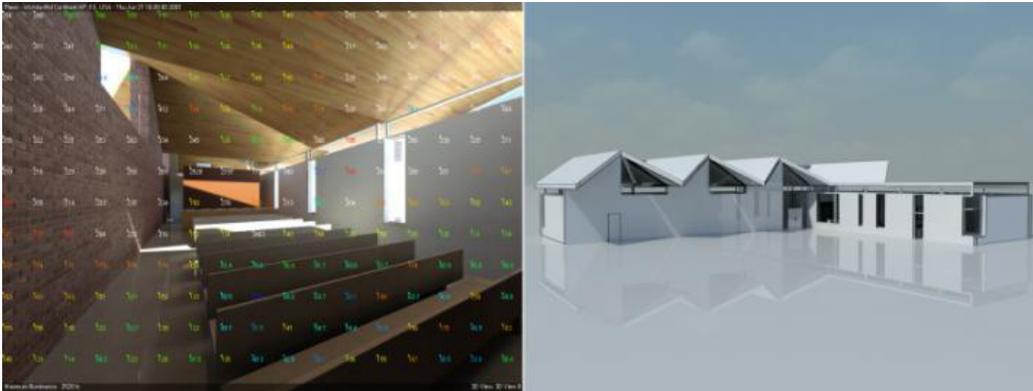


Daylight Simulation in 3ds Max Design 2009 – Advanced Concepts



Marion Landry / Pierre-Felix Breton

CONTENTS

- The effect of ground and surroundings on lighting analysis 2
- Guidelines for creating Materials and Finishes. 3
- Guidelines for your scene geometry 10
- What is Exposure Control? 12
- External Links 14
- About the Authors 15

Advanced Lighting Analysis Concepts in 3ds Max Design 2009

Summary

This document walks the reader through the various principles and workflows for carrying out an accurate daylight analysis in Autodesk® 3ds Max® Design 2009 software with the Exposure™ functionality feature. This document is an addendum to the white paper entitled “Daylight Simulation in 3ds Max Design 2009—Getting Started.”

Exposure is a key technology, exclusive to 3ds Max Design, for simulating and analyzing sun, sky, and artificial lighting in a 3D scene. Ideal for sustainable architecture projects, this powerful feature set has been designed to assist architects in evaluating light intensity in their designs. This can facilitate the evaluation of indoor environmental quality—required, for example, for LEED 8.1 certification. In addition to light metering functionality with graphical output, Exposure also features the popular Autodesk 3ds Max software sun and sky models, a quick-settings dashboard interface and an intelligent user interface for accessing the various aspects of the software used in a light simulation, such as render settings, light settings, and material settings.

The Effect of Ground and Surroundings on Lighting Analysis

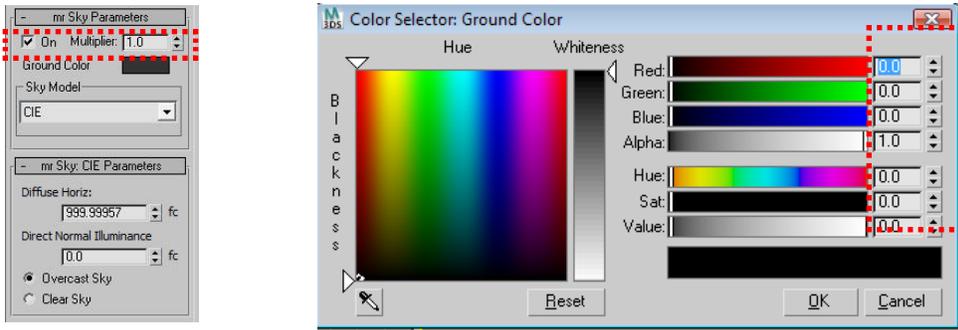
The ground has an important impact on the result of your lighting analysis. If you position a camera from the ceiling looking down and out, you will find the ground and environment surrounding your building covers a large portion of your field of view. This means that most of the light illuminating a ceiling actually comes from the ground. Accordingly, if the ground is not modeled correctly, the resulting light levels will not be correct either.

The following section discusses various aspects related to the definition of a correct ground and surroundings for simulation.

