AV2742
An Introduction to Using mental ray® in 3ds Max Design

Matt Stachoni
Senior AEC / BIM Applications Technical Specialist, *CADapult LTD*

matt@stachoni.com
matts@cadapult.net
Twitter: @MattStachoni

Class Summary & Key Learning Objectives

This class is intended primarily to provide users of 3ds Max Design 2014 a basic understanding of the mental ray rendering engine and its primary features.

This is an entry-level class. It is not intended as an exhaustive summary of every feature or available option.

The goal is to provide a fundamental education on the following three concepts:

- Understand the base theory behind mental ray's ray tracing and sampling techniques;
- Understand each of the primary functions in mental ray: Photon Mapping (Global Illumination), Final Gather, Daylight Systems, Ambient Occlusion, and Caustics
- Understand how to apply each of these functions to your scenes without a lot of guesswork and wasted rendering time

Class summary

Things we may mention in class but won't explicitly cover in detail:

- Every button, dial, switch, gadget, widget, doohickey, and thingamabob in the mental ray user interface;
- Backburner-based network rendering / Distributed Bucket rendering;
- Importons and Irradiance Particles (whatever those are);
- mental ray proxy objects;
- Animation;
- Lighting analysis tools;
- Specific issues with importing models from Revit and other applications.

Section I
Introduction to mental ray

What is mental ray®?

mental ray (no uppercase) is the premier production-quality rendering engine found in most of Autodesk's applications, such as 3ds Max / 3ds Max Design, Maya, Revit, Navisworks, and AutoCAD.

Initially developed by mental images GmbH in late 1980's

Widely used in the film industry

mental images purchased by NVIDIA in 2007

Became the NVIDIA Advanced Rendering Center (ARC)

NVIDIA ARC also develops iray®, the "other" rendering engine in 3ds Max

mental ray Implementation in 3ds Max Design

NVIDIA ARC develops mental ray (mr) & iray independently of ISVs (Autodesk)

Autodesk implements mental ray into 3ds Max / 3ds Max Design, Maya, AutoCAD, Revit, Navisworks, etc.

Autodesk decides what features are implemented and what adjustments are exposed in each application

Latest iteration is **mental ray 3.11** in 3ds Max Design 2014

As new features come online Autodesk has to build the UI to support them

Autodesk may implement a new mr feature in a specific release or via a service pack as they become available

NVIDIA ARC Strategy

Today: mr is largely CPU-bound. Does not use graphics card to create the image

NVIDIA: The future of rendering is to be done on the graphics card (GPU) with multiple GPUs in one system

Expandable to the Cloud = render farm with 1000s of GPUs

NVIDIA CUDA = Programmable GPU architecture found on all cards (GeForce/Quadro)

GPU = 12x CPU speed

NVIDIA: mental ray / iray = standalone products that can be implemented

Optix: General purpose GPU-based rendering engine for developers

mental ray's Future

NVIDIA:

Adding at least one GPU-based feature in every major release of mr

In 2014: Ambient Occlusion can be computed on the GPU

(No UI - enabled via scripts or String Options)

mental ray Future

In 2015: Final Gather on GPU

mental ray features

Adaptive ray tracing and sampling (rasterizer)

Highly parallelized processing: Support for multiple CPUs / cores

Distributed bucket rendering / Backburner network rendering

32-bit High Dynamic Range (HDR) environment

Ray traced shadows

Energy conserving materials (Arch & Design / Autodesk)

Support for photometric lights and the Daylight System (mr Sun and mr Sky)

mr Physical Sky environment map

mr Photographic exposure control

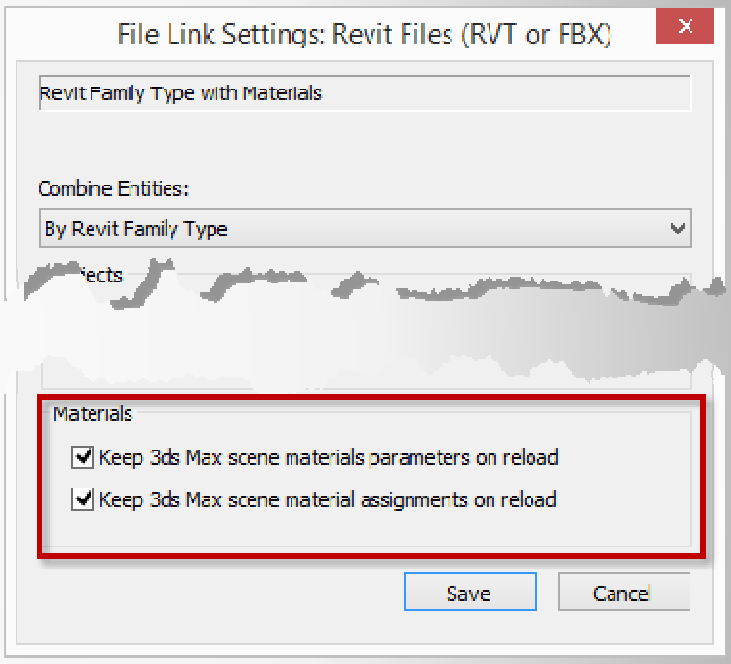
Lighting Analysis tools

Efficiency: Presets; save and reuse GI / FG maps

Simplified Rendered Frame Window controls

Mental ray in Revit vs. 3ds Max Design

- Better shadow studies
- More powerful material mapping
- Easily change / override materials
- Preserve material changes through design iterations
- Faster & better quality images



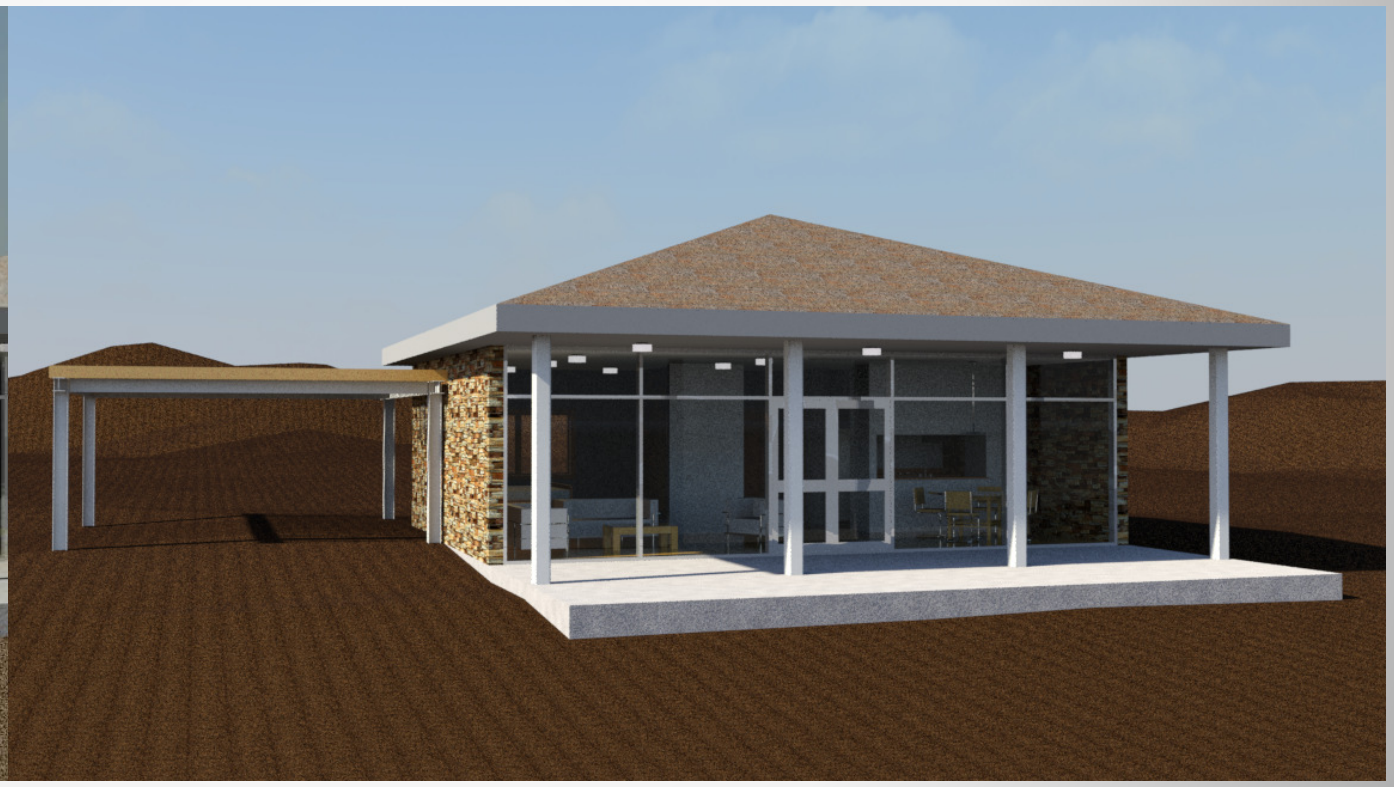
mental ray in Revit vs. 3ds Max Design (continued)

- Special Effects & Render Elements
- Distributed / Backburner network rendering
- Global Illumination (photon mapping)
- Pre-compute, save, and reuse Final Gather and Global Illumination maps
- Arch & Design material adds additional functionality
- Built-in Lighting Analysis

mental ray in Revit vs. 3ds Max Design

Revit: 10:24 @ Medium Preset

3ds Max: 8:11 @ Medium FG Preset



mental ray Sampling

- Sampling: The method by which a single pixel color is established from 3D geometry, lighting, and materials
- mr shoots sampling rays from the camera through the bitmap “grid” to the 3D scene
- Evaluates color / lighting at sample point
- Colors that pixel

