Using 3ds Max and mental ray for Architectural Visualization

Introduction

This white paper looks at using mental ray® software for architectural visualization. Autodesk® 3ds Max® 9 software includes many major feature and workflow improvements to reduce complexity and make rendering with mental ray far more approachable for Architects and designers.

This document summarizes the important aspects of photorealistic renderings that Architects, designers and visualization professionals may want to consider when creating presentation images, visualizations for design review, or physical analysis of lighting. It identifies the main areas involved in physically based renderings and provides guidance as well as tips-and-tricks on how to use them in 3ds Max. The main areas of focus include:

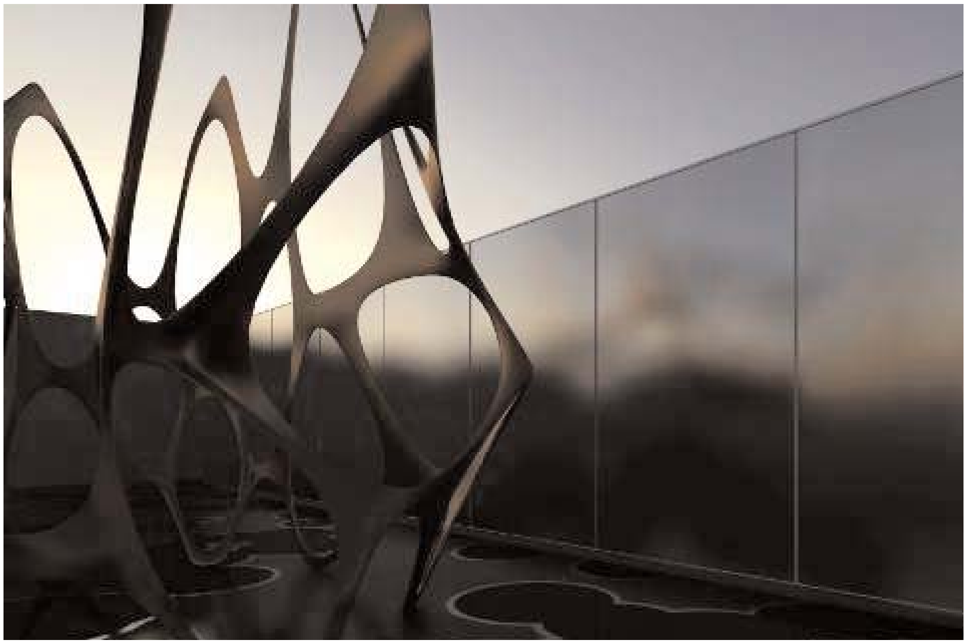
- Lighting and materials theory
- The mental ray renderer
- The mental ray daylight system
- Arch+Design material for mental ray, and more

Included with this document are sample scene files and renders to help provide context.

Image rendered from the sample file, which can be found along with this document.

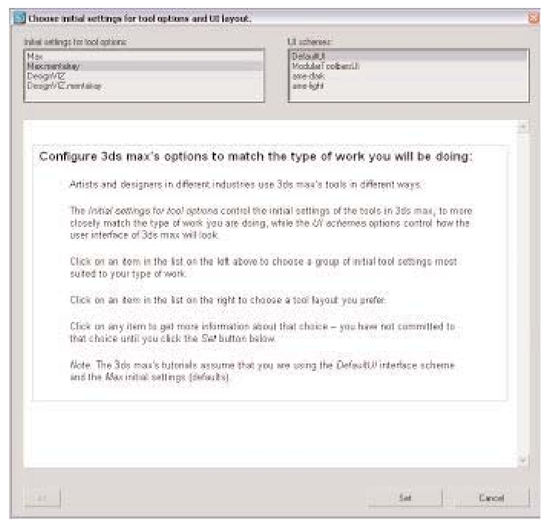
Transforming Digital Painting into Digital Photography

In the real world, energy is emitted by light sources, bounces around, and is absorbed by surfaces. The same principles apply in global illumination rendering, especially in architectural visualization. Architects, Designers and Visualization Professionals need be able to render images that approximate the real world as closely as possible. In combination with structure and surfaces, light can change the appearance of a room tremendously.



Setting up the Workbench

Profile Presets
3ds Max software ships with a tool that enables you to preset environmental defaults that suit the workflow of photorealistic renderings done with mental ray. This is a great place to start.



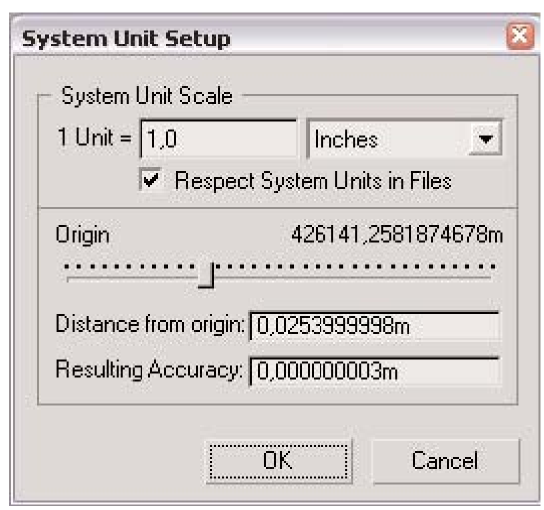
By choosing the 'Design VIZ/mental ray' profile, you get the following:

- mental ray renderer
- Exposure control
- New mental ray 'Arch+Design' material in the 'Material Editor'
- New 'mr Sun' and 'mr Sky' plug-ins in the daylight system
- Lights that cast shadows and are set to be ray-traced

Units and Scale
Physically based lighting computation implies that light attenuates using the inverse square falloff law, which simply means the intensity of light declines exponentially with the distance it travels. Therefore, it is crucial that the scale of your scene corresponds to real-world data—otherwise the results will get corrupted.

A common mistake is to import an airport at the size of a shoebox or a room at the size of a stadium. In one case, the lighting computation will be too bright, and in the other case, it will be too dark.

To verify your scale settings, check the 'System Unit Scale' settings in the 'Customize | Units Setup | System Unit Setup dialog box':



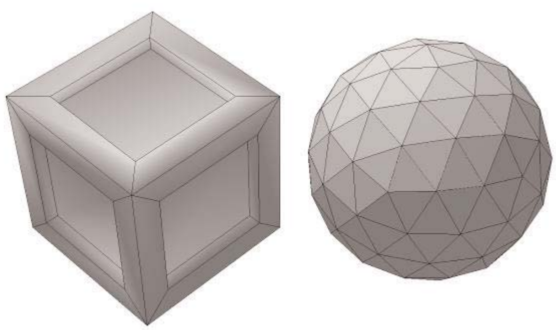
You may also want to use the 'Tools | Measure Distance' tool to verify known dimensions in the scene, as well as set the 'Unit Conversion' function in the Import menu when, for example, importing a DWG™ file from AutoCAD® software.

Optimizing Geometry for Rendering

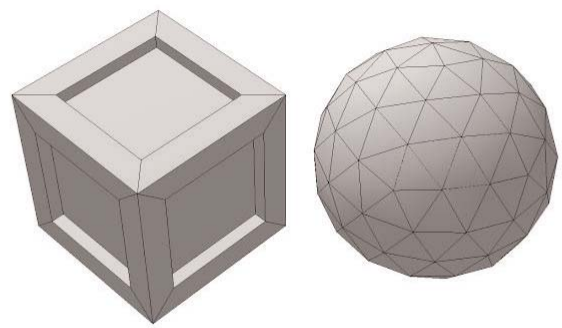
Good renderings require good geometry. Good geometry does not mean you must model everything. You can obtain many detailed effects with optimizations such as bump maps or cutout maps. It only means that the geometry must correspond roughly to what the renderer expects. It is important to start with a clean model. Fortunately, mental ray is more tolerant than radiosity in this respect; you do not have to create perfect models, but more accurate models make rendering easier and more efficient. The following sections describe good practices for optimizing geometry before rendering.

Smoothing Angles

All 3D geometry—including both edged objects and rounded forms—is made up of polygons. To display them smoothly, 3ds Max interpolates between the surface normals to simulate a rounded form and not a faceted one. When importing a file from another computer-aided design (CAD) or 3D application or when working with the Edit Poly modifier, you may find that the information about which normals to smooth by interpolation and which to keep sharp edged with no interpolation can sometimes get lost or corrupted. Instead of re-importing a file or asking your client to resend it, try the Smooth modifier. In most cases, the problems disappear.



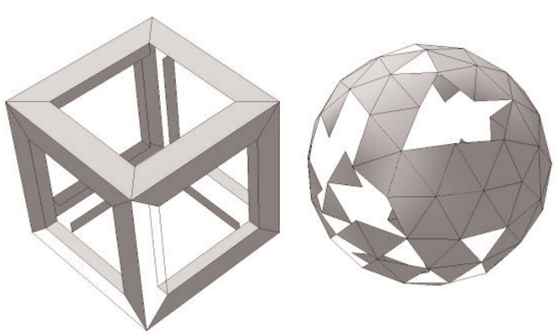
The cube's faces are smoothed with an angle that's too high, the sphere's faces with an angle that's too low.



This is how the cube and the sphere should look according to smoothing groups.

Flipped Normals

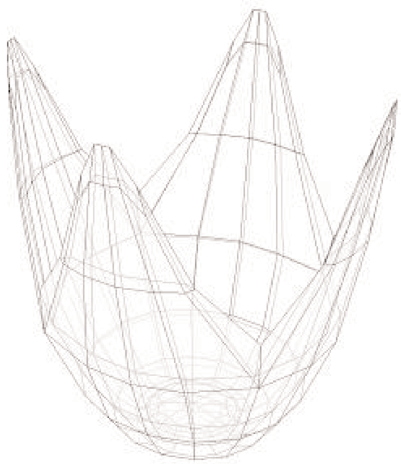
Rendering the face of a geometric shape requires both the vertices that define it and information about its orientation. This can be seen as information about which is the front and which the back of the face, which is done by the surface normal as well. When importing a model from a CAD package, you may find that direction information can get lost or corrupted. The problem is that from the back, a polygon is invisible and appears as a hole in the model. To fix this problem, try toggling 'Backface Culling' in the 'Object Properties' dialog box, or assign a material and make it two-sided. If there are only a few faces with the wrong orientation, you can add an 'Edit Poly' modifier and use Flip on the affected faces. If the import is poor, you can use a two-sided material such as the 'Arch+Design' material to fix the faces without spending too much time on cleanup.



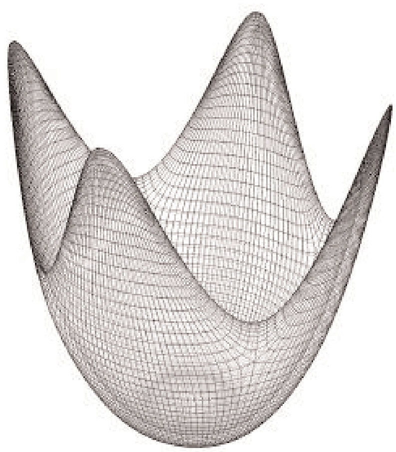
The geometry is the same as in the preceding example, but some faces are flipped so they appear to be invisible. Orientation information can be lost or corrupted during import.