Set the Ground Color to black in the mental ray Sky

The mental ray® (mr) Sky Ground Color corresponds to the diffuse reflectance of an infinite ground plane (“virtual ground”) that is created internally by mental ray® software at render time. While the Ground reflectance is correctly interpreted by the renderer, the main problem comes from the way it bounces rays from the Sun and Sky. Internally, the “virtual ground” bounces light rays from the Sun which does not always match the Sun and Sky model you may have set in the UI. As a result, the renderer could bounce a lot more light than expected.

There is a simple workaround for this. First, set the Ground Color to black (zero reflectance). This will prevent the problem described above, as the ground will absorb all incoming light.

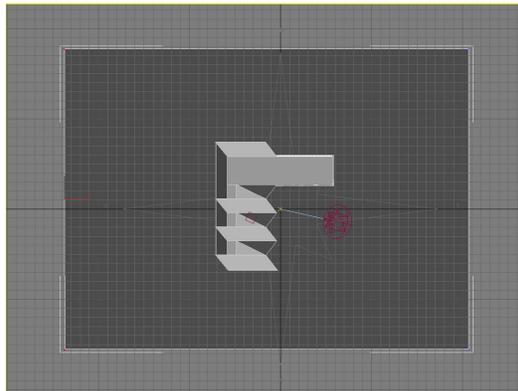


The Ground Color must be set to black Red Green Blue(RGB: 0,0,0) to prevent mental ray from internally creating incorrectly biased results.

Then, by modeling a ground plane, simply make sure the light that is bounced from it takes into account the Sun and Sky model you selected.

Create a ground plane around your building

If you don't have an accurate 3D model and reflectance information about the surroundings of your building, start with a large ground plane around your building. In other words, do not let your building “float in air.” By modeling a large surface representing the ground, you allow daylight to be reflected off the ground and into your building. In order to mimic typical ground conditions, set your ground surface to a diffuse material with a RGB color of 0.20, 0.20, 0.20 (20% diffuse reflectance).



A large surface with a diffuse material has been modeled around the building to represent the ground and allow the daylight to bounce back onto the ceiling.

Note: Be careful not to create ground planes that cross through your building. We have seen cases where the ground plane traverses the middle of an office space and this will affect the lighting reports negatively.

If you have snow on the ground, you may have to work with different ground plane material properties.

Guidelines for Creating Materials and Finishes

To produce accurate lighting analysis results, you should consider not only the light sources but the Materials definitions. For those to be correctly defined, you need to understand how the mental ray renderer expects them to be defined. The following section covers the basics of defining physically correct materials.

Note: The following section is intended to provide some initial leads on the topic. If you want to pursue it more deeply, you may want to consult the following document from the CIBSE: <http://www.cibse.org/index.cfm?go=publications.view&item=164>

The “problem”

While many graphical user interfaces allow users to specify RGB colors via color pickers, the resulting RGB value used by a simulation doesn't usually correspond to the color displayed on your computer screen. As a result, picking a color based on the appearance of that color on your screen will lead to physically incorrect outcomes.

Diffuse Color versus Diffuse Reflectance

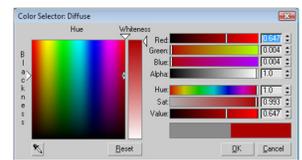
It is really about “absolute reflectivity” rather than “perceived color”

In the end, the apple will still reflect the same amount of light whether you look at it under bright sunlight or a dimly lit livingroom. Your eyes won't perceive it the same way, but that doesn't mean that the apple's physical properties have changed.

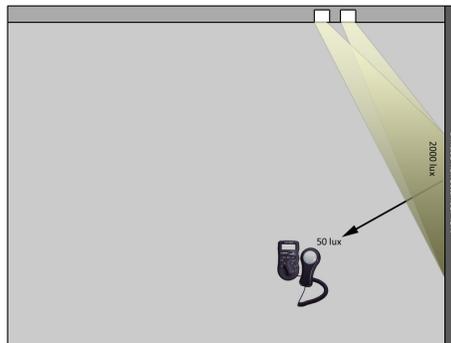
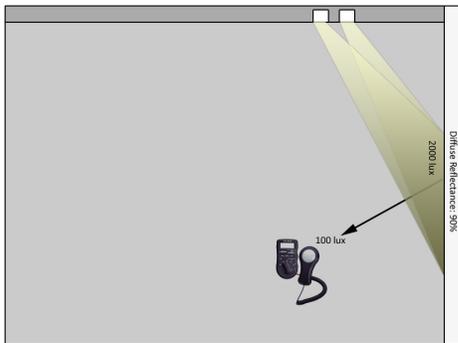
No matter which type of material you use, the amount of light bounced back on the scene has a direct relationship with the material's color. For example, a white wall reflects more light than a dark gray wall. A dark gray wall in sunlight reflects more light than a white wall in a dim room. This is the behavior of diffuse reflectance. This is not to be confused with glossiness (for glossy or matte finishes).