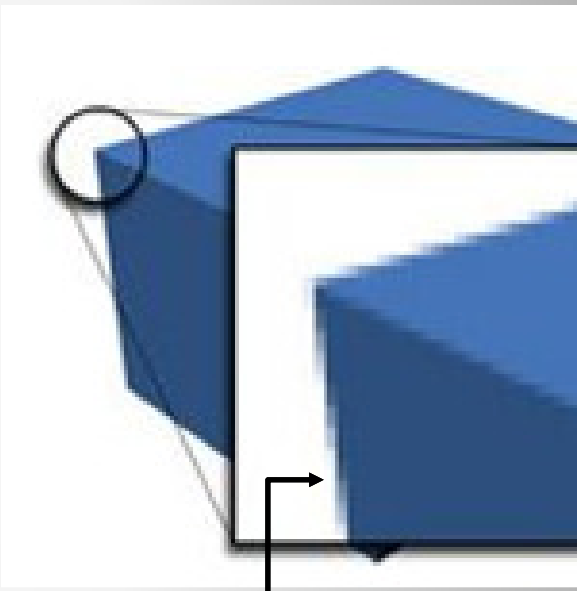
Sampling Concepts

Sampling is the way 3D geometry resolves to a bitmap

Samples need to take into account contributions by surrounding pixels

Blend colors together eliminates “jaggies” at high contrast areas

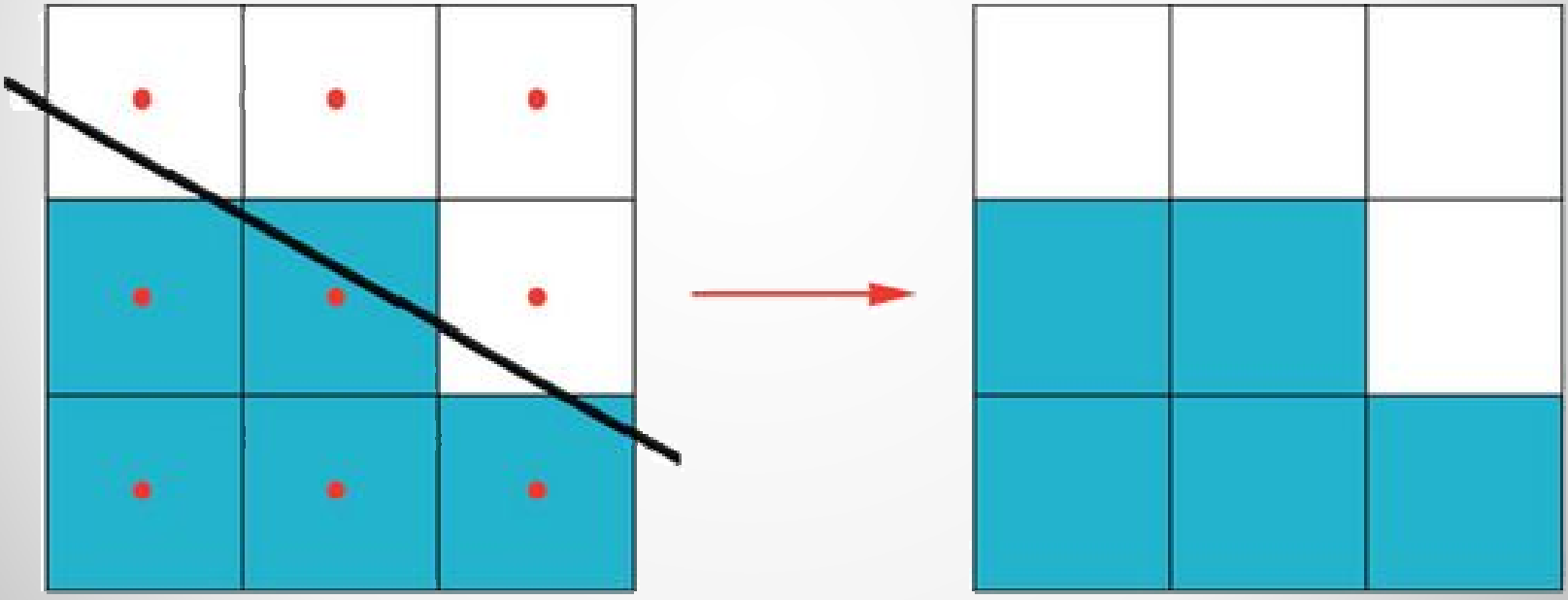
Adaptive sampling = change sampling to meet the need



Pixels along the edge are colored solid blue, white, or a combination of the two to create a smoother look

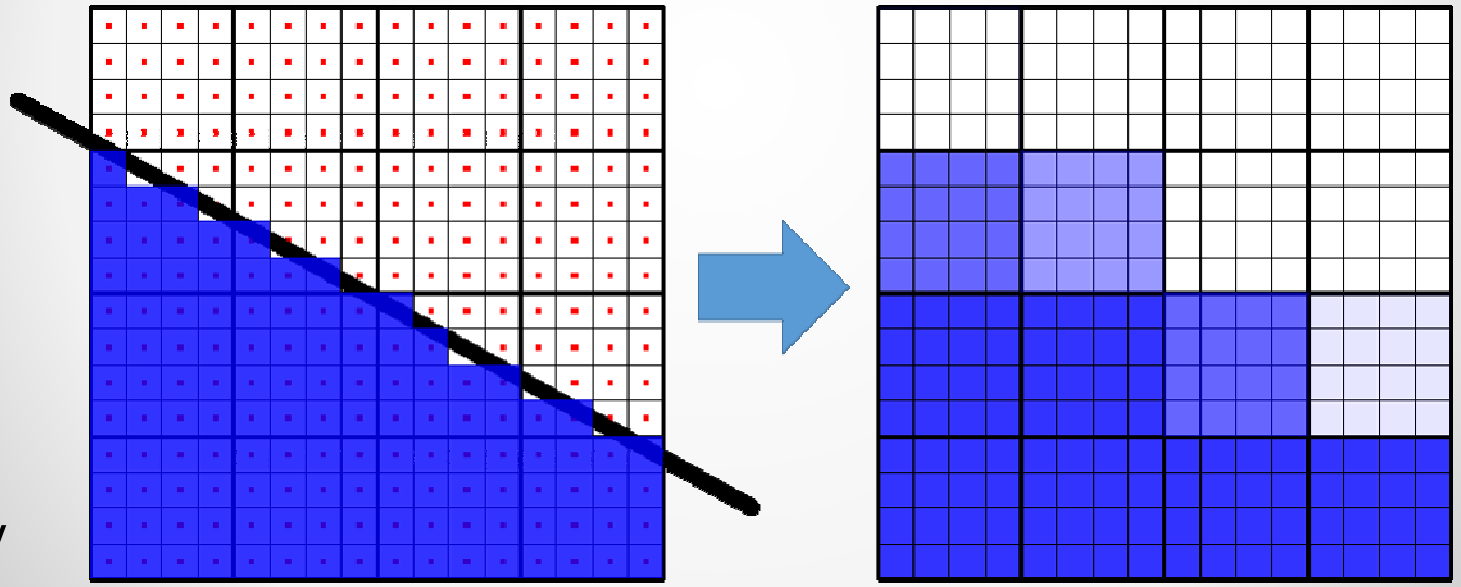
Sampling Applied

Single Pixel Sampling:
Rays evaluate color at the center of pixel and color pixel based on that one sample.



Sampling Applied

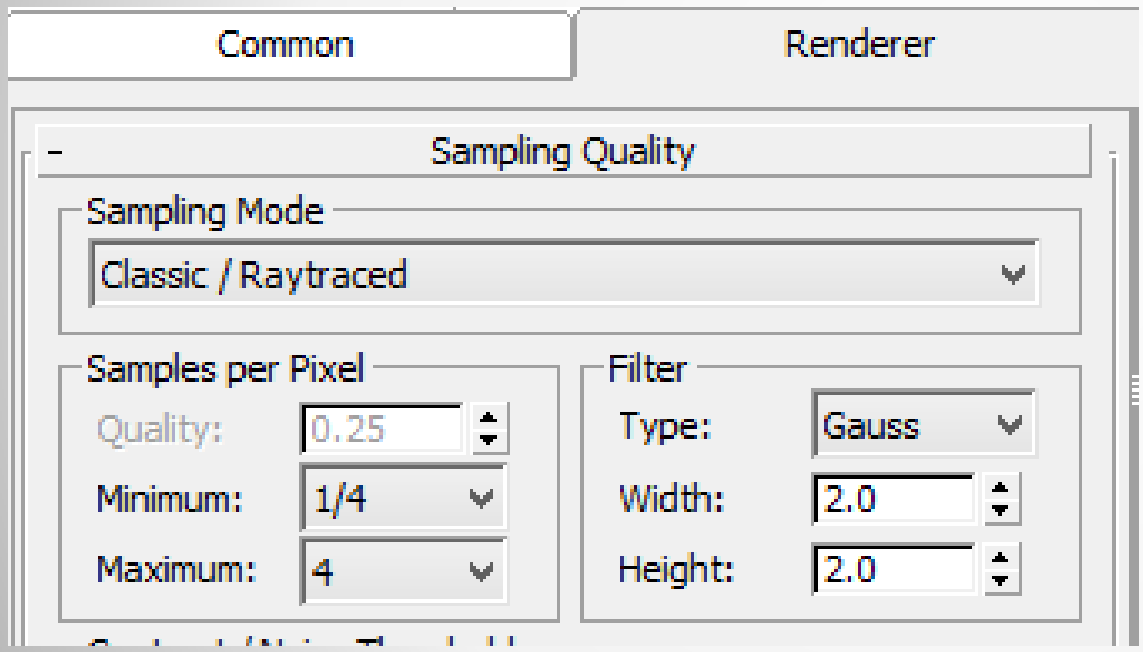
Sub-Pixel Sampling:
Divide each pixel into 4, 16, 64 subpixels
Evaluate each subpixel and average* colors for final pixel color



* Not really

Sampling Applied

Controlling Sub-Pixel Sampling using Classic / Raytraced Mode:
Render Setup > Renderer tab:



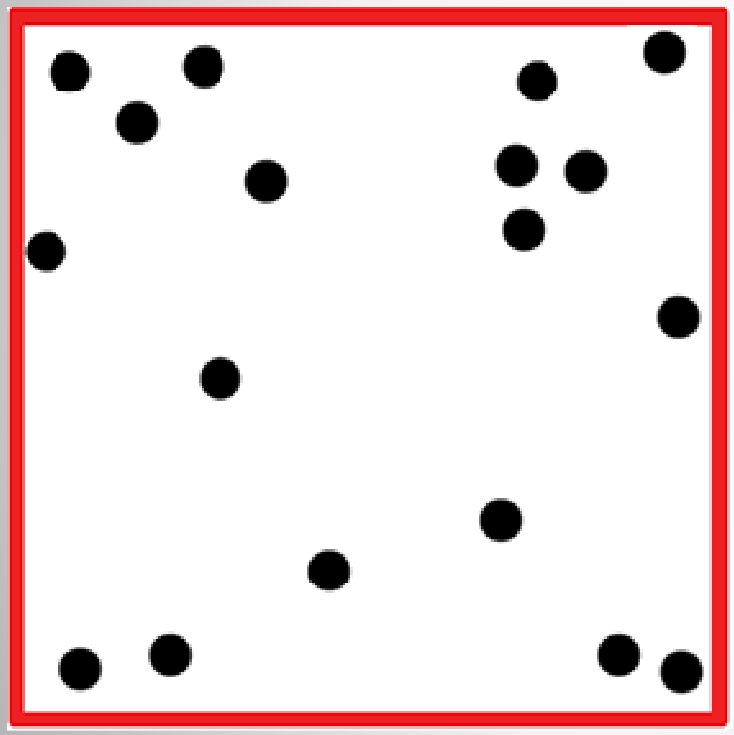
Min & Max = Number of sampling rays per pixel

Min of ¼ = one ray per 4 pixels (undersampled)

Max of 4 = 4 rays per pixel

Unified Sampling in 3ds Max Design 2014

New in 3ds Max Design 2014. Samples no longer in a “grid”



Pixel sampling uses a new Quasi-Monte Carlo (QMC) approach to figure out where to concentrate additional samples.