Polygon Count

It is good practice to think about how many polygons an object should consist of before modeling it. This is true for all geometric objects, especially curved and round ones. Each face needs to be rendered, but using many polygons on a round object can quickly add up to inefficiencies, especially if objects are copied within the scene. On the other hand, using too few polygons makes an object appear segmented.



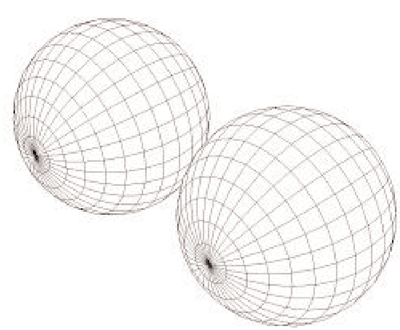
Picking a polygon count that is too low for your model gives unsatisfactory results for architectural rendering.



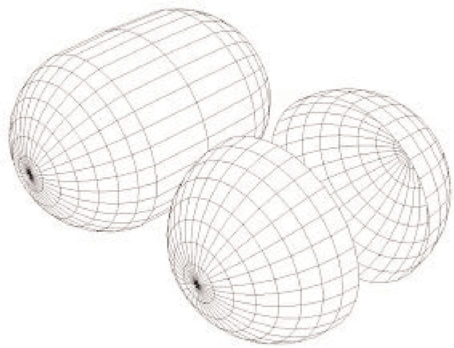
In this example, the bowl's appearance is improved because the shape allows for additional faces without destroying the bowl itself; you could simply add a 'Turbosmooth modifier'.

Unwelded Vertices

In some cases, a model might look as if it is closed, but instead each face is separated and the vertices of neighboring faces are unwelded—that is, not connected. Unwelded vertices can introduce many problems, including large file sizes due to thousands of unnecessary vertices, damage to the object when moving faces or altering the model, and even problems with proper smoothing and normal interpolation, since the faces appear unconnected to 3ds Max. If the 'Smooth modifier' doesn't correct smoothing problems, check for unwelded vertices. To weld vertices, simply add the 'Weld Vertices' modifier and choose an appropriate radius.



Both spheres look the same, but the right one has a row of unwelded vertices. This wastes memory (for example, instancing an object many times) and makes it difficult to modify geometry.



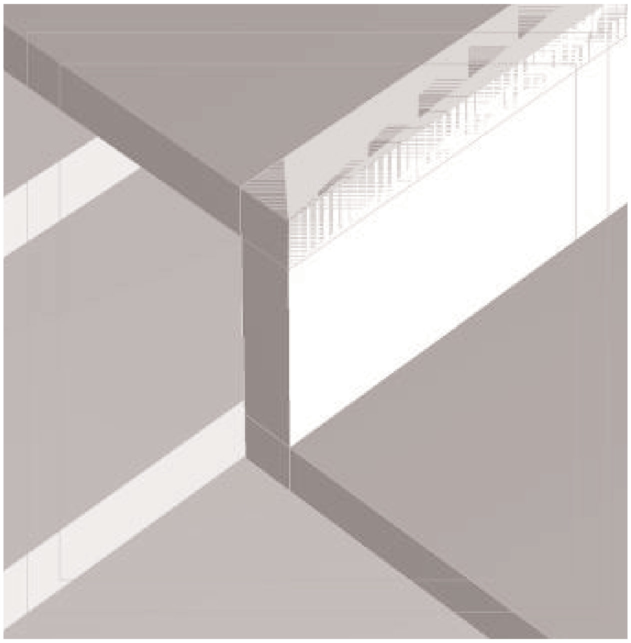
Problems appear when moving half the faces with an 'Edit Poly' modifier. Welding the vertices corrects the loose edges.

Under certain light conditions you can even see unwelded vertices by studying a render of the object.

Overlapping Surfaces
Watch out for faces that overlap precisely. The renderer cannot determine which one to put in front, and a black pattern artifact will appear. Overlapping faces can be introduced by careless modeling or by importing a file, such as a CAD file with versioned geometry overlapping precisely on several layers.

Light Leaks
Since indirect lighting calculations have to be interpolated in some way because of their complex nature, it is crucial to avoid light leaks when modeling. Light leaks are caused by geometry, usually edges, that let indirect light pass through, even if this would not happen in the real world. The problem is most obvious in scenes with high contrast, such as sun-light on an enclosed space with an opening. If not modeled properly, faulty geometry can let light pass into the space through open edges.

Even if your model looks good in the viewport, it might show light leaks during rendering. Check your render setup for possible causes. For example, radiosity might let light crawl underneath a wall if the floor is not disconnected. If the photon search radius is set too high for thin walls, the sun will be interpolated to the inside. Final Gathering is usually the most robust way to work around potential light leaks.



Unlike unwelded vertices, overlapping surfaces are easy to spot.

When the 'photon search radius' set too high for think walls, sun is interpolated to the inside.

Indirect Illumination

In the real world, light bounces off a surface, illuminating other surfaces repeatedly until all light is absorbed. This effect is called ‘indirect illumination’ (known in Computer Graphics as ‘global illumination’, or GI). It’s very complex and takes time to calculate. That’s why this effect is turned off by default. Since allowing light to bounce throughout a scene indefinitely makes rendering inefficient, the mental ray renderer enables you to specify the number of bounces to be calculated.

mental ray software provides two methods to calculate indirect light: ‘global illumination with photons’ and ‘Final Gathering’ (FG), which you can use individually or together. Each approach has its benefits. The most important difference between these methods is that FG calculates indirect light into the scene via samples from the camera. Photons, on the other hand, are cast from a light source into the scene, stored on surfaces, and then seen by the camera. Both features use interpolation methods.

Final Gathering
Scenes with greater lighting, such as most outdoor scenes, can take advantage of ‘Final Gathering’. FG is a quick, clean approach for those purposes and gives better and more variants in shading than photons. As a rule, try ‘Final Gathering’ first. Many projects can be done exclusively with FG, incorporating multiple bounces, if necessary. FG is also a good solution for indoor scenes that are lit well directly, without the need for many bounces. FG can calculate multiple bounces, but using photons is often faster. With the presets in 3ds Max, you can quickly set Final Gathering from a ‘Fast Draft’ mode to ‘Production’ mode and back again. You can preview FG during the prepass, which will give you a rough impression of how the rendering will ultimately look.

Global Illumination with Photons
If FG doesn’t provide what you need, try photons. This method is generally more accurate than FG in terms of transporting light. If you need physically complete, accurate scenes for analysis purposes, such as via the Pseudo Color Exposure, use photons. Photons can quickly calculate multiple bounces and transport light far into a scene. An example would be a long highway tunnel with only two small openings—the photons method makes sure light gets as far into the tunnel as it would in the real world. The

same is generally true for scenes that are lit only from the outside through small openings. As photons are cast from the light source, the light finds the opening more easily than it would with 'Final Gathering', which searches for the opening through random sampling. The drawback of the photons method is that it is difficult to get detailed shading, especially on smaller objects. The calculation is fast, but also smooth. To get details, you would have to use so many photons that memory might become an issue. You can use 'Ambient Occlusion' to add details quickly to smoothed-out photon solutions.

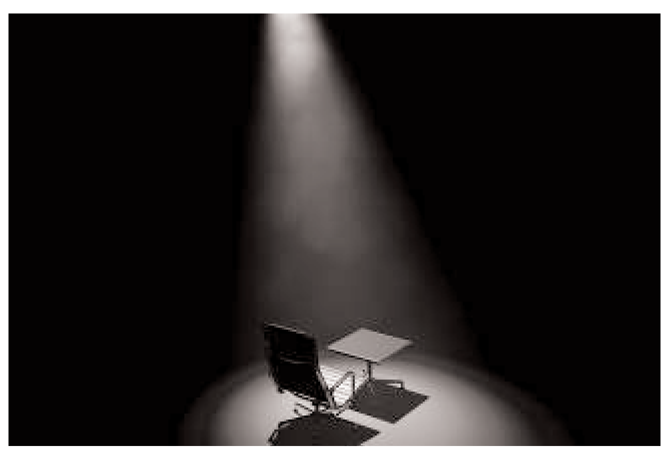
Photons and Final Gathering
mental ray gives you the best of both worlds: use FG for detailed scenes and photons to transport light as far as necessary with many bounces in a short time. If FG is activated as well, it does the rest, giving you a smooth but detailed result.

A room lit by the sun with a single Final Gather bounce. The light does not spread, even if you choose a high bounce value.

The same room lit by photons and cleaned up using the same single-bounce Final Gathering.

Artificial Light Sources

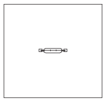
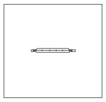
Photometric Lights
Photometric lights are closer to real-life lamps or fixtures than traditional CG lights (omni, spot, area, and directional). They are designed to handle attenuation and energy for GI/caustics automatically, based on the rules of physics. In addition, they can interpret photometric data in IES files, which contain specifically scanned lighting distribution information provided by lamp and fixture manufacturers.



If you don't get the results you want with photometric lights, try adjusting scene units, material reflectance basics, and exposure control settings.

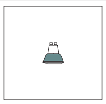
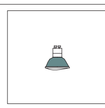
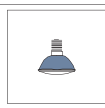
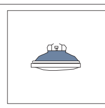
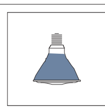
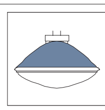
Typical Intensities and Distributions
Typical intensities may be another source of problems. The intensity of photometric lights is expressed in physical units used by lighting engineers (cd, lumens, or lux at a given distance). However, this is not enough to define how a light behaves in 3D space, where the specific distribution is also crucial.

Lamp index Tungsten Halogen Lamps

Description	Lamp type	Symbol	Wattage P (W)	Voltage U (V)	Socket	Lumens (lm)	Diameter D (mm)	Length L (mm)	Av. functional life acc. to manuf. spec. t (h)
Tungsten halogen lamps	T3		100	120	RSC	1650	9	79	1500
			150	120	RSC	2400	9	80	2000
	T4		150	120	RSC	2800	12	80	2000
Tungsten halogen lamps	T3		200	120	RSC	3600	9	102	2000
			300	120	RSC	5950	9	102	2000
			500	120	RSC	11100	9	102	2000
			300	120	RSC	6000	9	119	3000
	T6		1000	120	RSC	22000	19	143	2000

All lamp data is provided as a guide only. Current lamp manufacturers' data is to be used for calculation purposes.

Lamp index PAR Lamps

Description	Lamp type	Symbol	Wattage P (W)	Voltage U (V)	Socket	Intensity (cd)	Beam angle (°)	Diameter D (mm)	Length L (mm)	Av. functional life acc. to manuf. spec. t (h)
PAR lamps	PAR16		50	120	GZ10	640	40	51	51	2000
PAR lamps	PAR20		50	120	Med.	6000	10	64	80	2500
			50	120	Med.	1500	25	64	86	2000
			50	120	Med.	1500	25	64	83	2500
PAR lamps	PAR30		75	120	Med.	14900	9	95	92	3000
			75	120	Med.	2000	35	95	92	3000
PAR lamps	PAR36		50	12	Screw Term	35000	5	114	70	4000
			50	12	Screw Term	1300	30	114	70	4000
PAR lamps	PAR38		120	120	Med.	40000	10	121	135	4200
			120	120	Med.	25000	9	121	135	3000
			120	120	Med.	9000	30	121	135	4200
			120	120	Med.	5000	30	121	135	3000
PAR lamps	PAR56		300	120	Mog. End Prong	68000	10/8	178	127	2000
			300	120	Mog. End Prong	11000	37/18	178	127	2000
			500	120	Mog. End Prong	96000	8/13	178	127	4000
			500	120	Mog. End Prong	19000	22/44	178	127	4000

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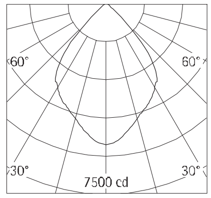
Reference table (c) ERCO Leuchten GmbH, www.erco.com

To understand how this works, imagine wrapping a light bulb in aluminum foil and adding collimating lenses to direct the light flux into a concentrated zone. The light still emits the same amount of energy, but now it's concentrated in a defined direction, labeled Peak Intensity in the following table. That is the combination of intensity and distribution. This is where IES data comes in, since an effect like this would be very time consuming to re-create in production, especially when dealing with several hundred light sources.