Indirect light bounces off surfaces in a diffuse manner in all directions (also known as “Lambertian”). In contrast, directed bouncing light, such as the pattern of a mirror in sunlight, is called a *caustic* or *specular reflection*.

Typically, for physically based raytracers, the diffuse *color* of a material is in fact a diffuse *reflectance* value; where 0.5 means that the material reflects 50% of the incoming light for all R, G, and B components. For example, a white wall will not reflect more than about 90% of the light it receives. Therefore, the RGB color should not be more than 0.90, 0.90, 0.90 (floating point colors) or 230, 230, 230 (integer colors).



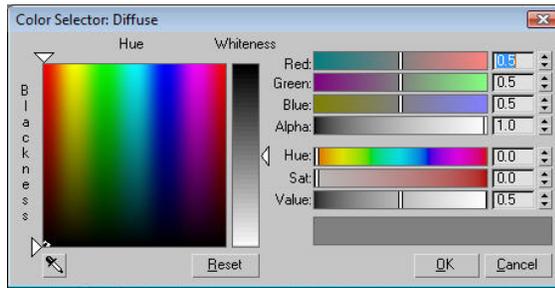
What is the right red to pick for this apple? It can be difficult to tell from what you see on your screen.



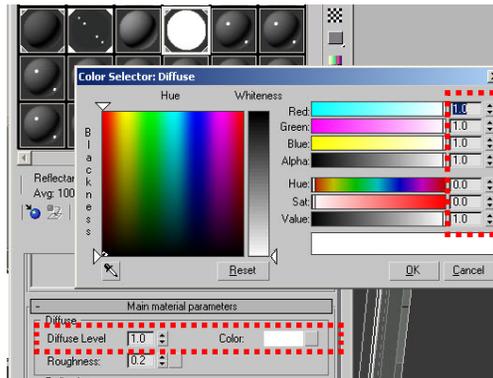
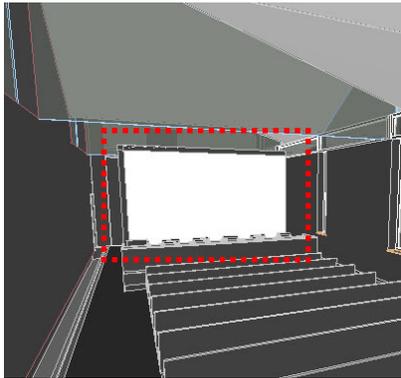
A white wall (90% reflectance) reflects twice the light of a grey wall (45% reflectance). This is directly caused by the diffuse color of the materials.

Daylight Simulation in Autodesk 3ds Max Design 2009

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



A RGB value of 0.5, 0.5, 0.5 for the diffuse *color* of a material represents a diffuse *reflectance* of 50%. This is also mathematically equivalent to a Saturation of 0.0 and a Value of 0.5 in HSV space.



A material with a perfectly white diffuse color corresponds (from a rendering point of view) to a diffuse reflectance of 100%. This is too reflective for a wall or ceiling. Normally, white paint should be around RGB 0.90,0.90,0.90 (90% reflectance).

Estimating material reflectance

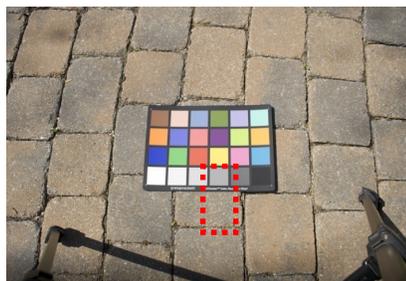
You can purchase a reference color chart that can help you estimate the diffuse reflectance of materials with a quick visual comparison. A popular one, the GretagMacbeth ColorChecker™ color chart is sold by X-Rite (<http://www.x-rite.com>) for roughly \$80.00 USD. Those cards have calibrated colors and the reflectance of each swatch is published and known.

