to meet the demanding challenges of rendering 3D animation and visual effects. This means RenderMan is fast, efficient, and able to handle an astonishing amount of geometric complexity along with offering cutting-edge effects.

Which implies that unlike other renderers, which are used for various other purposes such as architecture, design etc. Renderman has been specifically designed for the animation film industry. The latest version is RenderMan® Pro Server™ 16.0
Autodesk® Beast™ global illumination (GI) middleware is a set of tools for creating realistic lighting in games. Developers can simulate natural lighting effects, such as color bounce, soft shadows, high dynamic range lighting, and lighting of moving objects in real-time game environments.

Beast helps to increase the aesthetic quality of games, resulting in more compelling game experiences. New in Autodesk® Beast™ 2012 middleware, the Beast API enables developers to integrate the eRnsT interactive lighting preview tool into custom game level editors.

Precomputed GI—Prebake lighting for platform and engine independence, resulting in greater flexibility and portability.

Aesthetic quality and efficient workflows—Affect the overall lighting of the scene without the bounce lights or ambient fills used to "fake" GI.

Robust API—Integrate Beast into your game engine with a simpler interface.

LiquidLight® baking technology—Make soft shadows, color bleeding, spherical harmonics, ambient occlusion, high dynamic range, precomputed radiance transfer, and other sophisticated GI effects possible.

eRnsT—Explore and control lighting with a real-time visualizer and stand-alone lighting editor.

DistriBeast—Distribute renders on multiple machines and iterate faster.

Integration with Unreal® Engine 3—Easily get up and running with Beast.
Motion blur is an optical phenomenon which is created when objects or cameras move fast during an animation.

MENTAL RAY – MOTION BLUR

Mental ray offers several methods to create motion blur within the framework of the various sampling and filtering mechanisms. The type of motion blur which samples at various times within the shutter interval is often referred to as 3D motion blur, whereas the term 2D motion blur typically refers to a post-process to rendering.

Types:
- Object motion blur by motion transformation matrices.
- Motion deformations by per-vertex motion vectors.
- Multi-segment vertex motion blur for curved motion blur.
- Full motion blur of reflections, refractions, light sources, shadows, global illumination, and caustics.
- Depth of field implemented in lens shaders.
- Motion and depth output for post-processing motion blur and depth of field.
V RAY – MOTION BLUR

Vray tries to replicate how a camera works which is by opening the shutter and closing it again every frame - what it’s doing is correct, it’s capturing the objects movement from where it was at the start of the frame (let’s say frame 1 for arguments sake) and where it ends up (let’s say frame 2)

When vray calculates the blur, it does it using sub frame sampling to determine how the object has travelled between frames 1 and 2 and thus catches all of the positions in between.

The two available algorithms implemented by VRay are Monte Carlo motion blur and Analytic motion blur.

MAXWELL – MOTION BLUR

For still camera photography (Maxwell Render’s default), the amount of motion blur in an image is controlled by the Shutter Speed parameter. The lower the Shutter Speed is, the longer the shutter is open, and more pronounced the motion blur will be.

However, for animations – when replicating a film camera – the shutter speed is generally fixed to a certain speed, usually 24 frames per second (1/24). Since film cameras cannot control the amount of motion blur by changing the shutter speed, they instead have a rotating disc with an adjustable pie-shaped cut-out on it, which controls how long each frame is exposed. The width of the cut-out is called Shutter Angle, and is expressed in degrees. Fully open (180 degrees) will yield the maximum amount of motion blur, while a very narrow setting (say, 15 degrees) will produce very subtle motion blur. This feature automatically translates your usual ISO/ Shutter speed settings in combination with the Shutter Angle, so your animation exposure will match your still image exposure, while producing the proper amount of motion blur.

Maxwell Shutter (exposure) = FPS (frames per second) * 360 / Shutter Angle.

Shutter Angle = FPS * 360 / Maxwell Shutter (exposure).

% of motion blur = Shutter Angle * 100 / 360.
MENTAL RAY – SUNLIGHT SYSTEM

The mental ray physical sun & sky shaders are designed to enable physically plausible daylight simulations and very accurate renderings of daylight scenarios.