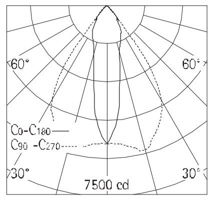
Photometric data from ERCO

Light intensity distribution
The spatial distribution of the lamp lumens results in a 3-dimensional body of light intensity distribution. A longitudinal or transverse section through this body results in a 2-dimensional light intensity distribution curve that indicates the light intensity of a luminaire for all angles of this plane.
Usually, this is displayed in a polar coordinate diagram from which the main direction of the beam is recognizable, e.g. direct or indirect emission. The unit of light intensity is Candela (cd).

The light intensity distribution of rotationally symmetrical luminaires is characterized by one symmetrical curve.

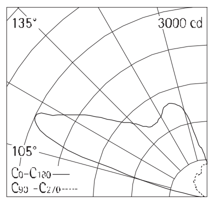


Axially symmetrical light sources need two curves, displaying the two main planes $C_0 - C_{180}$ (at right angles to the lamp position) and $C_{90} - C_{270}$ (parallel to the lamp).

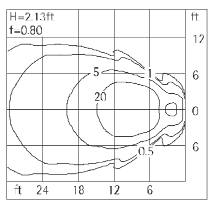


With luminaires for reflector lamps, the light intensity distribution curves are shown in the documents for both the narrow-beam lamp and the maximum permitted wide-beam lamp.

Asymmetrical distributions, mostly of wallwashers, are usually shown in the main curve $C_0 - C_{180}$.



Isolux curves
represent the illuminance distribution in a defined situation. The illuminance values are shown without regard to any maintained values. The letter H refers to the height of the front lens above the working plane.



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Wattage

Most people think the intensity of a real light source is measured in watts, but in fact, only wattages from the same kind of light sources can be properly compared. A halogen light may have the same wattage as an incandescent light bulb, but the intensity of the halogen source is much higher. Thinking and working in a generic unit for peak intensity, such as candela (cd), is preferable to using wattage. 3ds Max gives you the option of working in candela or lumens when you use photometric lights.

These various real-world light fixtures for different lighting purposes can also be rendered with mental ray.

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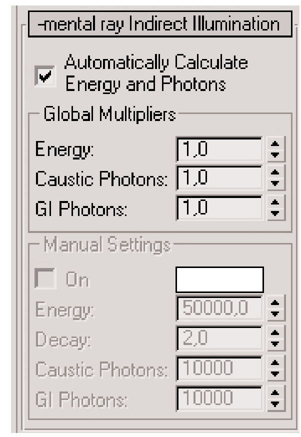

Global Illumination and Photometric Lights
It's easy to process photons or Final Gathering with photometric lights—simply switch on either, or both. The default settings are physically correct, so, for example, photons for GI and caustics are correctly distributed. Unless you have a reason to adjust one light locally, it's best to leave these values at their default settings. Having global control over photons in the render window is cleaner and easier to administer.

Physical Sun and Sky

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Create Endless Daytime Variations Quickly and Easily
The sun and sky system in 3ds Max enables you to quickly render an indoor or outdoor environment.

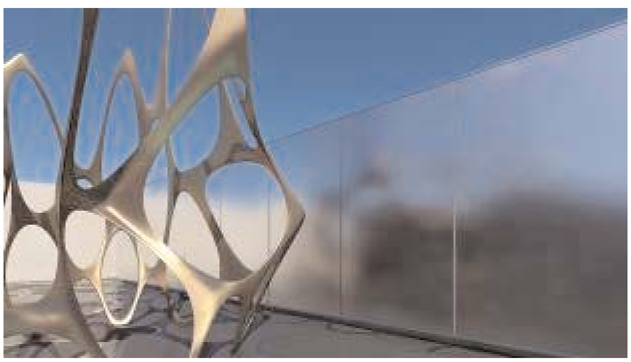
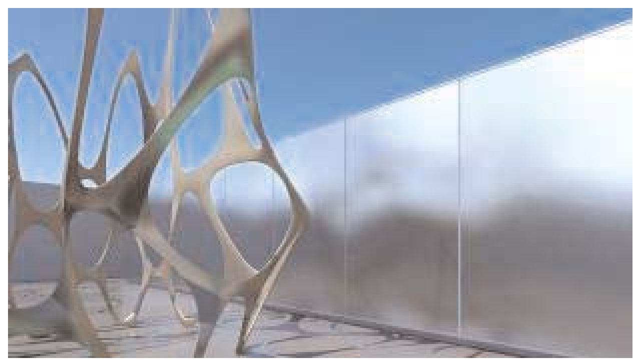
Assuming that the configurable defaults are set to Design VIZ/mental ray, using Sun and Sky requires just a few simple steps:

1. Create a geometric shape
2. Add a daylight system (the mental ray defaults use the new mr Sun and mr Sky)
3. Apply the sky shader to the background. (You are prompted to do so when you create the daylight system)

4. Enable the ‘Log Exposure’ control (and enable it for environment maps), since the system is working with true high dynamic range (HDR) values, which offer great results for both lighting and reflections
5. Enable Final Gather
6. Render

The sky shader contributes to the blue gradient and provides illumination from the sky dome. The sun variable illuminates the scene as if it were a directional light, including the option to use soft shadows, which were not previously available for directional lights. Sky features are mappable; for example, you can add clouds.




Outdoor scene illuminated by the sun and sky system. The background, all lighting, and reflections were procedurally generated by the Sky shader.

Illuminating an Indoor Scene

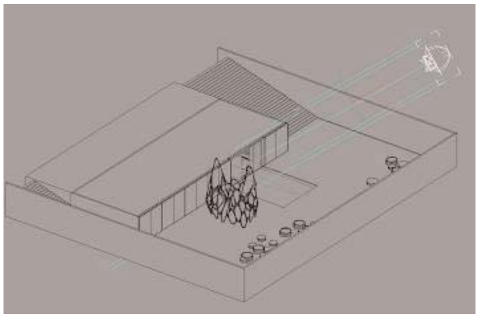
The new Final Gather methods and photon compactification and target enable workflows where the sole light source is outside a building (daylight system), illuminating an indoor scene through windows, just as in real life.

Indoor scene illuminated with sun and sky only. © 2007 Electric Gobo / Karcher, www.electricgobo.com

Photon Target

In the past, photon emission could create problems with sunlight. Imagine you're rendering an interior shot that's in the middle of a city. To get a few photons to enter through the window of the interior you're rendering, you would have to flood the entire city with millions of photons, and even then, few photons would find their way through your window. the mental ray 'Sun's Radius' parameter lets you limit the photon source.

Aiming the photon target at the window prevents photons from getting lost without contributing to the scene.



Advantages over HDR Maps

Using large HDR maps in the background has the following drawbacks:

- Since many architectural renderings are meant for high-resolution prints, HDR environments must be extremely large to avoid pixelization. Large HDR environments can cause memory problems.
- HDR maps don't change color with the sun position and therefore provide only one static mood. The dynamic mr Sky offers an unlimited range of moods.
- The mr Sky shader generates a procedural HDR gradient that consumes virtually no memory and does not increases render time.

© Electric Gobo / Karcher, using procedural cloud map created by Jeff Patton

The mental ray daylight system allows all parameters to be mapped, as in this example with a procedural cloud texture.

Exposure Control

Physically based rendering requires exposure control, also called tone mapping. *Tone mapping* is the procedure of mapping a numeric lighting intensity in HDR from the scene into an RGB value of the pixels in the rendered frame.

Why It Is Required

Physical light intensities range from zero to numbers approaching infinity in bright sunlight. The range of contrast available on display monitors is limited compared to this dynamic range, and common image formats are even more limited: TIF and JPEG images are eight-bit images, ranging from a value of zero for black to 255 for white. In these files, white can only be 255 times brighter than black, a fraction of the range in the real world. Tone mapping helps compensate for the difference in range.

Here are a few examples of real-life scenes measured with a luminance meter:

Sky luminance at horizon and zenith:
2600 cd / 360 cd / m2.

Luminance on the leaves: 500 cd / m2.

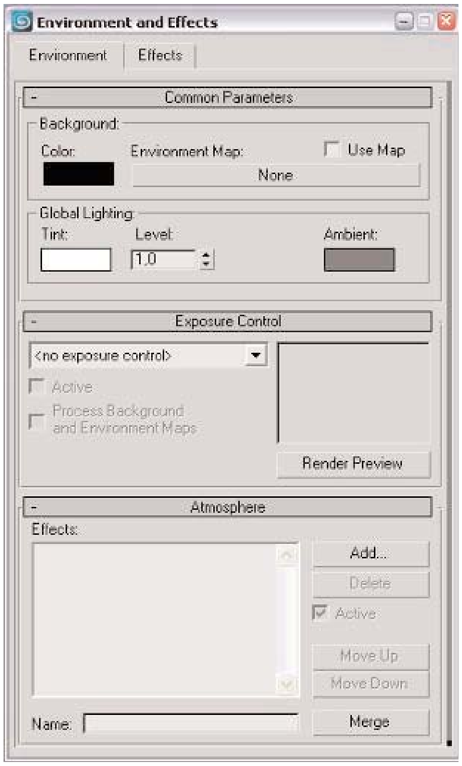
Moonlit backyard, luminance on the roof of the garage:
0.22 cd / m2.

Kids' play set luminance (brightest): 0.1 cd /m2.

Assuming that the rendering engine can use real-world units for light sources (lumens, candela, or lux at distance) and real-world units for materials (reflectance), the resulting images will necessarily be beyond the range of what a monitor can display.

Therefore, it's necessary to compress the calculated image (ranging from zero to infinity) into a displayable image (ranging from zero to 255). This process is called *tone mapping* or *exposure*.

To enable exposure control in 3ds Max, use the 'Environment and Effects' dialog box:



When you change the brightness and contrast controls, the light levels of your scene don't change; only the aperture of your camera does. This is far better than adjusting each light source in a scene one by one. If you want to shoot a photo, you would be more likely to close the diaphragm than wait for the sun to set. The exposure controls control light in the same way.