For example, the patch #22 (called “neutral 5”) has a diffuse reflectance of 19%. This means that for a rendering engine, the correct RGB value would be R0.19, G0.19, and B0.19.



Patch name	Diffuse reflectance	Corresponding RGB color
white 9.5 (.05 D)	90.94	.9094
neutral 8 (.23 D)	58.50	.585
neutral 6.5 (.44 D)	35.71	.3571
neutral 5 (.70 D)	19.12	.1912
neutral 3.5 (1.05 D)	8.87	.0887

The industry-standard GretagMacbeth ColorChecker™ has known reflectance values that can be used for comparison against other finishes. Here, we are listing the reflectances of the lower row of swatches (white to black).



Visually, we can deduce that the average reflectance of the pavement is roughly 20%. Its brightness is close to that of swatch #22 on the chart, which has a known reflectance of 20%. This level of precision is good enough for most lighting analysis workflows.

Wall paints and color books

Paint manufacturers usually indicate the average diffuse reflectance of all their colors. Be careful not to confuse Diffuse Reflectance with the finish such as eggshell, flat, or semi gloss, which is more descriptive of specularly (glossiness).

When working with 3ds Max Design, be careful with color books provided with software packages or obtained from the web. Several software packages provide color books based on manufacturer content. For example, the Adobe® Photoshop® application provides Pantone® colors, and AutoCAD® software provides RAL and DIC colors. You can even find color books from paint manufacturers such as Benjamin Moore (<http://www.benjaminmoore.com>).

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 a little bit unpredictable with Global Illumination rendering engines.

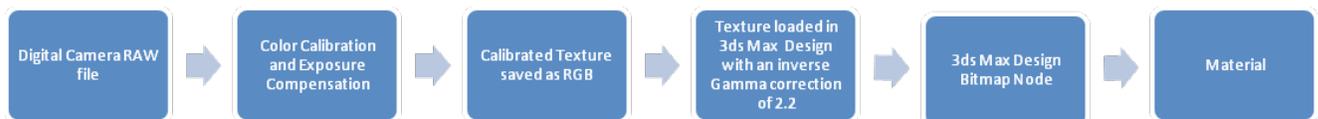
We have found that a Pantone color, selected in AutoCAD or Photoshop software, will not generally process correctly with a Global Illumination (GI) renderer. Using a Pantone color supplied by a client may be better than eyeballing it, but be aware that you are not running a physical simulation. Check 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.

Texture maps

As previously described, the amount of light bounced from a material is defined by its diffuse color. With textures, the reflectance of the material is defined by every pixel.

As a result, if the texture is overly bright, incorrectly gamma corrected, or if your digital camera / scanner is not calibrated properly, your texture will provide wrong reflectance values to the renderer. Consequently, lighting analysis reports will be incorrect.

For correct lighting analysis results with texture maps, your color process needs to be set up with a workflow that can be summarized like this:



Calibrating digital cameras, scanners, and gamma correction workflows are beyond the scope of this document. If you are unfamiliar with these processes, we recommend you remove all textures from your model and assume average reflectance values using grey shades.

Glass and glazing for lighting analysis

Depending on your needs, the mental ray engine has the ability to either attenuate light rays through volumes or not. As ray tracing is intimately related to the geometry of your model, especially with a transparent object, it is important to establish a strategy for modeling glazing assemblies for lighting analysis.

The following section will describe the main workflows to create the type of glass you need and provide information on their application for lighting analysis workflows.

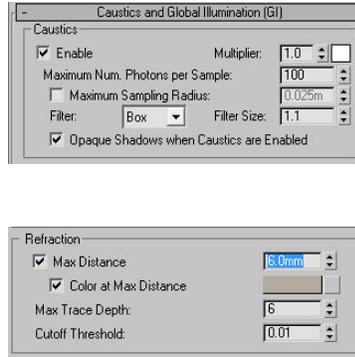
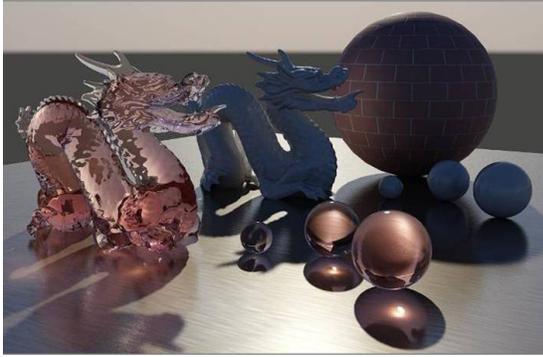
Solid glass with attenuation and refraction through volumes

For a total physical simulation of solid glass, you could model every sheet of glass as a real solid object and set the renderer to attenuate light correctly as it traverses the volume. This requires “caustics” effects to be enabled to handle glass refraction inside the volumes correctly.