The mia physicalsun and mia physicalsky are intended to be used together, with the mia physicalsun shader applied to a directional light that represents the sun light, and the mia physicalsky shader used as the scenes camera environment shader. The environment shader should be used to illuminate the scene with the help of Final Gathering (which must be enabled) and bounced light from the sun can be handled either by final gather, diffuse bounces, or via GI (photons).

V RAY – SUNLIGHT SYSTEM

The VRaySun and VRaySky are special features which are provided by the V-Ray renderer. Developed to work together, the VRaySun and VRaySky reproduce the real-life Sun and Sky environment of the Earth. Both are coded so that they change their appearance depending on the direction of the VRaySun.

MAXWELL – SUNLIGHT SYSTEM

Maxwell Render™ has a sophisticated atmosphere model that reproduces the skylight conditions at different locations/times/dates. The atmosphere parameters allow users to customize the look of the sky and the resulting light in the scene. Users can also create pre-sets of the sky
settings to quickly load a new sky or share their pre-sets with other users, or save a sky as an HDR/EXR map.
IMAGE BASED LIGHTING

Image Based Lighting is a technique to create photo-realistic images. With image-based lighting, one can use an environment texture (an image file) to illuminate the scene. Typically, the image is a photograph of a real environment, either a panoramic image or a photograph produced by taking pictures of a chrome ball (to capture the surrounding environment).

MENTAL RAY - IBL

When an IBL node is created one or more of the following mental ray for Maya shaders is used:

**Environment Shader** Along with Final Gathering this shader implements classic style image-based lighting. The color of the environment is picked up by final gather rays and incorporated into surface illumination. An environment shader is passive. It doesn't actively contribute to the scene's lighting; instead, it gets sampled only as needed. Best results are achieved if the IBL texture is diffuse. A specific case would be a texture consisting of a single color; this results in ambient occlusion computation.

**Photon Emission Shader** Photons are emitted from the IBL environment sphere. These photons pick up their energies (or colors) from the IBL texture. A photon emission shader emits all its photons once per frame. It is more active than an environment shader in this sense. Photons work best with mostly diffuse IBL textures.

**Light Shader** A low-resolution control texture is computed (from the file or procedural IBL texture) and mapped to the IBL environment sphere. Whenever direct lights are sampled, the light shader is invoked. In this sense, the light shader approach is the most active one, and the most expensive. The IBL environment can be seen as one big area light. This approach works
best (also due to importance sampling) if the IBL texture contains sharp features, and preferably contains many more black than non-black pixels.

**V Ray - IBL**

IBL (image-based lighting) is a new feature, provided by V-Ray renderer. The V-Ray dome light has been extended to support arbitrary texture maps that determine the amount of light coming from each direction on the virtual dome hemisphere. V-Ray then uses importance sampling to trace more rays in the directions where most of the light is coming from. This ensures speed and quality that were never before possible with pure gathering GI methods.

**Maxwell - IBL**

There are several available channels for specifying MXI/ HDR/ EXR maps. This is a powerful feature as it allows the user to have more control over the effects of the environment on the scene. For example, you can use one MXI/ HDR/ EXR map for the illumination of the scene, and another map for the reflections.

- **Background channel:** Allows the addition of an MXI/ HDR/ EXR map as a background environment, supplying a background image in the scene. Screen mapping can be used to map the MXI/ HDR/ EXR image to screen coordinates. This channel does not provide any scene illumination or reflections.

- **Reflection channel:** Add an MXI/ HDR/ EXR map for reflections on scene objects.

- **Refraction channel:** Add an MXI/ HDR/ EXR map for refractions on scene objects.

- **Illumination channel:** Add an MXI/ HDR/ EXR map for scene illumination.
GLOBAL ILLUMINATION

Virtually all modern GI renderers are based on the rendering equation introduced by James T. Kajiya in his 1986 paper "The Rendering Equation". This equation describes how light is propagated throughout a scene. In his paper, Kajiya also proposed a method for computing an image based on the rendering equation using a Monte Carlo method called path tracing.

MENTAL RAY – GI

mental ray for Maya can render with Global illumination, the technique used to capture indirect illumination (the natural phenomenon where light bounces off anything in its path until it is completely absorbed) mental ray for Maya creates Global illumination by tracing the paths of photons and recording their bounce points in a photon map.

V RAY – GI

VRay supports a number of different methods for solving the GI equation - exact, approximate, shooting and gathering. Some methods are more suitable for some specific types of scenes.