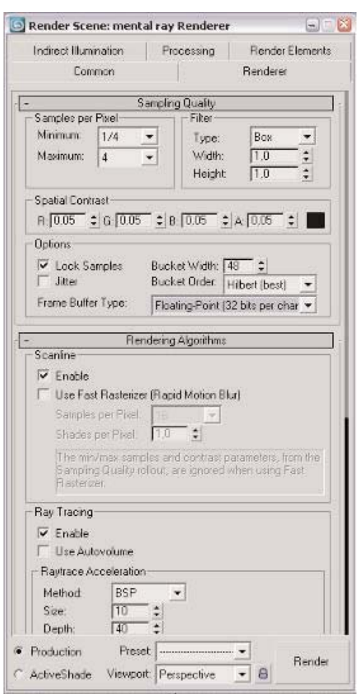
The image on the left is exposed toward the inside of the room, and the image on the right is exposed toward the outer courtyard. Both are correct; the direction of the exposure is up to you.

Rendering without Exposure Control
If you prefer not to use the exposure control plug-in, you can render your image in 32-bit format and control the tonal range using HDR Shop, Autodesk® Combustion® (release 4), Autodesk® Toxik®, or other software.

To render an image without exposure control:

1. Set the 'Exposure Control' to 'Logarithmic' and clear the following check boxes:

2. Enable '32-bit rendering' with mental ray:



Save to a PIC or EXR file (both support 32-bit data). To select specific HDR values, right-click the frame buffer.

Materials, Colors, and Reflectance

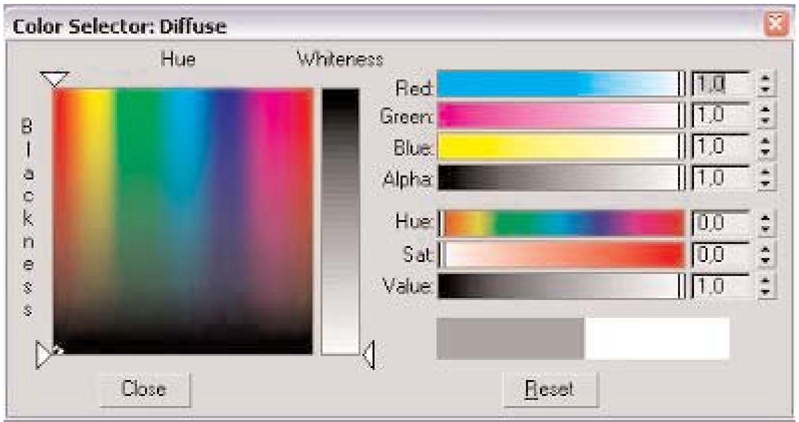
Understanding Reflectance
No matter which type of material you use, the amount of light bounced back to the scene has a direct relation with the material's color. For example, a white wall reflects more light than a dark gray wall. A dark gray wall in sunlight reflects more light than a white wall in a dim room. This is the behavior of diffuse reflectance, not to be confused with glossiness (for glossy or matte finishes). All indirect light bounces off surfaces in a diffuse (or lambertian) manner in all directions. In contrast, directed bouncing light, such as the pattern of a mirror in sunlight, is called *caustic reflection*, and is rarely needed in for architectural renderings.

Understanding Diffuse Reflectance

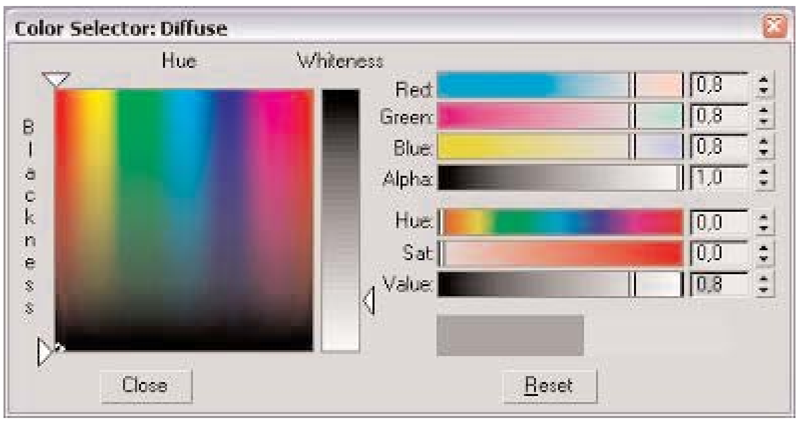
A common mistake is using a color that looks good onscreen (in the color picker or the material preview). These colors are usually too bright for the global illumination renderer, resulting in overly saturated images that are incorrect from a physics point of view. To get a better feel for colors in images, try using the 'Pick Color' tool on a digital photo. You'll find that almost every color is less saturated in an image than in the mind's eye.

Typically, a white wall would not reflect more than about 85 percent of the light it receives. Therefore, the RGB color should not be more than 0.85, 0.85, 0.85 (float colors) or 217, 217, 217 (integer colors).

To select the desired color, select the tint (Hue) of your material and then rely on the "V" value, which usually closely matches the reflectance of your material.



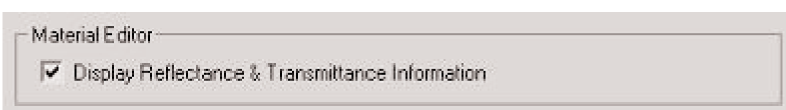
This is an incorrect color for a white wall: the rendering engine would interpret this as 100 percent reflective, which is impossible in the real world. No light absorption will happen in the lighting calculation of the renderer, and your scene would get flooded with light bouncing around forever and flattening out all contrasts.



This color reflects about 80 percent of the received energy.

Enable the Reflectance Information in the 3ds Max Material Editor
The 3ds Max Material Editor can evaluate the reflectance and transmittance of most materials.

Enable this feature by choosing Customize | Preferences | Radiosity | Display Reflectance Information in the Material Editor. To see the effect, close and restart the ‘Material Editor’.



Be sure to watch the values displayed in the ‘Material Editor’. These crucial values affect the results of your global illumination solution. A material that reflects too much light will over saturate your image and violate the rules of physics.

Typical Material Reflectance

The following table lists the typical reflectance of common materials. Use it as a starting point.

Material	Minimum	Maximum
Ceramic	20%	70%
Fabric	20%	70%
Masonry	20%	50%
Metal	30%	90%
Paint	30%	95%
Paper	30%	70%
Plastic	20%	80%
Stone	20%	70%
Wood	20%	50%

Reflectance table

Paint and Reflectance

Paint manufacturers usually indicate the average diffuse reflectance of all their colors. However, don't confuse reflectance with the finish, such as eggshell, flat, or semi gloss, which is more descriptive of specularity.

Look for something like "PR XX" in the back of color selection swatches.

Be careful with color books provided with software packages or on the web. Several software packages provide color books based on manufacturer content. For example, the Adobe® Photoshop® application provides Pantone® colors, and AutoCAD provides RAL and DIC colors. You can even find color books from paint manufacturers such as Benjamin Moore and Para.

However, these colors are not defined with global illumination rendering in mind. They are approximations based on display, lighting conditions, and gamma settings, making them unreliable with GI engines.

Picking a Pantone color in AutoCAD or Photoshop software, for example, and assuming that the GI renderer will process it correctly is a mistake. Using a Pantone color supplied by a client may be better than eyeballing it, but be aware that you are not running a physical simulation. Check the rules in this document to make sure your approximated color does not exceed reflectance values from the real world. Darken the color if necessary.

Estimating the Color and Diffuse Reflectance of a Material

The best way to measure a color is by using a spectrophotometer. You can then derive a correct RGB equivalent that makes sense for the measured data. Unfortunately, this is not an easy process.

However, there are other relatively reliable techniques for obtaining the color of a material. These methods involve

- Using a light meter to measure the reflectance of a surface
- Photographing or scanning materials using calibrated devices and comparing colors against known or calibrated sources such as Macbeth colors charts

For a complete description of these methods, see *Rendering with Radiance* by Greg Ward Larson and Rob Shakespeare for a detailed chapter on the topic.

Meeting Client Expectations

You needn't be an expert in photometrics to work with mental ray in 3ds Max. You and your client can correct important colors as throughout the project. Although you should always look for a physical way of working, the bottom line is that some colors, such as those used in logos or packaging, should correspond exactly to the client's specifications. The client in this case will not care if it is rendered physically or done in postprocessing, as long as it matches perfectly in print. A useful way to prepare for emergency corrections is to render out black and white masks for crucial objects in the scene to use as selections in image editing software. Communicate clearly and regularly with the people printing your renderings to get the results you need for a final presentation.

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Textures and Reflectance

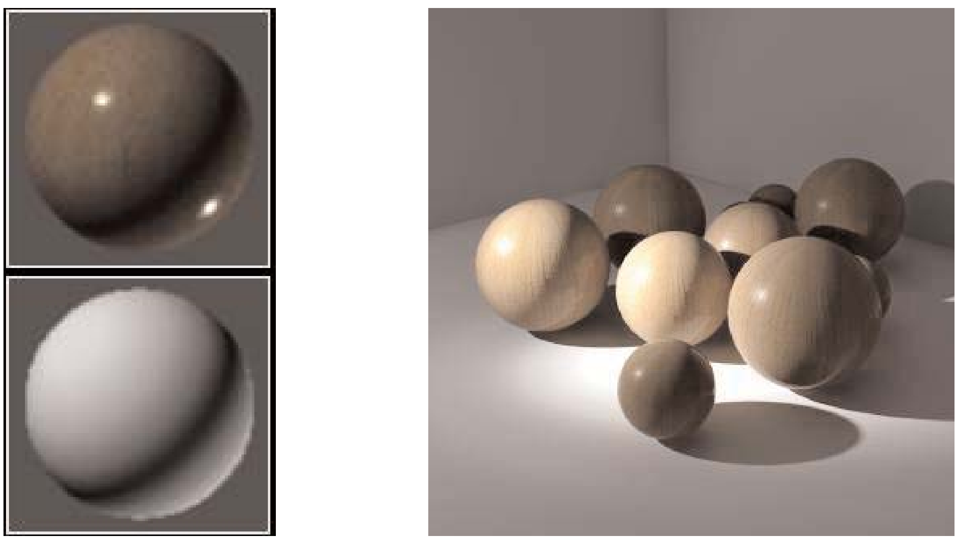
Suppose you took a picture of a brick wall or wood and want to use it in your material as a texture. You need to keep a few things in mind:

- The colors are the result of a lit material, whether lit by the flash of your camera or your digital scanner. Therefore the raw texture requires some calibration to reflect the correct color: it usually needs to be toned down a bit and slightly desaturated. Many digital cameras amplify reds.
- The lighting conditions when the picture was shot also influence the resulting color. For example, a cloudy day will tint the environment a bluish color. Incandescent lighting will tint the environment a yellowish color. Avoid photographing images in bright sunlight, as this will fix a particular light source direction (light from the sun) into your texture, which will look odd if used in a scene that is lit differently.
- Your camera or scanner usually embeds gamma information in the images.
- Use a long lens to avoid pinching, which causes problems when you try to tile the image in your image editing software. This is especially true for textures with a pattern structure, such as tiles.

To resolve these issues, you must compensate for these situations:

- Ensure that the white balance of your camera is properly set. Calibrate it with a piece of white paper or a reference card.
- Rescale the values of the pixels in an image editor or directly in 3ds Max to reduce the effect of lighting when the picture was taken.
- Clear the 'Show End Result' check box in the Material Editor to make sure that the reflectance indicator evaluates only the texture and not the entire material.
- Reduce the RGB level until the reflectance of the texture is within a reasonable range (see table earlier in this section).