While this is technically possible, this is overkill for typical analysis workflows; the complexity is greater for the user and increases the processing power required.



Look for an “R XXX” or “LRV” on the back of color swatches from paint manufacturers. These usually represent the Diffuse Reflectance value.



A solid glass material where light attenuates inside the volume enables you to really perceive the thickness variation of the glass. This is nice for special effects and “pretty pictures,” but overkill for typical lighting analysis workflows. To address these, you need to exploit the “caustics” feature of mental ray and the Color at Max Distance for Refractions in the Architecture and Design (A&D) material.

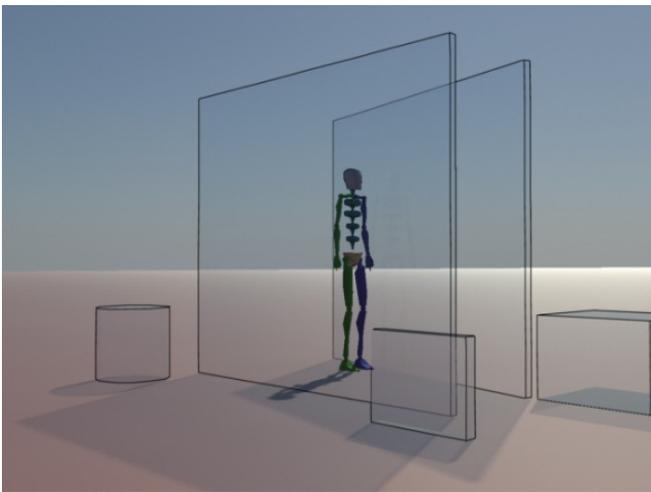
Instead, we recommend using another modeling strategy, which is described next.

Glazing as monolithic (solid) geometry, without attenuation and refraction inside volumes

We recommend you model glass panes as solid boxes and tell the renderer to not attenuate or refract light inside the volumes. This will let the raytracer cast rays through windows without having to refract light inside the geometry.

With this technique, the glass panes will more or less turn into “gel filters” where light energy is attenuated (*which is what you want*), but refraction and distortion of light will not be taken into account (*this will save rendering time*).

Here is how it works. The Transparency Color of your material (typically the A&D material or ProMaterials™ functionality Glazing will attenuate light rays for *each* polygon that is traversed, *without* refracting it). Light will only be filtered by a faint color.

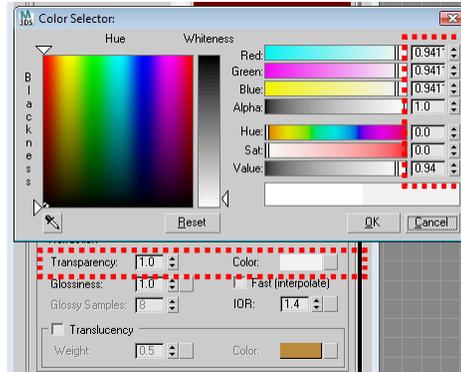
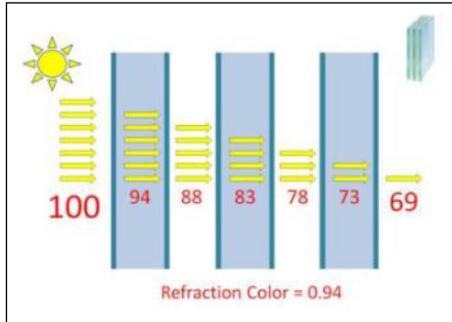


This image represents solid objects where attenuation inside volumes and refraction is *disabled*. This is a perfect strategy for architectural glazing and lighting analysis. Notice how light attenuates (shadows) without being refracted. The material acts as a pure “gel filter,” which works well for glass panes. Obviously, on curved objects this looks unnatural.