Exact methods

VRay supports two exact methods for calculating the rendering equation: QMC GI and progressive path tracing. The difference between the two is that QMC GI works with traditional image construction algorithms (bucket rendering) and is adaptive, whereas path tracing refines the whole image at once and does not perform any adaptation.

Approximate methods

All other methods used VRay (irradiance map, light cache, photon map) are approximate methods.

Shooting methods
The photon map is the only shooting method in VRay. Caustics can also be computed with photon mapping, in combination with a gathering method.

**Gathering methods**

All other methods in VRay (QMC GI, irradiance map, light cache) are gathering methods.

**MAXWELL – GI**

Maxwell Render was among the first widely available implementations of unbiased rendering and its G.I. algorithm was linked directly to a physical camera paradigm to provide a simplified rendering experience wherein the user was not required to adjust arbitrary illumination parameter settings, as was typical of scanline renderers and raytracers of the time.

In computer graphics, **unbiased rendering** refers to a rendering technique that does not introduce any systematic error, or bias, into the radiance approximation. Because of this fact, they are often used to generate the reference image by which other rendering techniques are compared to. Mathematically speaking, the expected value of the unbiased estimator will always be the correct value, for any number of samples. Error found in an unbiased rendering will be due to variance, which manifests itself as high-frequency noise in the resultant image. Variance is reduced by for \( n \) samples, meaning that four times as many samples are needed to halve the error. This makes unbiased rendering techniques less attractive for realtime or interactive rate applications. Conversely, an image produced by an unbiased renderer that appears smooth and noiseless is probabilistically correct.
CAUSTICS

Caustics are light patterns that are created when light from a light source illuminates a diffuse surface via one or more specular reflections or transmissions. Examples are:

1. The light patterns created on the bottom of a swimming pool as light is refracted by the water surface and reflected by the diffuse pool bottom.

2. Light being focused by a glass of water onto a diffuse table cloth.

3. The light emanating from the headlights of a car: the light is emitted by the filament of a light bulb, reflected by a parabolic mirror reflector (thereby being focused in the forward direction), and reflected by the diffuse road surface.

MENTAL RAY – CAUSTICS

Mental ray can render with Caustics, the light effects that caused by specular reflected or refracted light, like the shimmering light at the bottom of a pool of water.

Caustics cannot be simulated efficiently using standard ray marching since predicting the potential specular paths to a light source from any given surface is a difficult (and in many situations impossible) task. To overcome this problem mental ray uses a photon map. The photon map is generated in a preprocessing step in which photons are emitted from the light sources and traced through the scene using photon tracing.

The emission of photons is controlled using either one of the standard photon emitters for point lights, spot lights, directional lights, and area lights, or by using a user defined photon emitting shader.

To control the behavior of photons as they hit objects in the scene, it is necessary to attach photon material shaders to these objects. Photon material shaders are similar to normal material shaders with the main difference being that they trace the light in the opposite direction. Also, a photon shader distributes energy (flux) instead of collecting a color
Another important difference is the fact that photon material shaders do not need to send light rays to sample the contribution from the light sources in the scene.

V RAY - CAUSTICS

There are two systems for the computation of the caustics:

- Approximate
- Non-Approximate

The generation of caustics in approximate method is produced by caustics.

The second method is unbiased and the result obtained, though time taking, is accurate.

With the non-approximate method, it is compulsory to activate GI because it is part of the system for the generation of caustics.

MAXWELL - CAUSTICS

Maxwell, being a wave-based lighting solution, can render all types of caustic effects seen in real life. The two major types of caustic effects covered by Maxwell are:

**Refl. Caustics:** Render direct reflective caustics, indirect reflective caustics, or both. Direct reflective caustics come from light that bounced off a specular reflective object and created caustic light patterns on any subsequent object. Indirect reflective caustics come from light that bounced off an object, then off a specular reflective object, and then created a caustic light pattern on any subsequent surface.

**Refr. Caustics:** Render direct refractive caustics, indirect refractive caustics, or both. Direct refractive caustics come from direct light that has passed through a transparent material and has created a caustic light pattern on any subsequent surface. Indirect refractive caustics come from light that has first bounced off a surface, then passed through a refractive object, and caused a caustic light pattern on any subsequent surface.
Final gathering is a technique for estimating global illumination for a given point by either sampling a number of directions in the hemisphere over that point (such a sample set is called a final gather point), or by averaging a number of final gather points nearby since final gather points are too expensive to compute for every illuminated point.