This user adjusted materials to look right in the viewport: The map is 100 percent saturated, and the room 100 percent white. The result is that too much light is reflected, creating a washed-out look. It appears to have an additional light source instead of a single spot.



This user used the rough values from the reflectance table above as a starting point. The wall looks grayish in the Material Editor, but it has 85 percent reflectance. The result is a realistic and believable image of a room lit by a single spotlight.

Setting the Right Transmittance for Architectural Glass and Windows

Because there is absorption in any transparent material, avoid making materials 100 percent transparent. For example, a typical glass pane (0.125 inches thick) transmits about 90 percent of the visible light.

A windowpane on a curtain wall system or in a house is usually made of several layers of glass. Combined, the typical transmittance of the visible light ranges from about 75 percent (double glazing) to 60 percent (triple glazing).

In 3ds Max software, this means the transparency color must be set to attenuate the light while taking into account all the layers that are traversed by the light rays.

Follow these steps to determine transparency for multiple panes of glass. (Note that this is a tip for multipane glass for analysis purposes. This calculation is unnecessary for most presentation images.)

1. Determine how many glass panes you will model to represent the desired windowpane. You may model it entirely or abstract it as a single surface depending on whether your view is close or distant. With the latter you will improve rendering speed; with the former you will improve accuracy and details but slow rendering.
2. Evaluate the overall transmittance of your windowpane. If it is a double-glazed window, you need to obtain an overall transmittance of about 75 percent.
3. Since the light rays will traverse four surfaces and will be attenuated four times, you

must obtain an overall transmittance of 0.75.

Use the following formula to determine the 3ds Max material transmittance for each surface:

mt = VT^(1/n)

material transmittance = mt

overall transmittance = VT

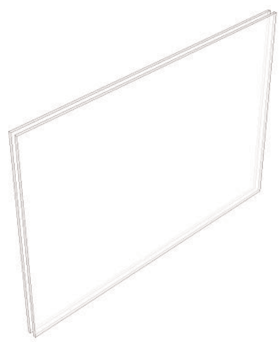
number of surfaces = n

You can use the Microsoft® Excel® Power function to perform the calculation:

mt = Power(VT,(1/n))

Example:

1. You model a double-glazing window with four surfaces.

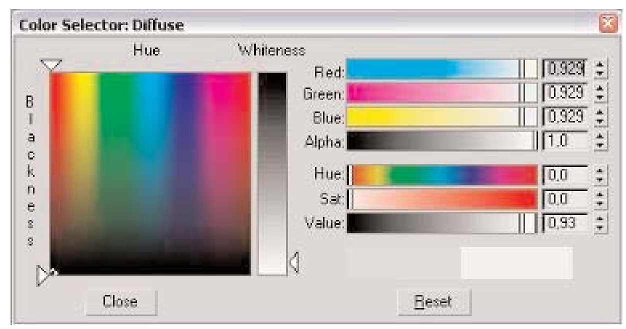


2. You want an overall visible transmittance of 0.75 (75 percent).

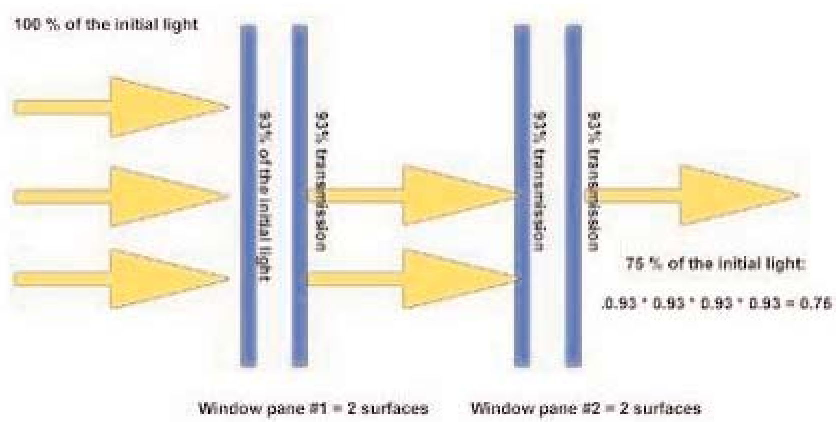
3. You apply the following formula:

   material transmittance = 0.75^(1/4) = 0.93

4. Your glass material must transmit 93 percent of the light.



This process is explained as follows: 100 percent of the light attenuates by 7 percent (93 percent transmittance) for each surface it traverses.



Light Filters (Theater Light Gels)
Similar to glass, light filters also affect the amount of light that is transmitted. Use the same technique as you would use for diffuse reflectance or transmittance to set the right color.

Refraction, Glass, Water, and Liquids

Realistic rendering of glass, water and liquids is explored using the Arch + Design shader

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Colored Glass

The tips in the previous section work well for clear glass but not necessarily colored glass. Many shaders set the transparency at the surface of the glass, which works well if you simply set a refractive color to some value, such as blue. This works perfectly for glass created with the 'Thin-Walled' option turned on. But for solid glass objects with varying thickness, this method does not accurately represent reality.

The example on the right was created using the Arch+Design material.

Refractive color set to orange.

The problem is evident: the bowl is not tinted according to the thickness of the glass, but rather according to the number of surfaces the light passes through. In reality, when you look straight through glass, it appears less tinted than when it's viewed tangentially through the sides of the bowl.

Consider a light ray that enters a glass object. If the color is at the surface, the ray is colored somewhat as it enters the object, retains this color through the object, and receives a second coloration (attenuation) when it exits the object.

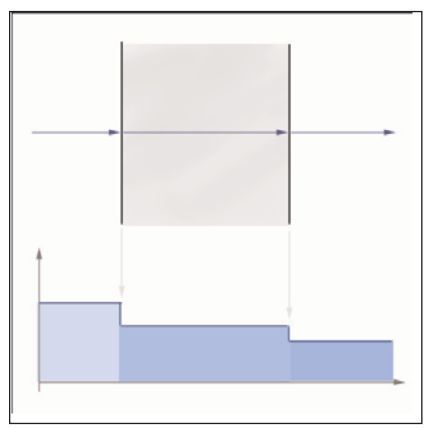
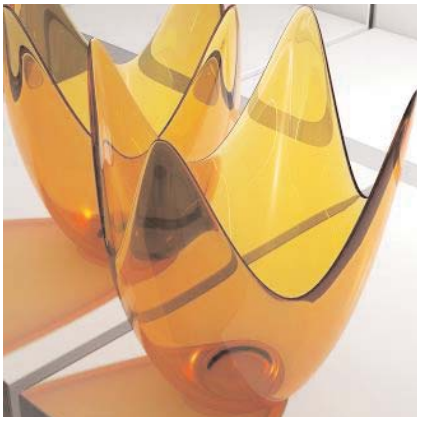


Diagram for glass with color changes at the surface.

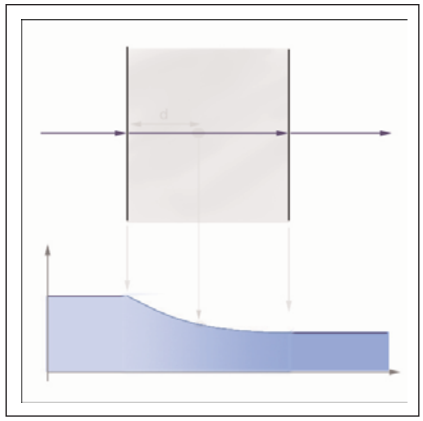
In the preceding illustration, the ray enters from the left. At the entry surface it drops in level and gets slightly darker (as shown at the bottom of the graph). It retains this color throughout its travel through the medium and drops in level again at the exit surface.

For simple glass objects, this is sufficient. For glass using the Thin-Walled option it provides correct results, but for complex solids it does not. It is especially wrong for negative spaces inside the glass because the light rays must travel through four surfaces instead of two, resulting in two extra steps of attenuation at the surface.

In real colored glass, light travels through the medium and is attenuated on the way through the object. In the Arch+Design material this effect is accomplished by using the 'Color at Max Distance' option, and setting the Refractive Color to white = neutral. This is the result:



Color at Max Distance set to orange.



d = Max Distance where attenuation is Color at Max Distance of the Arch+Design material.

This result is clearly superior; the thick areas at the sides of the bowl are much deeper orange than the thin areas. The following diagram illustrates the process:

The ray enters the medium and is attenuated throughout its travel path. The strength of the attenuation is such that precisely at the Max Distance (d in the figure), the attenuation matches that of Color at Max Distance (that is, at this depth the attenuation is the same as that received immediately at the surface with the previous model). The falloff is exponential, so that at double Max Distance, the effect is that of Color at Max Distance squared, and so on.

There is one minor trade-off: to correctly render the shadows of a material using this method, you must either use caustics or make sure mental ray is rendering shadows in 'Segment Shadow' mode. Using caustics naturally gives the most realistic shadows (the preceding image was not rendered with caustics), but it requires that you have caustic photons enabled and a physical light source that shoots caustic photons.

On the other hand, the mental ray segment shadows have a slightly lower performance than the more widely used Simple Shadow mode. In Simple Shadow mode, shadow intensity does not properly account for the attenuation through the media.

Water and Liquids

Water, like glass, is a dielectric with an index of refraction (IOR) of 1.3-1.5.The same principles that apply to glass also apply to solid bodies of water. Colored liquids use the same principles as colored glass, and so on.

To create a liquid in a container, it is important to understand how the Arch+Design material handles refraction through multiple surfaces compared to how refraction happens in the real world.

What is important for refraction is how to make the transition from one medium to another with a different IOR. Such a transition is known as an *interface*.

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For water in a glass, as an example, imagine a ray of light traveling through the air (IOR = 1.0, equal to no distortion) entering the glass, and refracted by the IOR of the glass (1.5). After traveling through the glass, the ray leaves the glass and enters the liquid—

that is, it passes an interface from one medium of IOR 1.5 to another medium of IOR 1.33.

One way to model this in computer graphics is to make the glass one separate, closed surface, with the normals pointing toward the inside of the glass and an IOR of 1.5, and make a second, closed surface for the beverage, with the normals pointing inward and an IOR of 1.33, leaving a small "air gap" between the container and the liquid.

While this approach works, there is a problem: when light goes from a higher to a lower IOR, there is a chance of an effect known as Total Internal Reflection (TIR). This is the effect you see when diving into a swimming pool and looking up. The objects above the surface can be seen only in a small circle straight above; anything below a certain angle shows only a reflection of the pool and things below the surface. The larger the difference in the IOR of the two media, the greater the chance of TIR.

So in this example, as the ray goes from glass (IOR = 1.5) to air, there is a high probability of TIR. But in reality, the ray would move from a medium of IOR = 1.5 to one of IOR = 1.33, which is a much smaller step with a much smaller probability of TIR. This will look different:

Correct refraction (left) versus the "air gap" method (right).

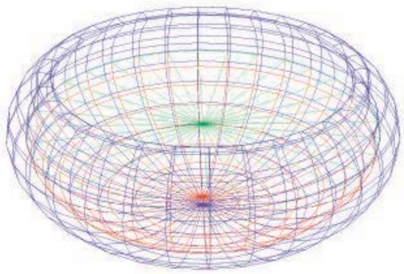
The result on the top is the correct result, but how it is obtained?