“Shotgun” sampling pattern

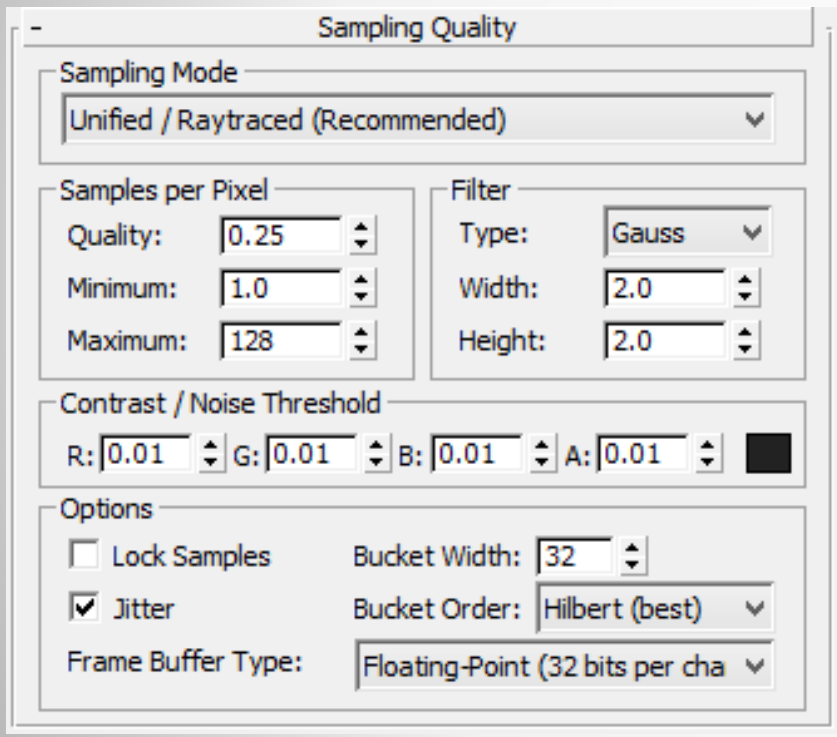
Faster & more efficient than Classic

Finds more detail easier

Allows for sampling through time, e.g. Motion Blur

Sampling Applied

Controlling Unified Sampling quality:



Single “Quality” knob:

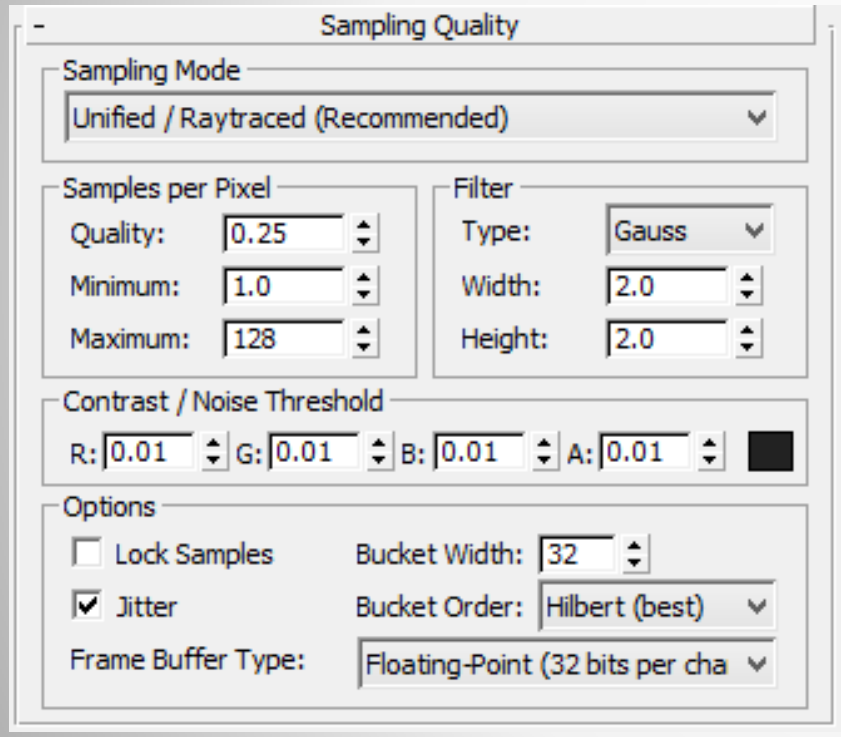
- 0.25 = low quality / draft
- 1.0 = good quality

Minimum < 1.0 = Undersampling

Maximum: Limits the samples per pixel

Sampling Applied

Controlling Unified Sampling quality:



Contrast / Noise Threshold:

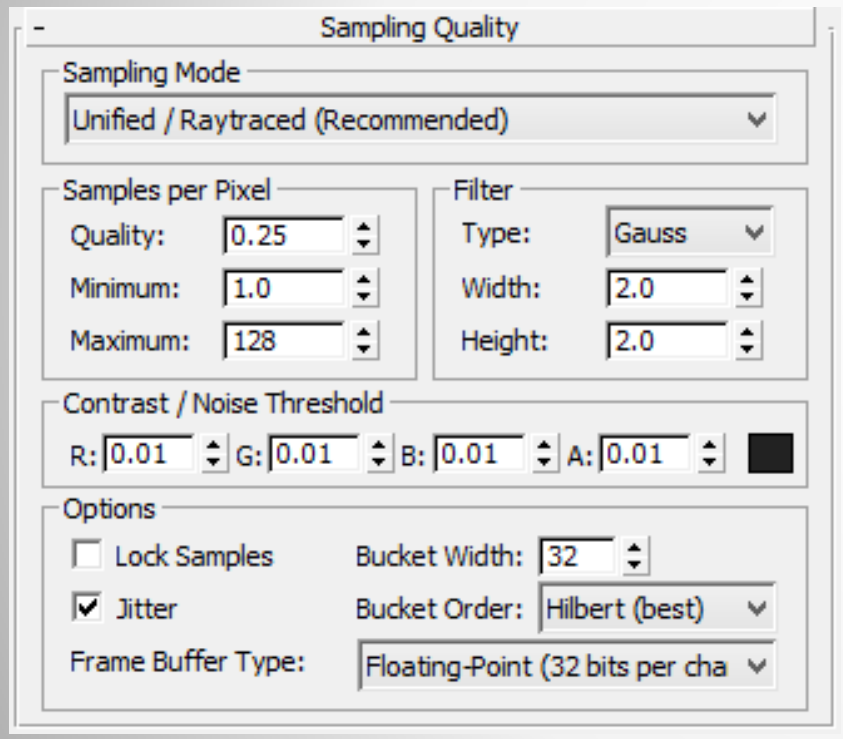
RGB & Alpha values for evaluating contrast between two samples

Recursive: If color value difference is greater than this, subdivide the pixel and sample again

Keep sampling until Maximum samples per pixel is reached.

Sampling Applied

Controlling Unified Sampling quality:



Colors are not simply averaged.

Filter = Algorithms for combining sample colors together.

Jitter: Adjusts sample rays to not sample at direct center of pixel

Sampling Methods Compared

Classic Sampling: 1:55

Unified Sampling: 1:48

Direct Illumination in CG

Light that emanates from a light source

Is not reflected, refracted, or absorbed

Provides a very flat scene

Back in olden times (late ‘90s): “Fakeosity” techniques used many direct lights with colors and soft shadows to emulate indirect illumination, sky dome, etc.

Replaced by GI / FG / AO / Daylight System / etc.