For diffuse scenes, final gathering often improves the quality of the global illumination solution.

In film production work, final gathering is often used rather than photon mapping, except for caustics. Final gathering by default supports a single bounce only.

MENTAL RAY – FINAL GATHER

Many render engines don’t calculate reflections of the light. To be more precise: they don't calculate the diffuse reflections. Diffuse reflections occur when light bounces off in all directions from non-reflective surfaces. In most cases this effect should somehow be taken into account to get a nice, realistically looking rendering.

Mental Ray offers a method that allows to calculate these diffuse light reflections: Final Gather. Final Gather is a method to approximate the diffuse reflections that occur in the real-world, while trying to keep render times as low as possible by using a smart calculation model.

With Final Gather the calculations of light are divided in two components:

Direct Illumination
Indirect Illumination
Indirect Illumination from other surfaces (light bounces of direct light)

Indirect Illumination from the environment (eg: skydome) Final Gather first calculates the direct illumination in the same way a normal renderer would. In this stage the basic light distribution across a scene is calculated.

In the second stage, Final Gather really kicks in. It determines the light intensity at any given point by examining the color values found within the hemisphere around that point. This is added to the light intensity calculated from the direct illumination.
Ambient occlusion is a technique which adds visual realism to the image without being physically correct. The ambient occlusion result can be used to darken concave areas, which human eye perceives as indirect illumination shadows, or contact shadows. The advantage of ambient occlusion is its computational speed. As it does not require any shading and may be computed with very short rays, the performance may be significantly higher than for final gathering.

V RAY – AO

AO can be used in two ways.

Either it is used to enhance details and contact shadows in indirect illumination (in which case there must exist some form of indirect illumination in the first place), or it is used together with a specied ambient light in a more traditional manner. Hence, if neither indirect light exists, nor any ambient light is specied, the AO will have no effect.
PROJECT - II

OBJECTIVE OF THE PROJECT

R&D ON THE LATEST TOOLS AND TECHNIQUES IN THE FIELD OF LIGHTING AND RENDERING
Introduction to Image Processing on the GPU

In the most recent generations of Graphic Processing Units (GPUs), the capacities of per-pixel and texturing operations have greatly increased. Millions of these GPUs are already present in the computers of consumers worldwide. Today you can easily apply those texturing and pixel engines, originally designed for 3D modeling and rendering, to many classic image-processing problems to provide tremendous speed increases over CPU-only implementations—and without any compromise in final image quality. This short introduction describes the basic methods of GPU usage for image processing and provides useful pointers to documentation, demo programs, and other developer tools.

In general, GPUs approach 2D image processing as a restricted form of 3D processing. Quite simply, a quadrilateral polygon is aligned to the desired image-screen rectangle and rendered; either to the screen or to an off-screen buffer in memory. The rendering can be done using either of the common graphics APIs: OpenGL or DirectX.

Each pixel in the rendered image can have image-based texturing applied (up to 16 simultaneous input images per pass can be accessed), and each pixel can run one or more small programs, called pixel shaders, to generate the final output color at each individual pixel. The GPU executes these shaders for many pixels at a time in parallel. Multiple passes of rendering may be executed, and the GPU provides additional image-blending hardware to permit images to be built-up in composed layers of arbitrary complexity. The results of each rendering pass, or any disk image, can likewise be passed back into the GPU pixel shader engine as another texture. This means that arbitrarily complex compositing operations can also be expressed as pixel shader operations. Image pixels can even be used as address indices into other images.
Pixel shaders operate in an IEEE floating-point execution environment, though their input and output images can be expressed as 8-bit or 16-bit integers per channel, or as 16-bit or 32-bit IEEE floating-point values per channel. This flexibility and precision permits pixel operations to be executed on the GPU without any loss of image quality when compared to traditional CPU-intensive methods. Since the results can be available at high speed, often the GPU-calculated result in a “preview” window can now also be the final, delivered result.
**Subsurface scattering** (or SSS) is a mechanism of light transport in which light penetrates the surface of a translucent object, is scattered by interacting with the material, and exits the surface at a different point. Skin is one of the good examples of sub-surface scattering.