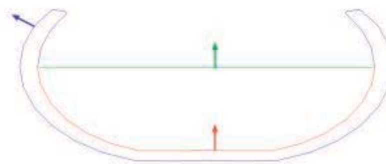
The solution to the problem is to rethink the modeling, not in terms of media, but in terms of interfaces. This example has three different interfaces, where we can consider the IOR as the ratio between the IORs of the outside and inside media:

- Air-glass interface (IOR = 1.5/1.0 = 1.5)
- Air-liquid interface (IOR = 1.33/1.0 = 1.33)
- Glass-liquid interface (IOR = 1.33/1.5 = 0.8)

In the most common case of an interface with air, the IOR to use is the IOR of the media (since the IOR of air is 1.0), whereas in an interface between two different media, the situation is different.

To correctly model this scenario, you then need three surfaces, each with a separate Arch+Design material applied:





These are the three interfaces for a liquid in a glass:

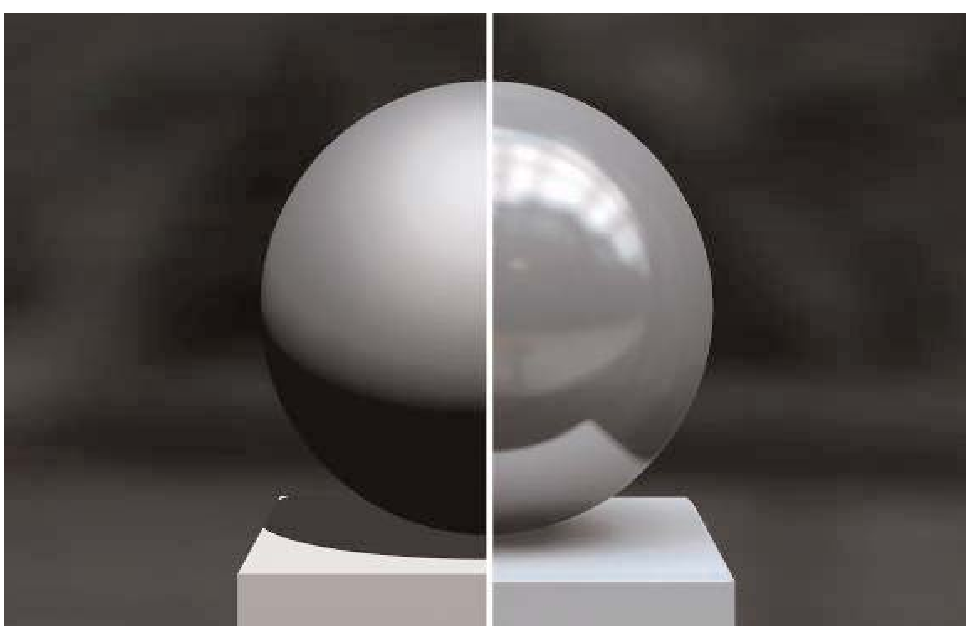
- The air-glass surface (blue), with normals pointing out of the glass, covering the area where air directly touches the glass, having an IOR of 1.5
- The air-liquid surface (green), with normals pointing out of the liquid, covering the area where air directly touches the liquid, having an IOR of 1.33
- The glass-liquid surface (red), with normals pointing out of the liquid, covering the area where the glass touches the liquid, having an IOR of 0.8

By setting a suitable ‘Max Distance’ and ‘Color at Max Distance’ for the two liquid materials (to get a colored liquid), the top image is the result.

Architecture and Design Material

You do not have to use the mental ray material. In fact, you should not use the mental ray material until you are experienced with mental ray concepts. The mental ray material is a very flexible material, mainly used for special effects or tweaks. There is seldom a need for it in an everyday architectural rendering

3ds Max now includes a new material dedicated to photorealistic renderings called the Architecture and Design Material (mr Arch+Design). This is the best choice for creating architectural renderings. It is easier to use and provides many advanced controls compared to the 3ds Max Architectural, Standard, Raytrace, or DGS materials. This material uses high-quality shading models and gives control over several parameters that are useful for photorealistic architectural renderings.



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High-end users can access the full complexity of the mental ray material, but beginners can still get great results using just a few controls.

While the complete UI seems complex at first, you'll find all the important controls at the top. By default, the advanced controls tab is closed.

3ds Max Integration

The new material is a real 3ds Max plug-in. It works well with the 'Reflectance/Transmittance' indicator and 'Show Map in Viewport' command. The diffuse color is also reported correctly in the viewport.

Preset Based

The preset (Templates) is inspired by the Architectural material. However, the technology is better; the preset only invokes a script located in the /plugCfg/mrArchMtl/ folder. There are no limitations on the function of that script—it can do anything, even something complex enough to fill in the map slots with procedural maps. Now, you can get presets that really look like tiles or wood.

Mappable Parameters

By adding maps to parameters, instead of just changing values, you can achieve interesting effects for more complex surfaces. The following example uses mapped color and glossiness. In combination with the Blend material, virtually any composite materials can be rendered.

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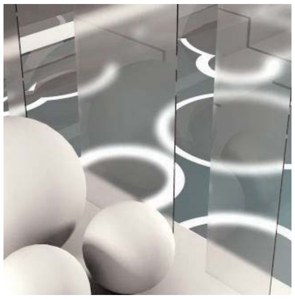
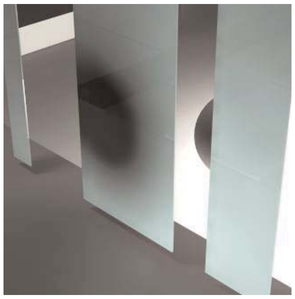
Physically Based

This shader is built for GI computation and conserves energy. This means that a translucent piece of paper cannot reflect and transmit more than 100 percent of the energy it receives, as is the case in real life. This is important, since many users, especially beginners, are unaware of the relationship between the diffuse and the specular values of a material in the real world. In the Arch+Design material these values are locked, which gives far better results.





Frosted Glass and Blurred Reflections
3ds Max users often want to reduce glossiness to blur reflections or refractions independently. This control is especially useful in architectural renderings; for example, you can use it to create a glass pane that's frosted on the back, so you get glossy refraction and specular reflection in a single material.

Translucency
The Arch+Design material has a translucency option. Closed objects can provide light scattering through the material, including backside shadows, useful for lampshades, sunlit curtains, opaque Perspex, or heavily frosted glass.

Anisotropy
Anistrophy is the difference in a physical property (absorbance, refractive index, density, etc.) for some material when measured along different axes. In the field of computer graphics, an anisotropic surface will change in appearance as it is rotated about its geometric normal

The Arch+Design material has anisotropy controls and is fully mappable to create complex effects such as brushed steel.

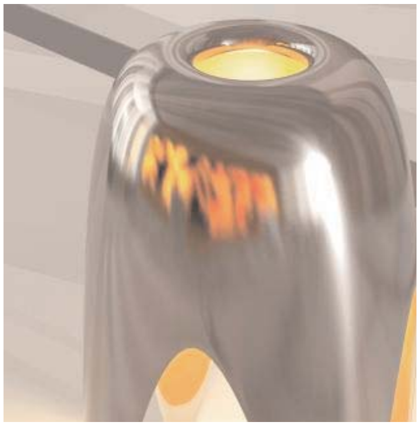
Interpolated Reflections and Refractions

Interpolating reflections and refractions is an optimization trick that increases the speed of rendering with a reduction in accuracy. Its main use is for glossy floors or shiny metals, where accuracy is unnecessary.

Some tests have shown a tenfold speed increase in renderings with acceptable quality. The quality largely depends on scene contrasts—in low- and mid-contrast scenes you get quality that is hard to distinguish from a rendering without interpolation, yet the image renders quickly and efficiently. In high-contrast scenes, as with the daylight system and its HDR sun, interpolation might cause artifacts due to different sample values. In those cases, you might need to turn off the Fast Glossy option.

No glossy reflections—100 percent render time.

Glossy reflections—200 percent render time.



Interpolated glossy reflections—160 percent render time.

Reflect Highlights + FG Only
This option disables ray-traced reflections and uses the Reflectivity/Glossiness spinners for a simpler and faster Phong highlight. If the option is turned on, the Arch+Design material is not only looking up light sources to create reflections, but, as well, the Final Gathering solution in the scene. This feature is new to 3ds Max. The effect looks similar to a very dull glossy reflection, but at the cost of almost no render time. So, if you have a brightly lit wall, the material will respond to that. If you imagine a huge auditorium with glossy leather seats, the power of this feature becomes obvious.

What looks like a smooth glossy reflection is an FG highlight. It looks convincing for certain surfaces and requires almost no additional render time.

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Client: ERCO Leuchten GmbH, www.erco.com rerendered by Zap Andersson, mental images

Final Gather Quality Multiplier/Importance Map

This optimization method enables you to specify which parts of an object receive more attention from the Final Gatherer at render time.

You can do the following:

1. Render a scene with Final Gathering.
2. Identify render artifacts caused by FG.
3. Paint a black and white map where you want to perform more sampling in Photoshop.
4. Reuse that map as screen map in the material.
5. Rerender.

FG will do more sampling in the identified areas.

Alternatively, you can simply use the FG Quality spinner locally on one material. An example might be a simple museum space with large, clean walls. For those kinds of scenes the global FG settings can be set low and still produce high quality. For detailed objects in the room, such as a statue, the FG quality can be raised for that individual object.

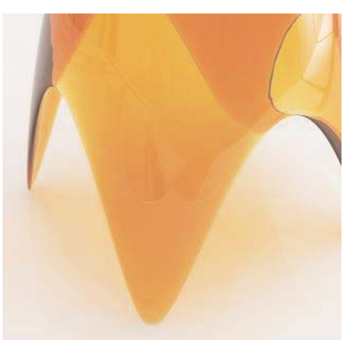
A very coarse Final Gathering solution

The local FG Quality parameter of the orange ball has been raised. This is a good way to push out detailed objects against plain walls.

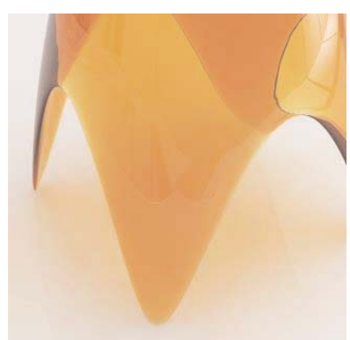
Ambient Occlusion

The popular Ambient Occlusion shader has been rolled into the material. Note, however, that the techniques have been optimized, so they're faster and better than the existing shader, especially for the Arch+Design material.

The main use for ambient occlusion is to improve the lighting effects on tiny details where objects intersect and remove floating object artifacts. In the past, these details required very high FG settings. Ambient occlusion produces similar or better results in a fraction of the render time.



Without Ambient Occlusion: notice how the object seems to float above the floor.



With Ambient Occlusion: note the "Contact Shadows" between the object and the floor. This version required just a few seconds of additional rendering time.

Round Corners Effect

This feature of the mr Arch+Design material is a subtle effect that helps remove the computer look of renderings.

In the real world, edges are not perfectly angular and sharp. There is always a little curve on every corner. Bent metals, molded plastics, cast metals, glass panels, and wood panels all have what we commonly call right angles, but in reality, there is always a bevel. In architectural renderings, this is especially important for furniture. This is where the Round Corners feature comes in handy, saving a lot of time and clutter, creating beveled edges on all furniture and similar geometry. This effect can be achieved with very little extra render time.