Note: This is how most Revit® Architecture software models are defined. A solid box representing the total thickness of the glazing assembly, where one polygon is facing inside the building and another is facing outside, regardless whether it represents a single sheet of glass, a double pane, or triple pane insulating glazing system.

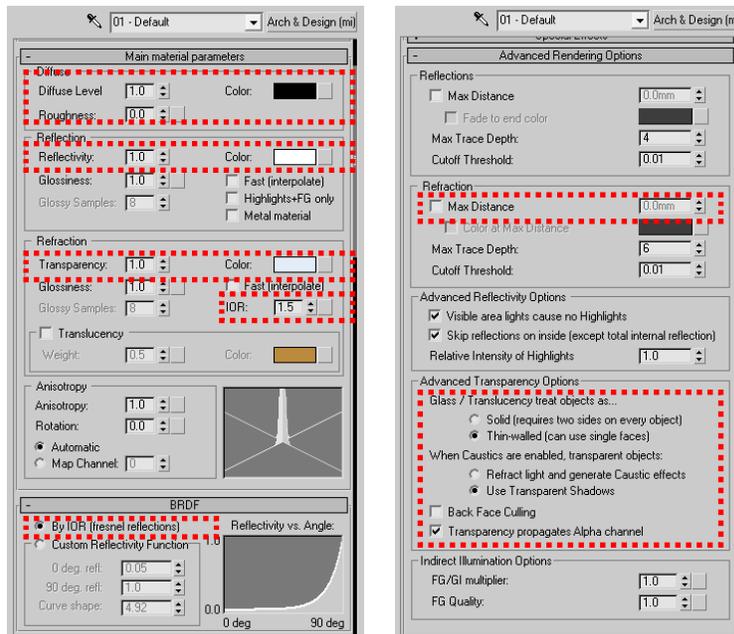
Daylight Simulation in Autodesk 3ds Max Design 2009

For example, if you modeled a triple glazing system where the thickness of the glass panes is physically represented, you will have six polygons to traverse. Therefore, if 6% of the light was lost after traversing each polygon (a Transparency Color set to 0.94), we would end up with a total glass transmissivity of $0.94 * 0.94 * 0.94 * 0.94 * 0.94 * 0.94 = 69\%$, which is plausible for a triple glazing system.

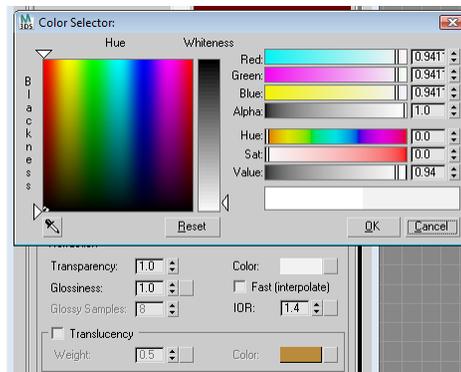


Each polygon traversed by a ray of light that loses 6% of the initial energy, for a total of 69% energy left on the other side of the glazing assembly. This amount of loss is ruled by the Transparency Color in the A&D Material. Attenuation happens each time a polygon is traversed by a light ray.

To create a similar material in 3ds Max Design 2009, you have 2 options: Use the Architecture and Design (A&D) Material or the ProMaterials Glazing Material. For the A&D Material, define the Diffuse, Reflection, and Refraction parameters as illustrated.

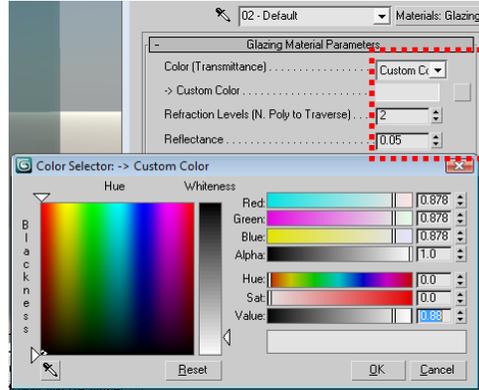
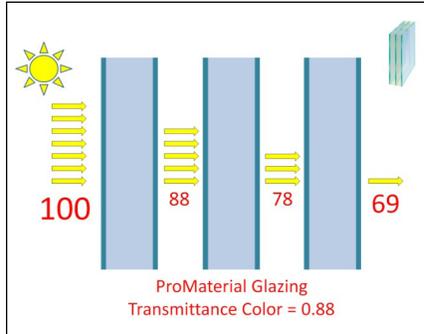


To create glass, the Diffuse Level must be set to 0.0, Reflectivity Level and Color must be set to 1.0, Transparency Level must be set to 1.0 and Transparency Color set to the desired transmittance value (0.94 in our case). The Index of Refraction IOR set to 1.5 will represent generic Glass. Finally, the A&D material must be prevented from attenuating and refracting through volumes in the Advanced Rendering Options.