In Mental Ray version 3.3 we can achieve this effect in a physically correct, as well as non-physically correct manner through the use of a few mental ray shaders. Mental ray for Maya version 3.4 and later include the shaders, therefore they need not be acquired through a 3rd party.

V-Ray FastSSS2 material uses a pre-pass to create fast and accurate subsurface scattering effects with support for both single and multiple scattering.
3D API’S

One fact of life in creating games for the PC is that your run-time platform is a constantly moving target. A game console’s hardware configuration is defined before the first box ships, and this configuration doesn’t change for the lifetime of the console, so developers know exactly what hardware they’ll have at run-time. Not so with the PC.

This inability to know exactly what hardware devices these applications (games, modeling tools, etc.) would be running on was one of two large driving factors that necessitated the creation of 3D APIs like OpenGL and Direct3D. By abstracting the hardware, an application could run on a variety of hardware, and conversely, one piece of hardware could run a variety of applications. The other was the need for developers to have common, known conventions for programming 3D so that they wouldn’t have to re-invent the wheel each time they began work on a new project.
The high-performance viewport introduced with Maya 2011 offers full-screen visual effects: motion blur, depth-of-field, and ambient occlusion, enabling the artist to evaluate his/her work in a higher fidelity environment and without needing to render or export to a game engine. Moreover, Viewport 2.0 provides component and manipulator display to support modeling workflows, together with batch rendering capabilities, and a high-performance API.
CUDA

CUDA is NVIDIA’s parallel computing architecture that enables dramatic increases in computing performance by harnessing the power of the GPU (graphics processing unit). Computing is evolving from "central processing" on the CPU to "co-processing" on the CPU and GPU. To enable this new computing paradigm, NVIDIA invented the CUDA parallel computing architecture.

The latest version is 4.0

With the recent launches of Microsoft Windows 7 and Apple Snow Leopard, GPU computing is going mainstream. In these new operating systems, the GPU will not only be the graphics processor, but also a general purpose parallel processor accessible to any application.
FUTURE OF RENDERING

Mental images – I RAY

iray is an intuitive to operate, interactive, consistent, high-performance global illumination rendering technology that generates photorealistic imagery by simulating the physical behavior of light.

Unlike current ray-tracing renderers, iray does not depend on complex renderer specific shaders and settings to approximate global illumination. iray achieves its high level of performance by taking full advantage of the CUDA programming model, allowing interactive previewing on both single and multiple NVIDIA GPU platforms. iray balances intuitive ease of use and scene setup with the highest quality photorealistic final frame output and interactive performance.

SPEED

By leveraging the power of NVIDIA Quadro® GPUs, iray progressively delivers physically accurate results without long wait times. iray’s revolutionary push-button rendering technology shaves hours of tuning and optimization off the rendering process.

SIMPLICITY

With iray, artists and designers are no longer required to acquire knowledge of how a renderer works. iray is developed so that designers can concentrate on creating beautiful objects and artists can focus on creating works of art without being bothered by understanding the mechanics of rendering.

QUALITY

iray automatically generates photorealistic imagery without introducing rendering algorithm specific artefacts, and without requiring the use of complex settings. iray progressively refines
the image until maximum fine detail is reached, providing a single process which smoothly combines interactive pre-visualization and final frame rendering.

**ACCURATE LIGHT SIMULATION**

iray simulates the behaviour of light without compromises. iray materials and lights are physically accurate. You will assign materials to surfaces just as it would happen in the real world: glass, wood, metal are not represented by shaders or shader graphs, but rather by glass, wood and metal presets guaranteed to consistently produce life-like results.

**PROGRESSIVE RESULTS, FASTER WORKFLOWS**

Render results are displayed progressively. Scene changes are visible right after a few seconds from the beginning of the rendering process, in full detail including global and indirect illumination. You can either decide to stop rendering and go back to make more changes, or let the rendering converge to a beautiful image.

**GPUS AND SYSTEMS**

iray is optimized and massively accelerated by NVIDIA CUDA-enabled GPUs but can run on a CPU or a hybrid mode which utilizes both types of processors simultaneously. Designers and artists looking for the fastest iray results can further boost their speed by adding additional GPUs to their system.
THANK YOU

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