Indirect Illumination Basic Concepts: The Physics of Light

Indirect Illumination in mr attempts to simulate the physical way light works in the real world

Photons of light are either reflected off of, absorbed by, or refracted (bent) through the material they interact with

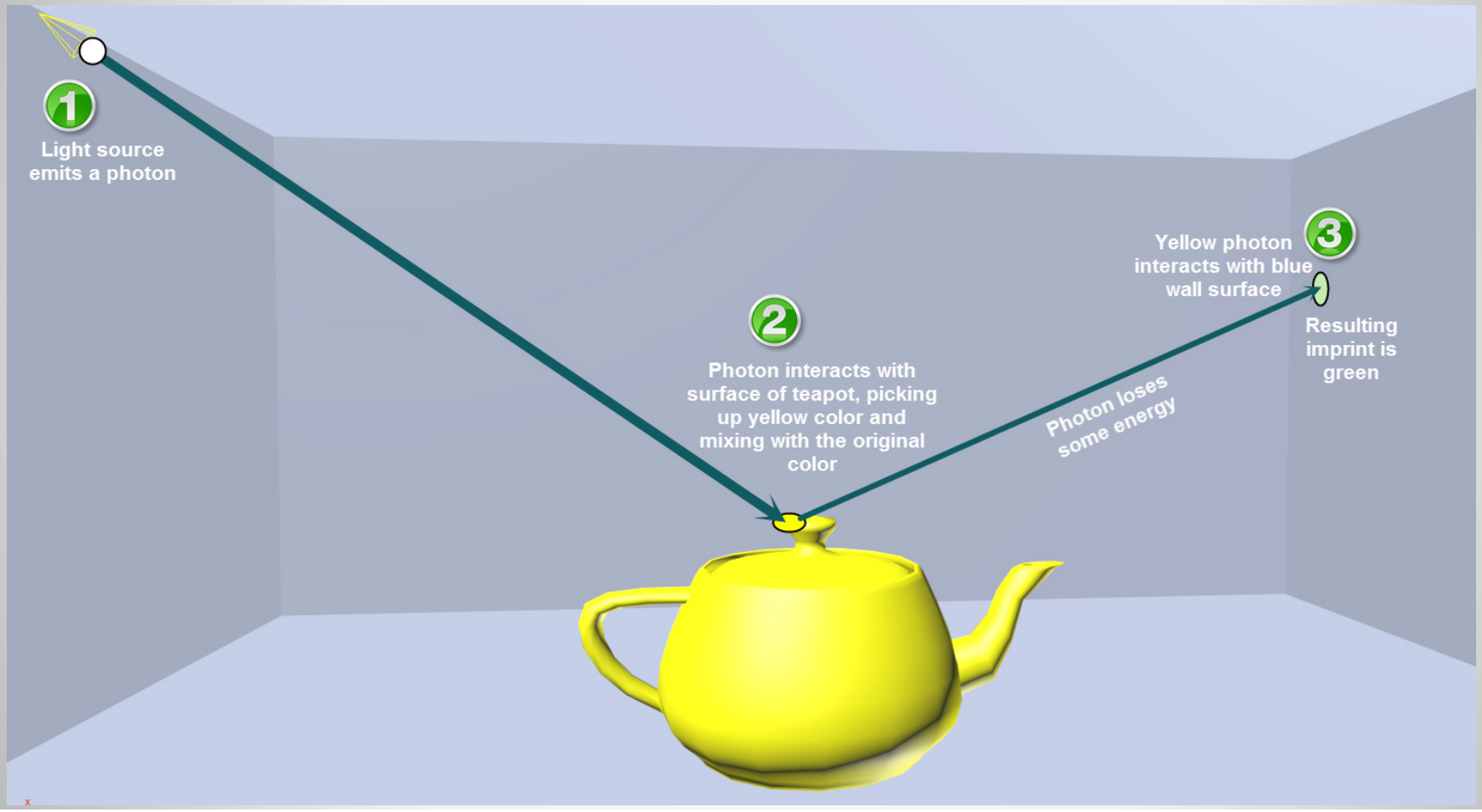
Photons have specific energies (intensity) and wavelengths (color)

Reflected photons are those whose wavelengths are not absorbed by the material – this gives objects their colors.

Photons impart their own color on the object surface they interact with

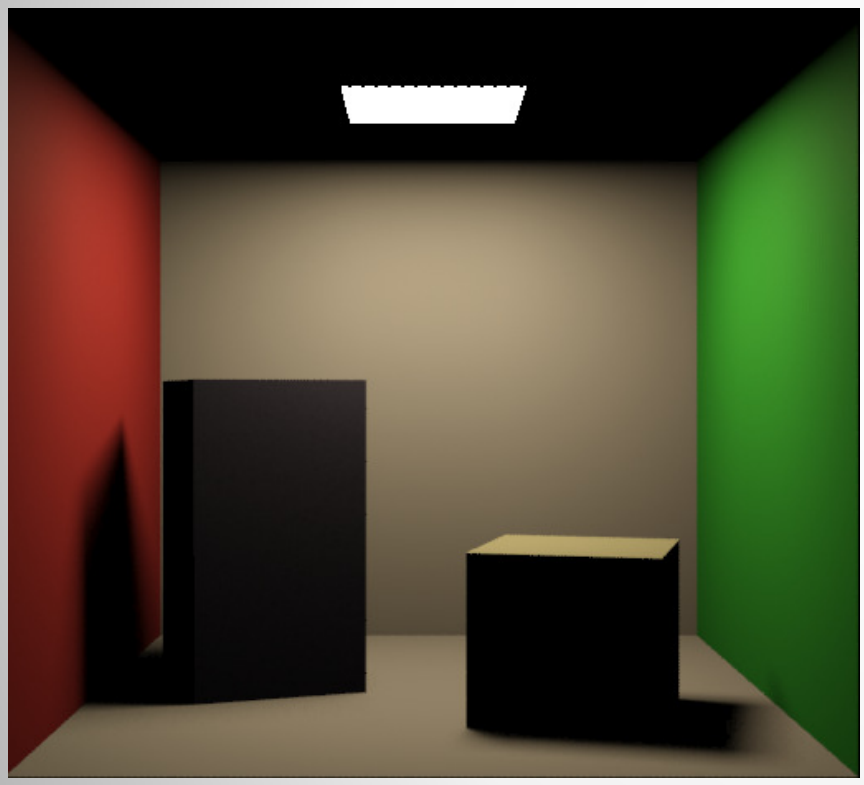
Objects are thus colored by other objects (color bleed)

The Physics of Light

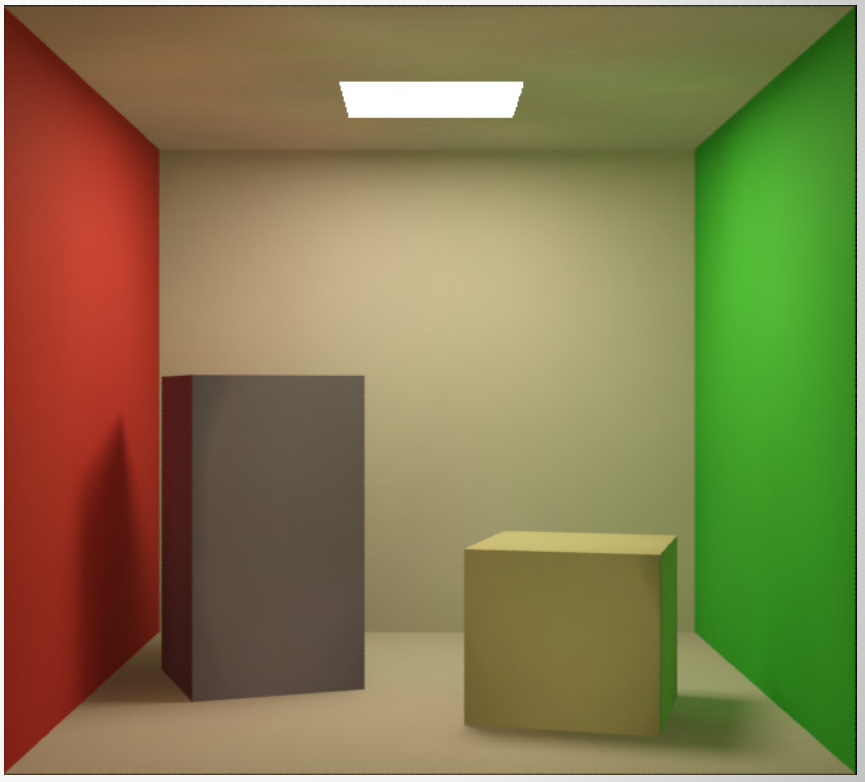


Direct and Indirect Illumination

Direct Illumination:



Add Indirect Illumination:



Model source: Jennifer O'Connell, Mastering mental ray: Rendering Techniques for 3D and CAD Professionals.

Indirect Illumination Terms: Global Illumination (Photon Mapping)

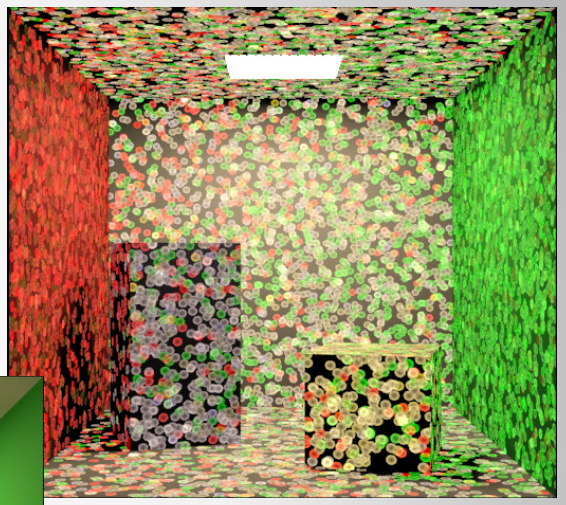
Shoots rays from the light to objects

Rays interact with scene objects, picking up color

Hit (sample) other surfaces

Impart new color on surface

Problem: Light splotches on surfaces need cleaned up



Model source: Jennifer O'Connell, Mastering mental ray: Rendering Techniques for 3D and CAD Professionals.