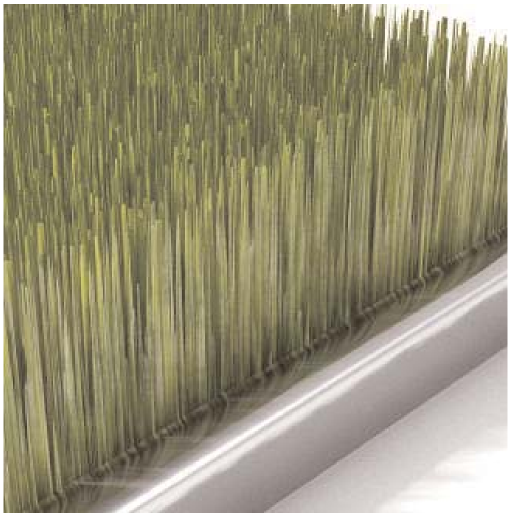
The Round Corners feature is an effect and does not alter the geometry itself. It is simply perturbing the normals at render time; technically, it is a bump map. Therefore, shadows still show geometry as if they had sharp edges.

The edges are too sharp for a realistic impression of a table.

The same geometry with the Round Corners shader. This version includes geometry fillets—which would be tedious to create for larger projects—without noticeable additional render time.

Displacement Mapping

Displacement mapping uses input similar to that used for bump maps, only it does not imitate a surface relief, but creates according geometry. Displacement mapping can require a lot of memory and time, but for close-ups with grass in the foreground, it is often the best choice. For better results, consider using a Normal map. It takes some time to set up but gives great surface variation for important midground details.



Bump Mapping, Glossiness Only

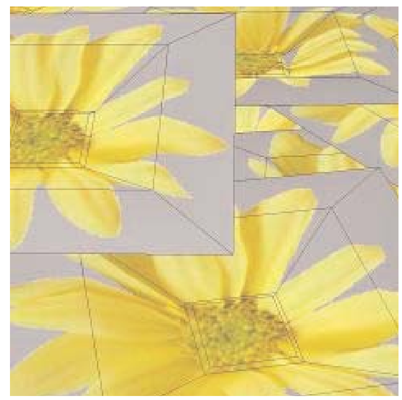
The material offers the option to do bump mapping on glossiness only. The main use of this option is to simulate thick varnishes where the bumps are only in the varnish layer and not on actual geometry, as on many floors.

Indirect Illumination Bump Mapping

Final Gathering can create bump mapping based on indirect illumination, which gives additional details in smoothed-out, dull shadow areas.

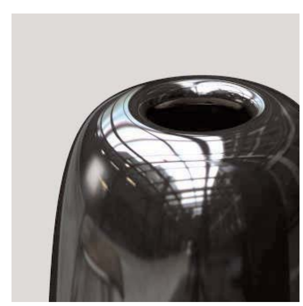
Cutout Mapping

This new feature offers results not achievable with other mental ray shaders in 3ds Max. If your project requires many arbitrarily shaped holes or cutouts on geometry—for example, on perforated metal, grates, or ornamental railings or fauna—you will probably not model them. The old technique of using an opacity map to make areas appear invisible to fake the detail always had the problem of the same result with specular and other channels, as well as not having the holes to still render reflections. The new cutout option resolves these problems: it does not shade anything at all in those areas you cut away with a map.



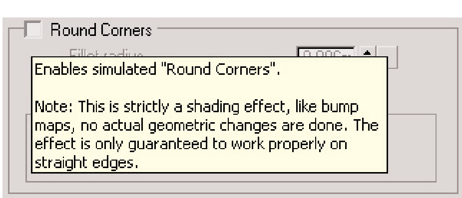
Separate Environment Channel

3ds Max makes it easy to separate the environment map for reflection and refraction from the background, which helps tremendously with high-end compositing or quick client previews for product visualization in HDR environments. You can set an environment locally to override the scene environment for reflections and refraction. This feature can be accessed in both the Arch+Design material as well as the mental ray Physical Sky shader.



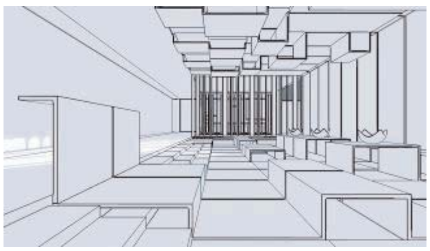
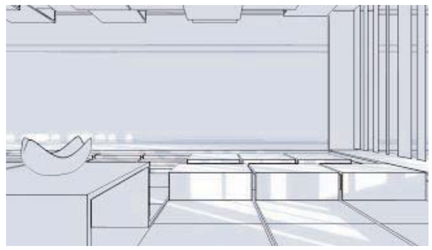
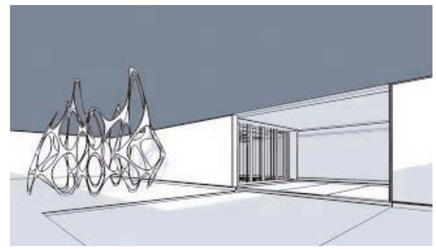
Tooltips

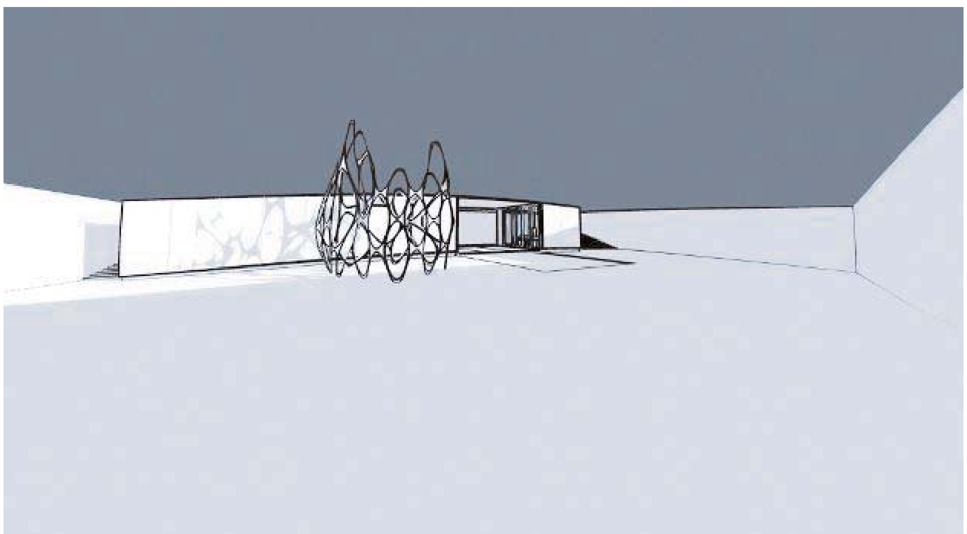
Hold the cursor over any interface element in the Arch+Design material to see helpful tooltips.



Toon Shading for Architectural Rendering

Sometimes a design in concept stage needs to be presented in an abstract and nonphotorealistic way. This is especially true for large-scale urban designs. 3ds Max and mental ray make this kind of output easy. You can do this in one of two ways: you can use either the standard Ink 'n Paint material or mental ray software's built in nonphotorealistic renderer (NPR) by enabling both Contours in the Rendering tab and the mental ray Connection Rollout of a material. Both do a good job, although the mental ray functionality is more flexible and offers more options, such as rendering directly into an EPS file with vectors. However, this approach needs more parameter setup to get the best results.



Toon/Contour Rendering can be combined easily with other shaders and effects.

Performance Tuning Tips for Global Illumination Parameters

Use a Layered Approach

In 3ds Max, use the following strategy:

- Use photons to quickly distribute the light energy, with a rough solution that covers large details of about six inches wide. The solution should be close to smooth, though it does not have to be perfect. It is important that there are no obvious dark areas that did not get any photons.
- Enable Final Gather to capture medium details that are about two inches wide. Use the presets as a starting point.
- Use ambient occlusion to capture small details that are a few millimeters wide.

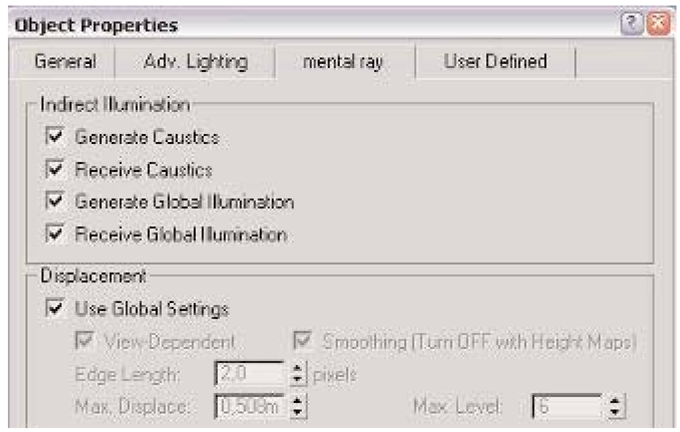
The radii are rules of thumb and may vary considerably for particular scenes.

Save Your Photons and Final Gather Maps on Disk

The result of the global illumination and Final Gather passes can be saved to disk if your light setup will not change. This is similar to saving a radiosity solution in the file. This feature is especially useful for camera animations. Final Gathering processes only the areas for which it did not find samples in the file, considerably accelerating a camera animation without sacrificing quality. Furthermore, saving samples to file reduces flickering during animations, which can happen when random samples are rendered anew with each frame.

Photons Tips

- mental ray works by counting stored photons on surfaces, not photons emitted by lights. This concept is fundamental to using photons properly. If you aim a spotlight to the sky and no surface can receive these photons, mental ray keeps emitting them forever and you get an error message in the mental ray rendering console.
- Make sure that most of your photons can actually be received by a surface.
- Lights and objects that cast caustics must be set to Generate Caustics. You can optimize a scene by switching off photon generation for tiny objects that do not contribute to the lighting in the scene, such as a pen on a table.



Optimize Photon Maps

To some extent, this method can be compared to adaptive subdivision for radiosity. It is an optimization method that merges photons that are close to each other.

For example, if within 1 square inch there are 2,000,000 photons of 10 units of energy, they will be merged as 1 photon of 2,000,000 units of energy.

This saves a tremendous amount of RAM and permits casting millions of photons in the scene without running out of memory.

The perfect use for this is the sun entering into a window, where a lot of energy and photons are concentrated on a very small area.

A lot of photons are landing on a very small area. Merging them saves a lot of RAM.

Limit the Ray Depth of Your Materials and Renderer
In architectural renderings, where you have several layers of glass and shiny floors, it may take a lot of time to render final high-resolution images. mental ray software offers many ways to reduce render time. One way is to reduce the number of reflections that the ray tracer has to do. You can set this option on the Rendering tab of the Rendering window.

In the real world, you rarely notice more than one level of reflection. For example, the image of a wall in a shiny floor may only show once, not twice. In rare cases, as with two mirrors in front of each other, you will need more than two levels of reflections.