Indirect Illumination Terms: Final Gather

Originally conceived as a cleanup tool for photon mapping (GI)

Can be used on its own to generate indirect illumination

Shoots rays from the *camera* (eye rays) to objects in the scene

Ray hits object (Final Gather Point)

Additional rays are cast from the Final Gather Point

Those sample additional surfaces

May bounce and sample more surfaces (Diffuse Bounces)

Returns values of illumination back to FG point

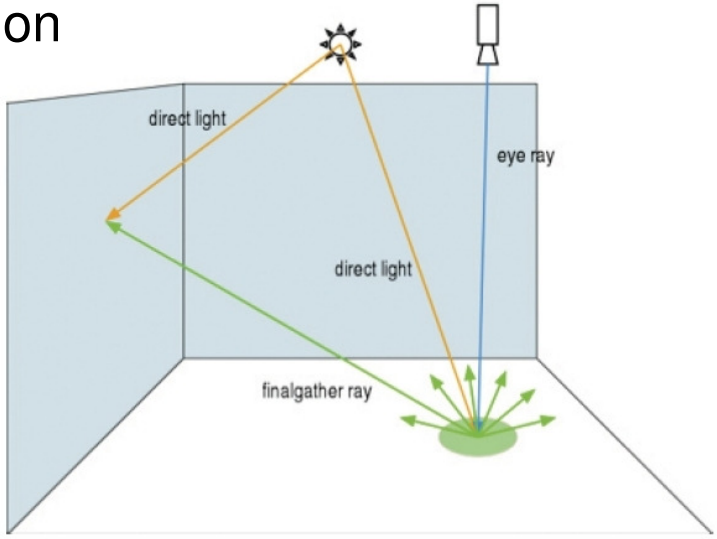
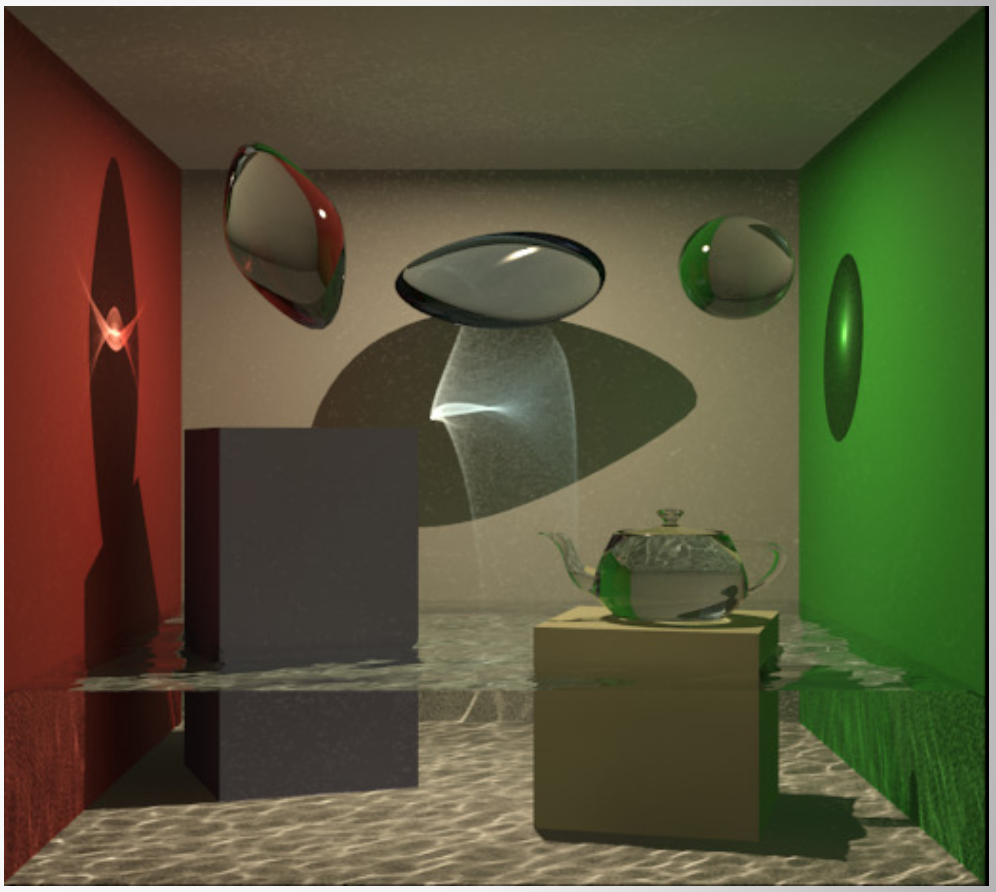


Image courtesy Paolo Berto, mental images

Indirect Illumination Terms: Caustics

Focused light that passes through transparent objects

Simulates water, liquids in glass, crystal, diamond, etc.



Model source:
Jennifer O'Connell, Mastering mental ray: Rendering Techniques for 3D and CAD Professionals.

Indirect Illumination Terms: Ambient Occlusion

Material-specific effect to provide contact shadows

Rays sent randomly from rendered samples a certain limited distance

If they hit something close by, darken the sample

mental ray features: Daylight System

Assembly of mr Sun and mr Sky to simulate accurate placement of sun in the sky based on time/location

Critical for realism in interior and exterior scenes

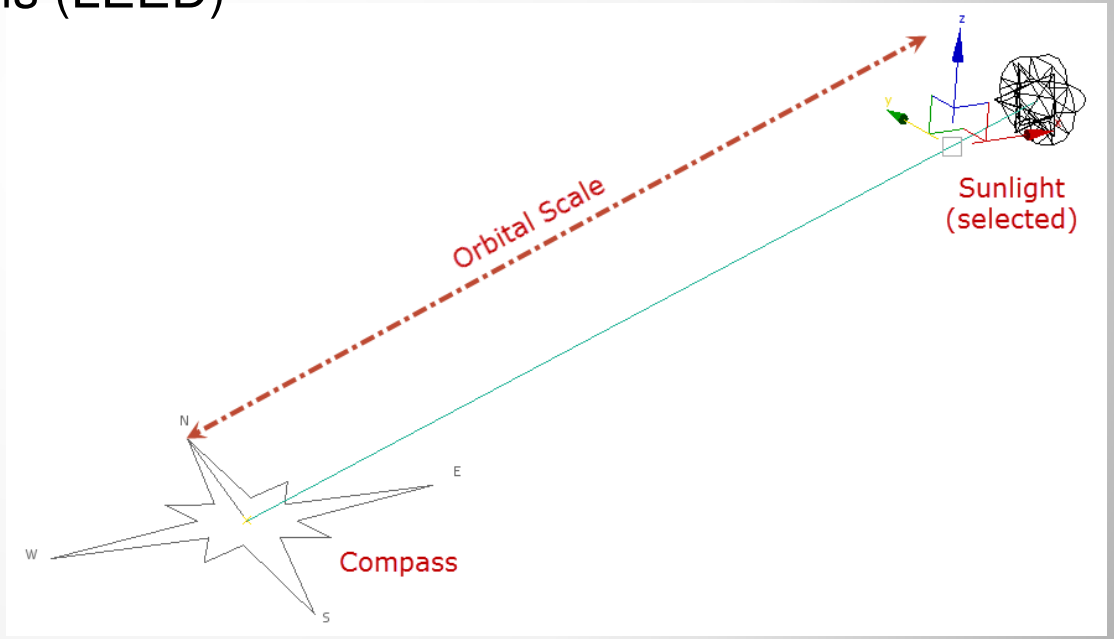
Can be used for Daylighting Analysis (LEED)

Can be animated

Easy to place and adjust

Automatically assigns an mr Physical Sky environment map

Automatically assigns the mr Photographic Exposure control

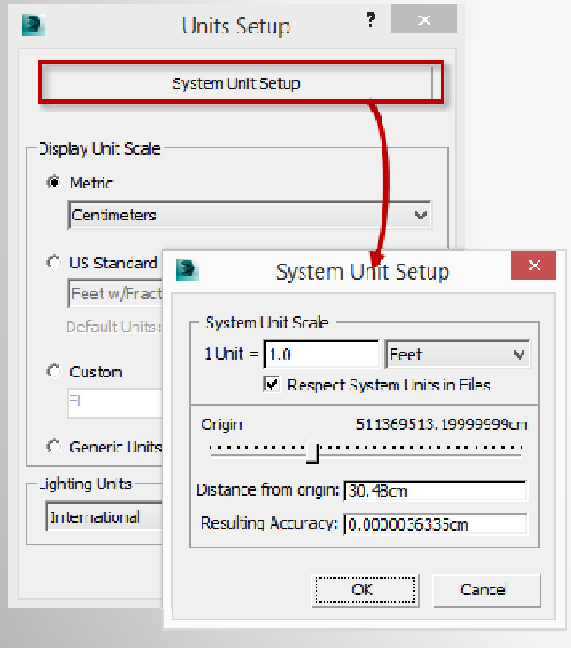


Considerations for mental ray: Units and Scale

Units are critical to ensure mental ray is working properly

mr relies on real-world sizes for everything

Always set up Units and Scale first, before any geometry is added



System Unit determines how large in real world the units in 3ds Max scene are.

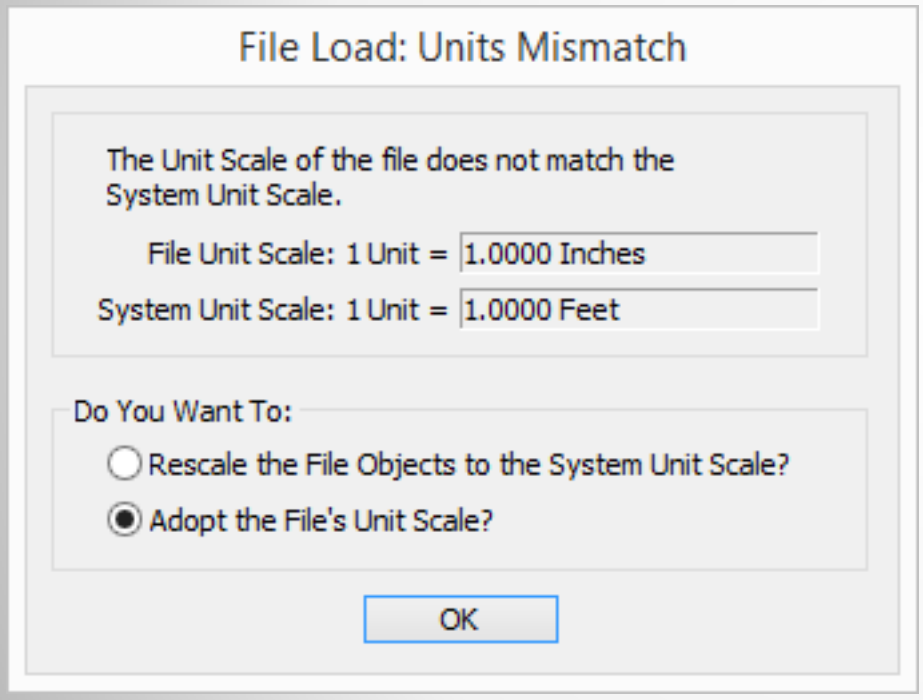
The larger the unit size, the less “precise” the model accuracy

Keep model near origin for best results

Display Units only affect display of units inside of the UI

Considerations for mental ray: Units and Scale

File Load Units Mismatch



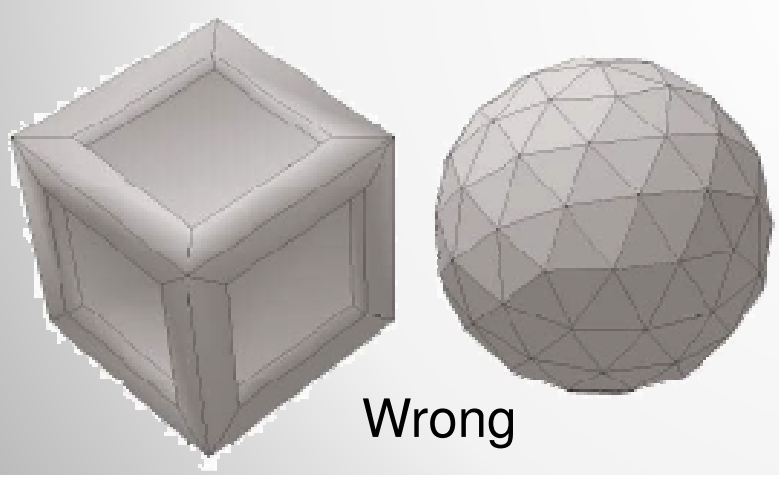
Units mismatch on import / link

Option to rescale objects to the system unit scale

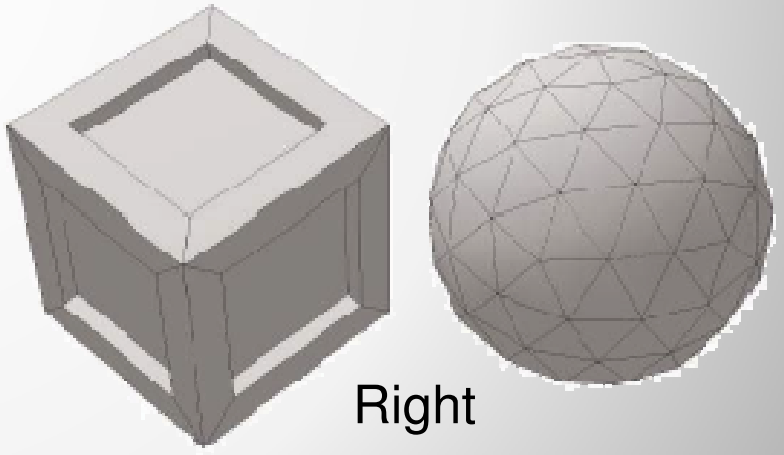
Adopt the incoming file's Units (preferred)

Considerations for mental ray: Modeling

- It is critical to model properly for mental ray
- Use real-world sizes always
- Editable Poly is preferred over Editable Mesh
- Revit and other solid models usually “watertight”
- Beware flopped normal & improper shading



Wrong



Right

Considerations for mental ray: Lighting and Exposure Control

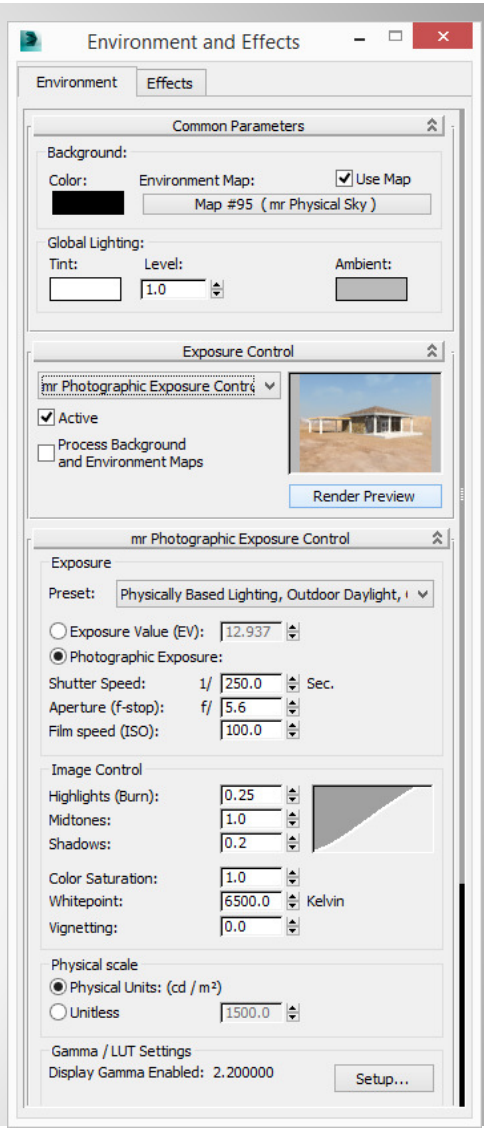
- Use Photometric lights with physically accurate properties – decay, intensity, color
- Always use Ray Traced Shadows
- Use IES files for accurate photometrics of artificial light sources
- Works with the mr Photographic Exposure Control to achieve correct exposure

Considerations for mental ray: mr Photographic Exposure Control

Easy | Medium | Hard ways of controlling exposure:

- Use Preset for lighting scenario
- Set a single Exposure Value (EV)
- Set settings for shutter speed, f-stop, ISO

Use Render Preview to establish proper exposure without wasting time



Considerations for mental ray: Materials

All rendering engines use their proprietary materials

mental ray = Arch & Design and Autodesk materials

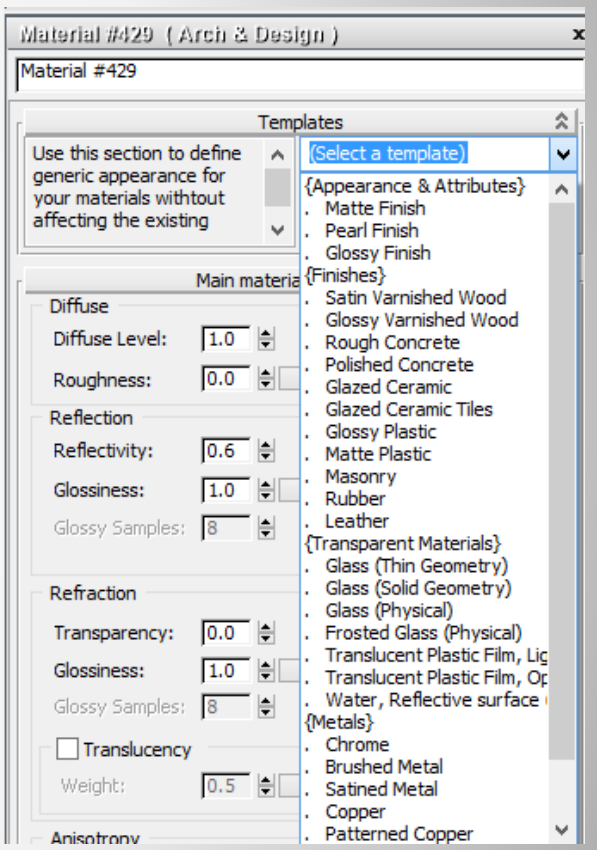
Physically accurate = “Energy conserving”

Arch & Design = monolithic material that can adjust to many different kinds of materials

Based on templates

Autodesk = Arch & Design based materials with limited options; easier UI, renders fast