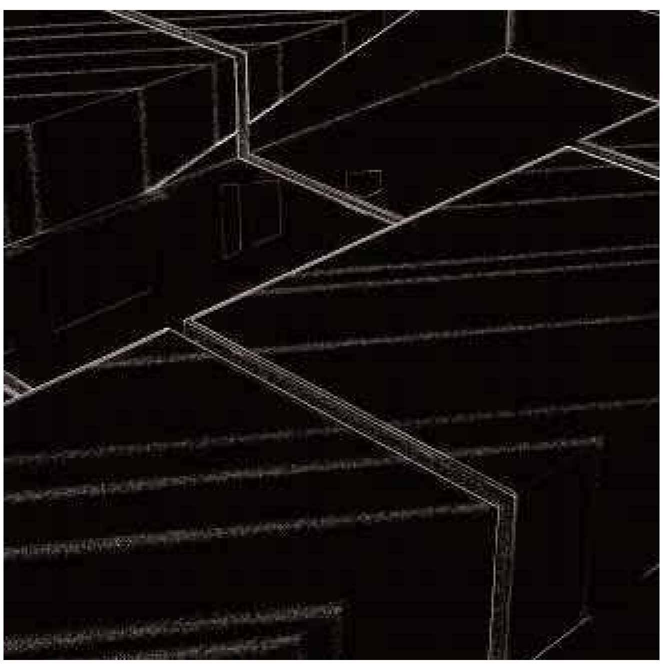
However, there are some cases where you need a higher number of rays to keep the ray from getting stuck inside the refractions:

Two refractive rays are calculated.

Eight refractive rays are calculated.

Diagnostics
Some of the previous sections covered technical settings such as Photon and Final Gathering radii and Image Sampling. You don't need this level of technical understanding to render a good image, but background knowledge about what's happening can help you track down problems or artifacts, or simply help you optimize an image to render twice as fast and with no loss of quality. To gain a better understanding of what's happening in your image, take a closer look at your scene from time to time. The best tools for this are as follows:

- The 'Last Rendering Time' display at the bottom of the screen, which shows how changing settings influences render time
- The mental ray rendering window, which reports on what mental ray is doing as it works in the background
- The 'Visual Diagnostic tools' in the 'Processing' menu in the Render window, which offer a closer look at photons and image sampling



Here the decision is made whether to use Min or Max for the Image Sampler.

Shader Sampling Versus Image Sampling
Sometimes changing the number of samples—for example, on a glossy material or an area light—influences how the Adaptive Image Sampler chooses its sampling rate. The following example shows how this works with area lighting with soft shadows, glossy reflections, and image sampling.

Generally, the quality of the area shadows computed by the ray tracer is improved by the number of samples performed at the light level. Eight to 32 sample points on a medium-sized (1 foot x 1 foot) area light work well for small images. Large area lights require more sample points, as do large images.

A small number of samples for an area light does not always mean faster rendering time. There are interesting interactions between the number of samples performed on a light and the number of samples performed by the renderer.

For example, if an area light is computed with a very low sampling rate (at the area light level), it creates noisy shadows. Because the renderer makes no distinction between geometry, textures, or shadows (everything is based on contrast), the renderer adaptively samples the small points created by the noisy shadows.

Here are a few examples:

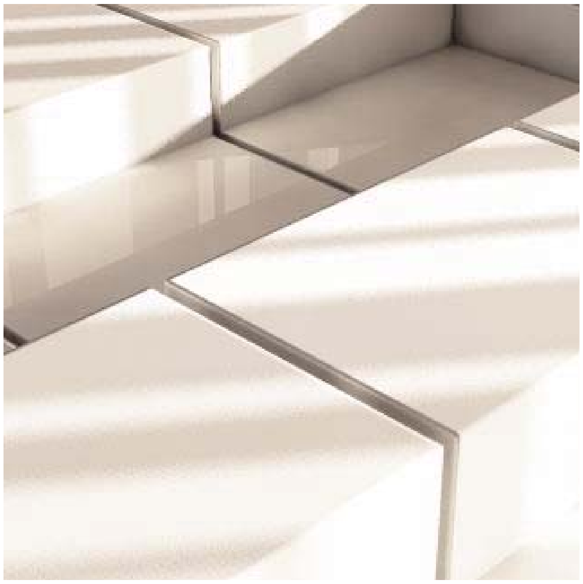


Image Sampling: 1-1/4, Shadow Sampling 2, 100 percent render time.

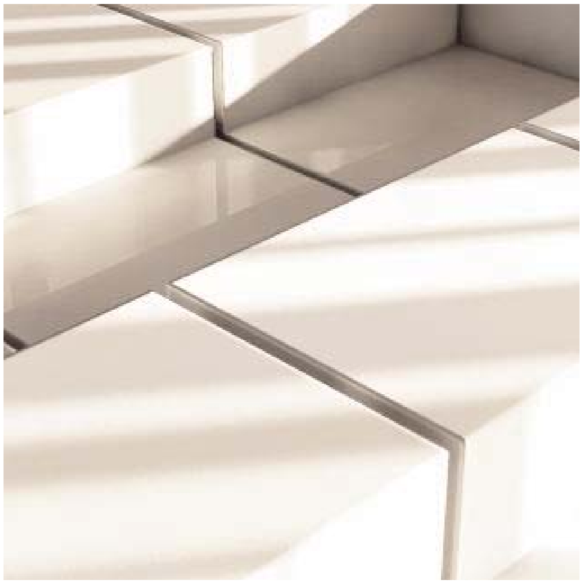


Image Sampling: 1-1/4, Shadow Sampling 64, 350 percent render time.

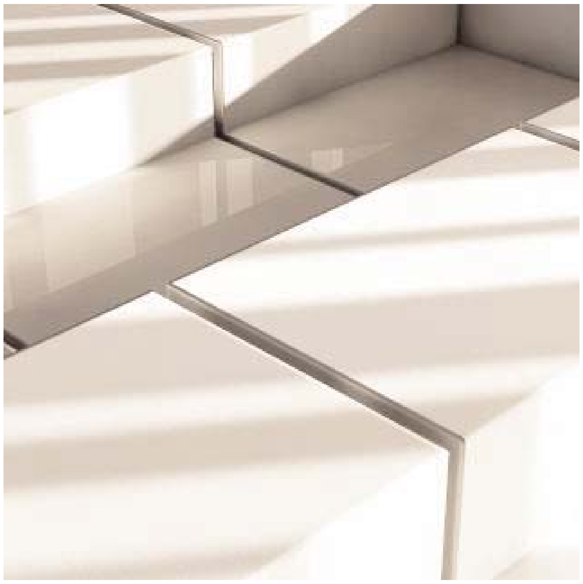


Image Sampling: 16-1, Shadow Sampling 2, 450 percent render time.

Image Sampling: 16-1, Shadow Sampling 64, 1000 percent render time.

The quality of the area shadows improves with the number of samples performed at the light level. But a high sampling rate for rendering also affects the quality of the area shadows (as seen in the first images). In this example, it appears that the image rendered with Min: 1 Max: 16 and Area Shadows with sampling rate 2 provides the best ratio of time to quality. This might vary according to the configuration of your scene—for example, fine details in a forest scene or large, smooth walls in a museum image.

Distributed Rendering
You can use mental ray to render one image distributed in parallel on several computers. This function is especially helpful for high-resolution stills, such as those used for architectural renderings.

To use distributed rendering:

1. Install 3ds Max on other computers on your network.
2. Open the Processing Panel in the Render menu.
3. Activate Distributed Render.
4. Add the computers by adding their IP addresses or network names (you only need to do this the first time).
5. Render.

You will now see all computers contribute to rendering the image. Be sure to open the mental ray rendering window to monitor how the nodes perform in detail. This feature speeds output considerably. If you experience problems with the preceding steps, you or your administrator might want to check your network settings—especially firewall settings.

Ray Falloff
mental ray is fast at shooting short rays. Rays are shot in places where the rendering needs to sample the surroundings, as with Final Gathering or Glossy Reflections. By manually optimizing the distances for a ray to look for objects, you can save a lot of unnecessary render time. For example, if you are rendering an outdoor scene with Final Gathering and glossy reflections, you might want to turn on FG Falloff. You can use the distance parameters to limit rays so they're not followed hundreds or thousands of meters into an empty environment. Set an appropriate maximum distance and the rendering will go faster, with no visible impact on quality.

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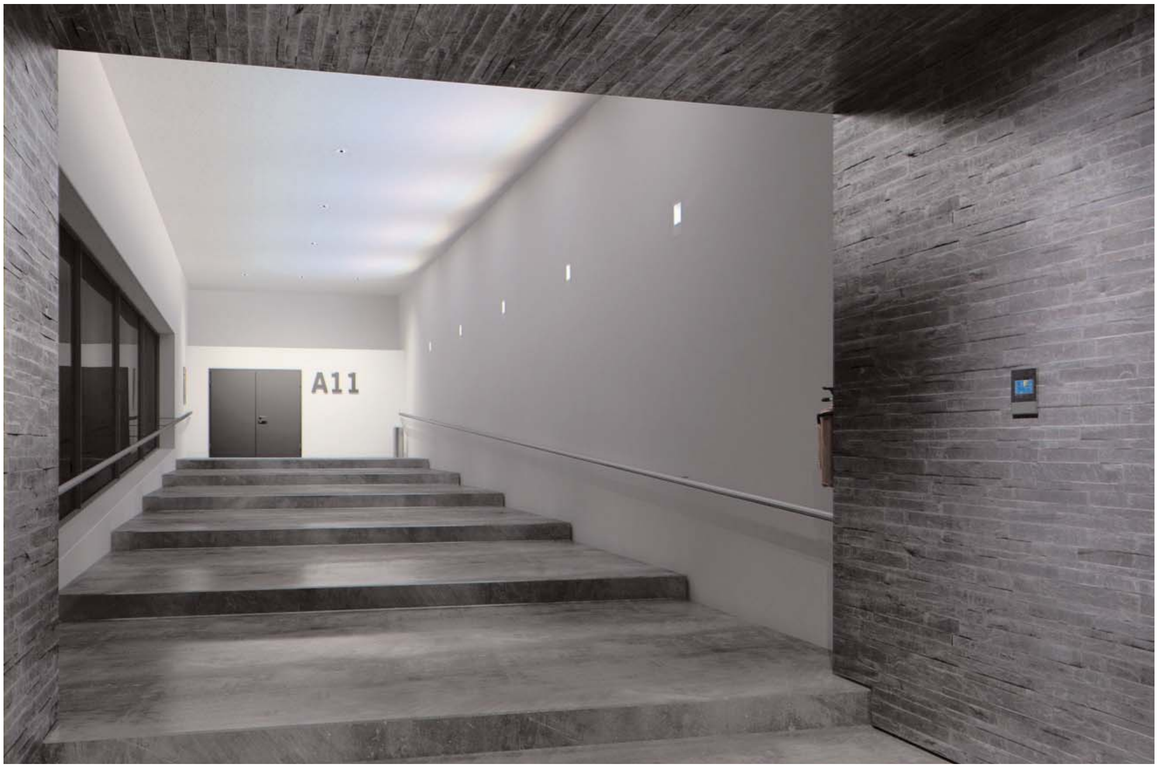

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Conclusion

Thank you for taking the time to explore this white paper. We hope this summary of the important aspects of creating photorealistic renderings for architectural visualization has helped you. For more information, please visit the 3ds Max web pages at www.autodesk.com/me and the mental ray website at www.mentalimages.com