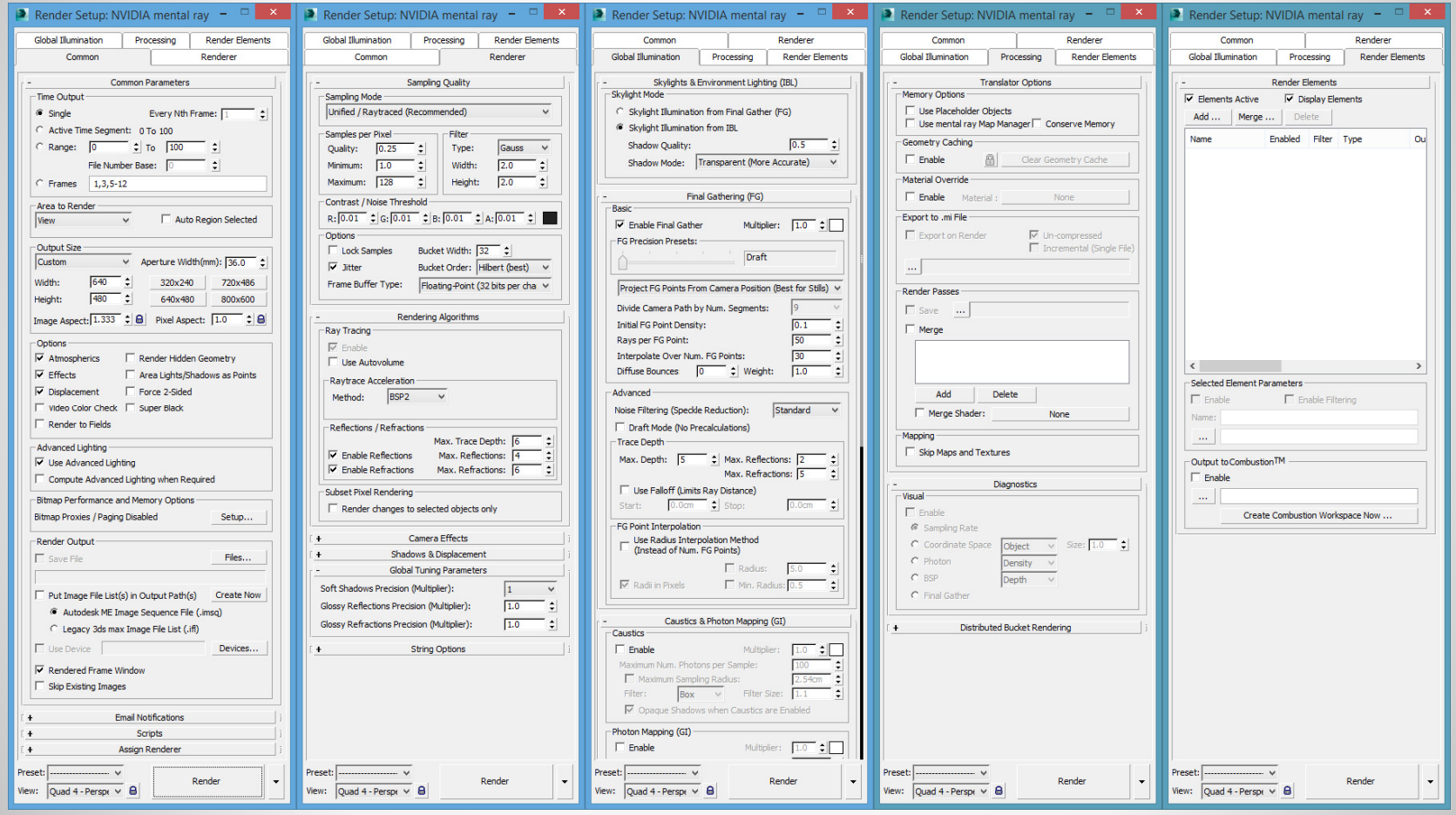
Both work equally well



Arch & Design Material

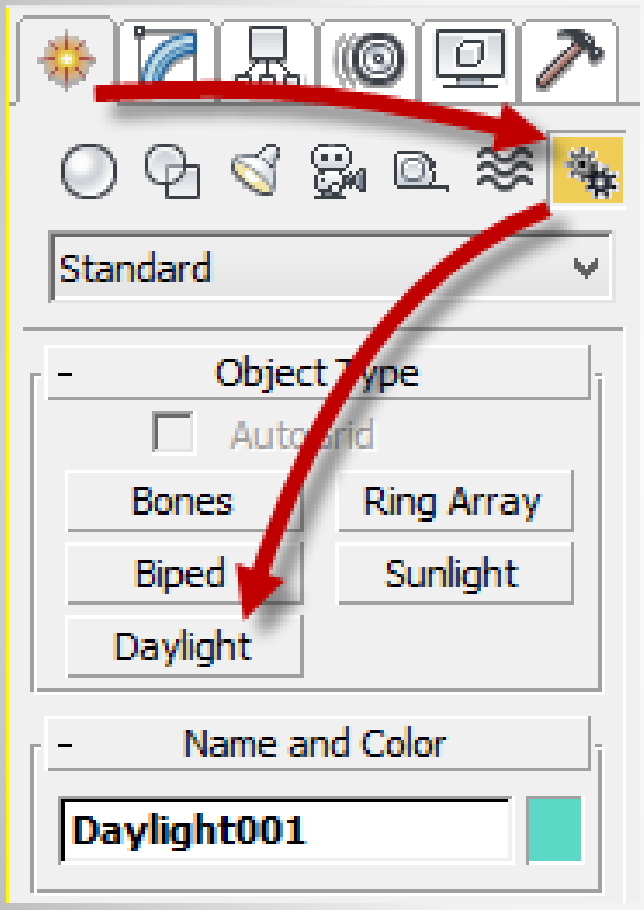
- Easy to use & flexible
- Transparent objects can be treated as a solid (refracting) or thin (non-refracting, uses single faces)
- Round Corners – Applies a fillet to corners at render time
- Ambient Occlusion- Darkens inside corners, provides contact shadows
- Powdery surfaces / subsurface scatterings easy

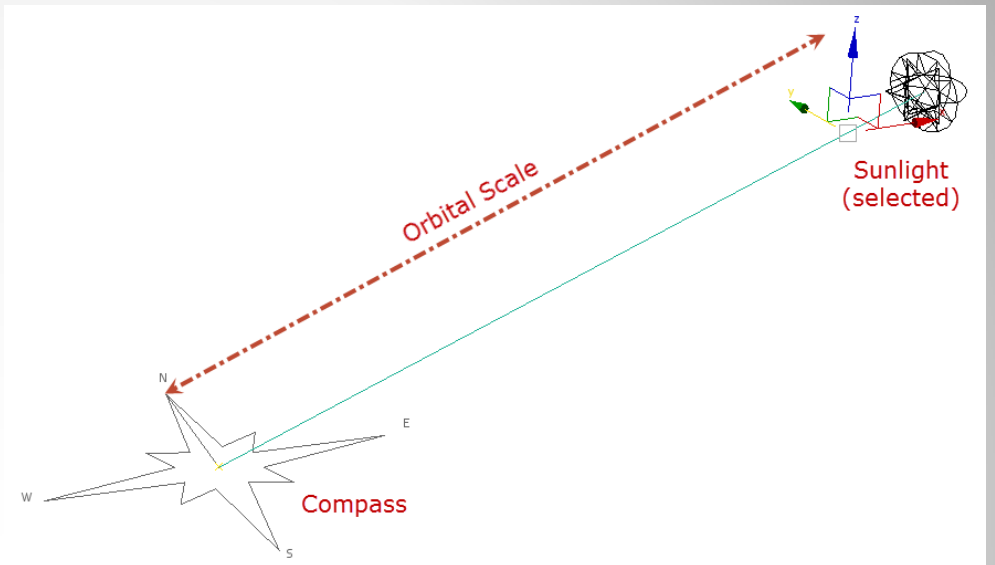
Rendering Setup Dialog



Section II
mental ray Indirect Illumination Tools

Daylight System





Global Illumination (Photon Mapping)

Photon Mapping (GI)

- [x] Enable — Multiplier: 1.0
- Maximum Num. Photons per Sample: 500
- [ ] Maximum Sampling Radius: 0'1.0"
- [ ] Merge Nearby Photons (saves memory): 0'0.0"
- [ ] Optimize for Final Gather (Slower GI)

Volumes

- Maximum Num. Photons per Sample: 100
- [ ] Maximum Sampling Radius: 0'1.0"

Trace Depth

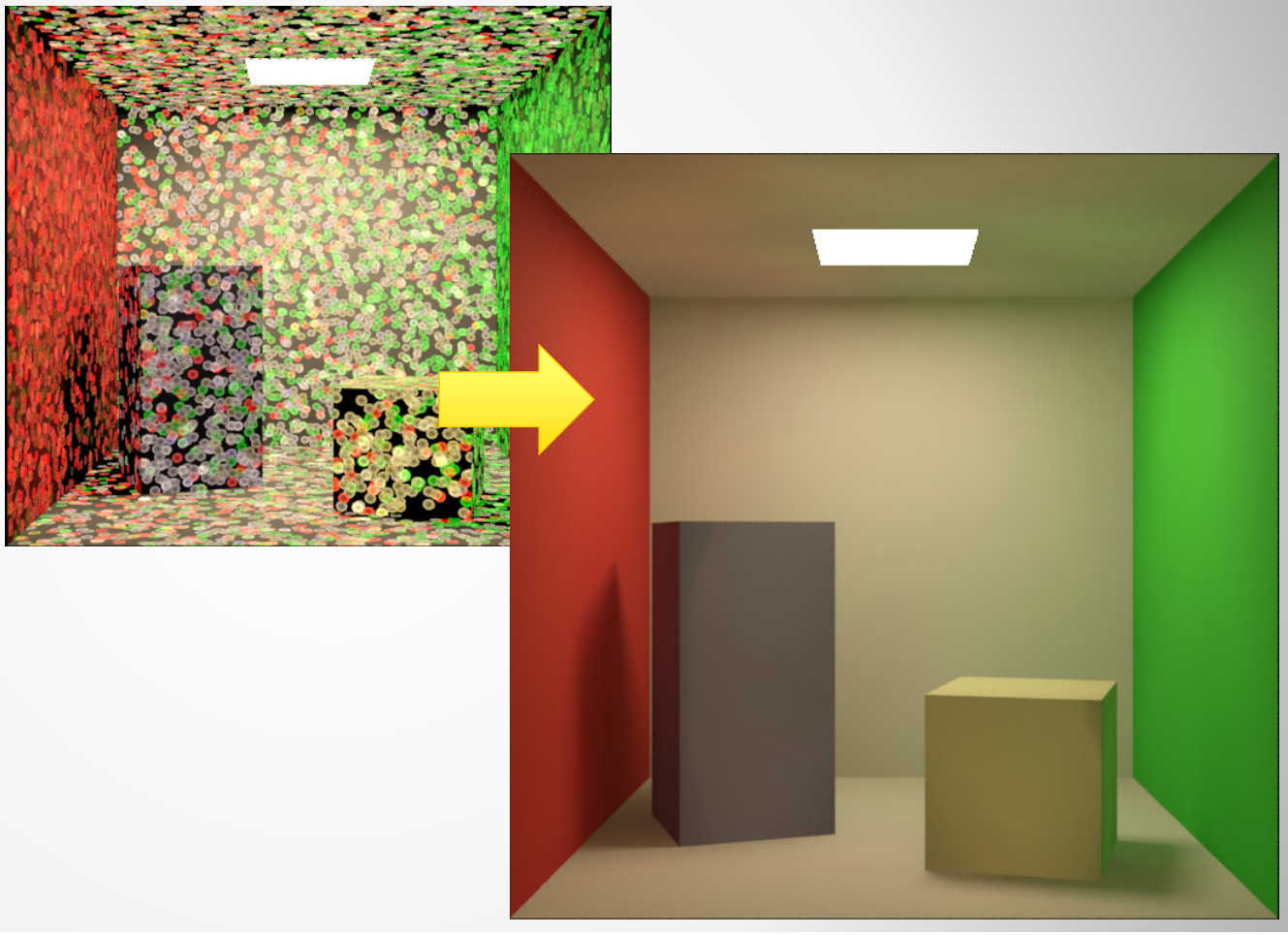
- Max. Depth: 5
- Max. Reflections: 5
- Max. Refractions: 5

Light Properties

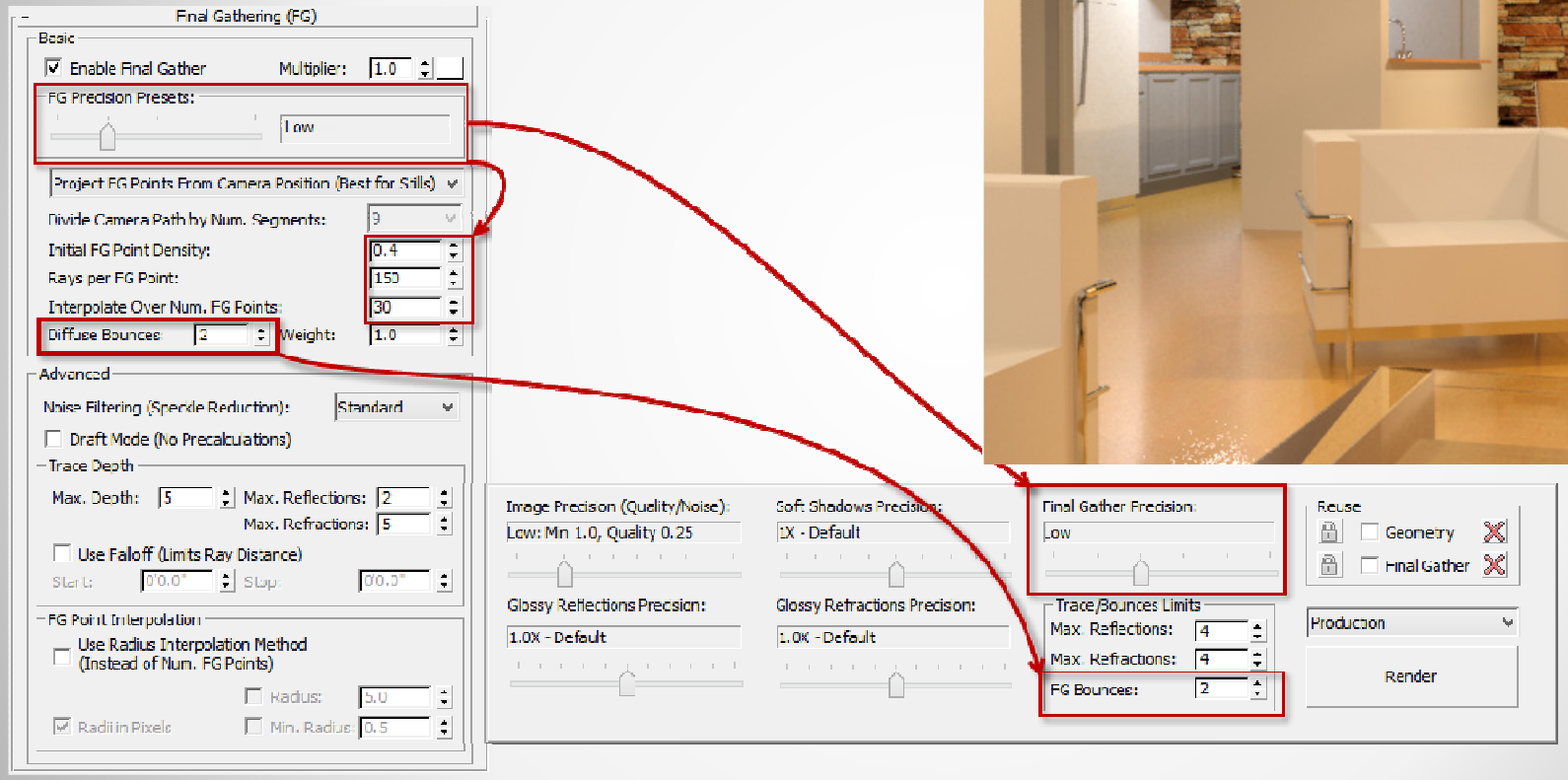
- Average Caustic Photons per Light: 10000
- Average GI Photons per Light: 10000
- Decay: 2.0

Geometry Properties

- [ ] All Objects Generate & Receive GI and Caustics



Final Gather



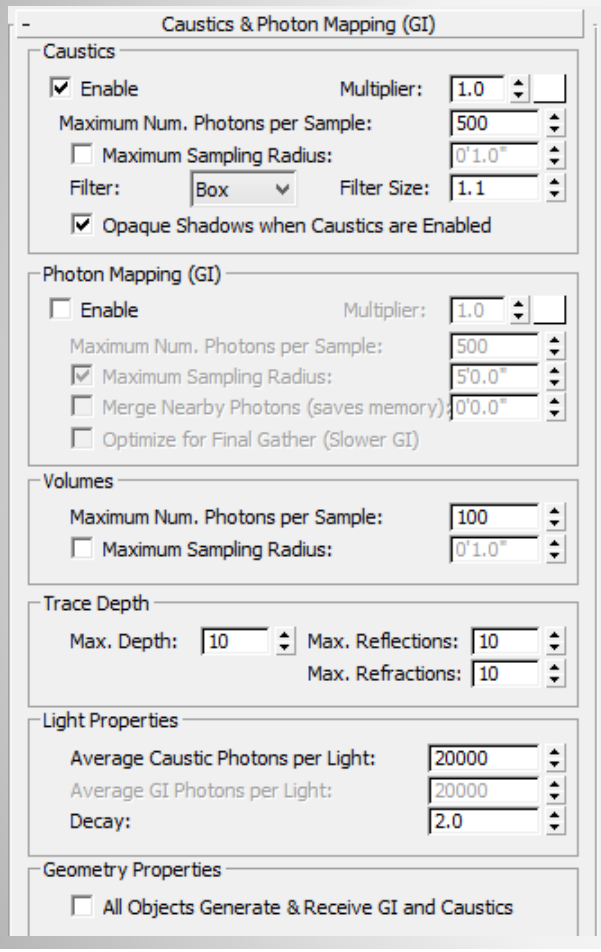
Final Gather

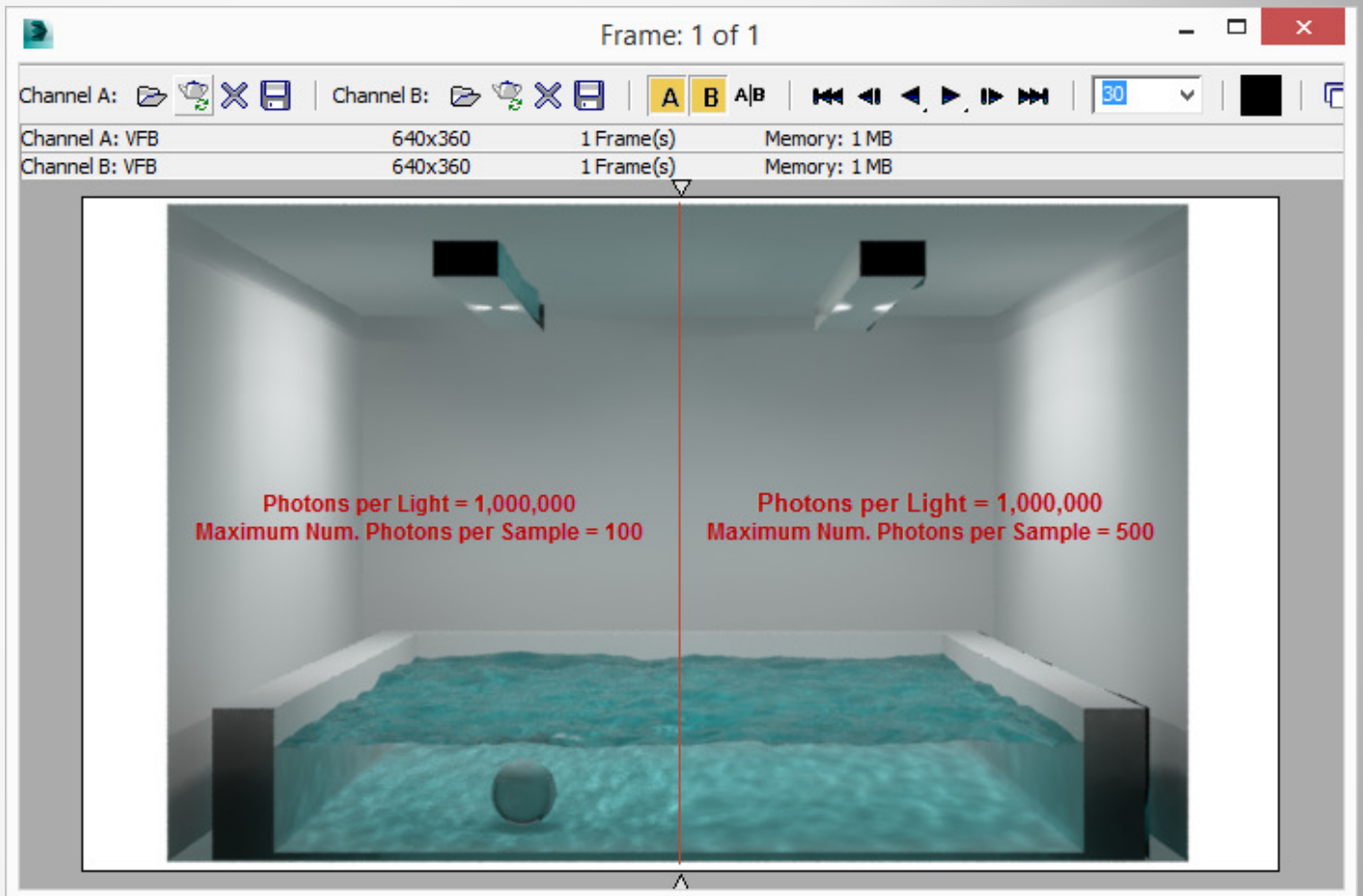
FG – Draft, 1 Bounce

FG – Low, 2 Bounces

FG – Medium, 3 Bounces

Caustics


Caustics & Photon Mapping (GI)
Caustics
Enable
Multiplier: 1.0
Maximum Num. Photons per Sample: 500
Maximum Sampling Radius: 0'1.0"
Filter: Box
Filter Size: 1.1
Opaque Shadows when Caustics are Enabled
Photon Mapping (GI)
Enable
Multiplier: 1.0
Maximum Num. Photons per Sample: 500
Maximum Sampling Radius: 5'0.0"
Merge Nearby Photons (saves memory): 0'0.0"
Optimize for Final Gather (Slower GI)
Volumes
Maximum Num. Photons per Sample: 100
Maximum Sampling Radius: 0'1.0"
Trace Depth
Max. Depth: 10
Max. Reflections: 10
Max. Refractions: 10
Light Properties
Average Caustic Photons per Light: 20000
Average GI Photons per Light: 20000
Decay: 2.0
Geometry Properties
All Objects Generate & Receive GI and Caustics


Frame: 1 of 1
Channel A:
Channel B:
Channel A: VFB 640x360 1 Frame(s) Memory: 1 MB
Channel B: VFB 640x360 1 Frame(s) Memory: 1 MB
Photons per Light = 1,000,000
Maximum Num. Photons per Sample = 100
Photons per Light = 1,000,000
Maximum Num. Photons per Sample = 500

Thank You!

Please fill out your evaluation forms online after class!

Please see me if you need the answers