Daylight Simulation in Autodesk 3ds Max Design 2009

If you want to make your life easier, the ProMaterials Glazing is already built in to handle the case described above. Since you want to create a solid glass layer that attenuates light by a factor of 88%, all you need to do is specify the Transmittance of the ProMaterials Glazing Material to 0.88 and instruct it that this applies when traversing 2 polygons.



A ProMaterials Glazing Material set to attenuate light by a factor of 12% after traversing 2 polygons will produce identical results as the case described previously.

Metal-coated glazing

It is currently not possible to simulate metallic coatings where the transmittance and reflectance of glazing systems does not obey the traditional Fresnel falloff curve.

Translucent glazing

Although the mental ray Architectural & Design Material shader has the capability of weighting specular transmittance (clear) and diffuse transmittance (translucent), we have no formal study that proves that the resulting luminance and illuminance levels are accurate.

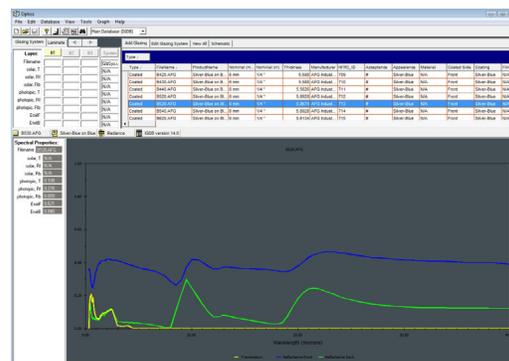
Manufacturer-based glazing data

Several glass manufacturers provide optical data to the Windows® operating system and Daylight Group of the Lawrence Berkeley National Laboratory (<http://windows.lbl.gov>).

This group maintains a database and publishes this data via a program called Optics 5. From Optics 5 you can then export a Radiance Material (*.rad file), which can be interpreted as mental ray A&D Material parameters.

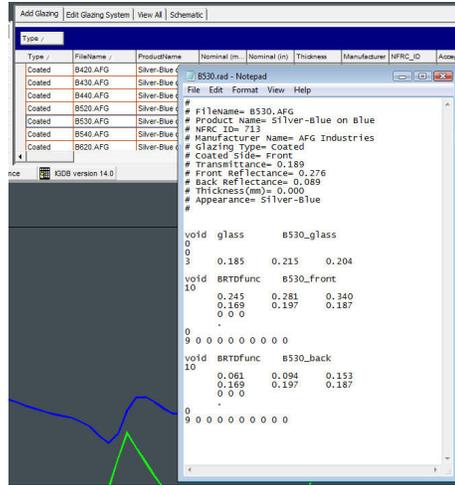
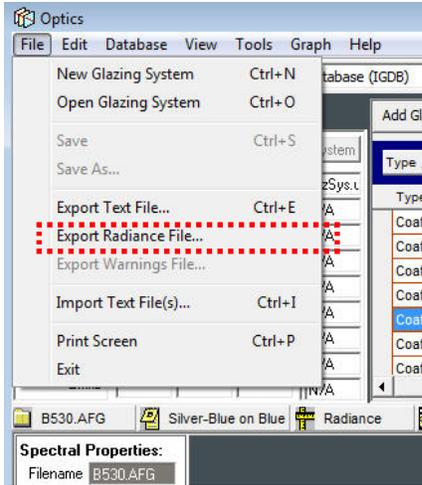
To convert Optics 5 data into A&D Material suitable for lighting analysis, export a glazing or glass definition as Radiance (*.rad) from Optics 5. You will find this command under File | Export to Radiance File.

Note: You can find detailed information about the Radiance (.rad) file format at: <http://radsite.lbl.gov/radiance/refer/ray.html#BRTDFUnc>*



The screenshot of the Optics 5 Program from Lawrence Berkeley National Laboratory. Data can be exported to Radiance and converted to 3ds Max Design materials suitable for lighting analysis.

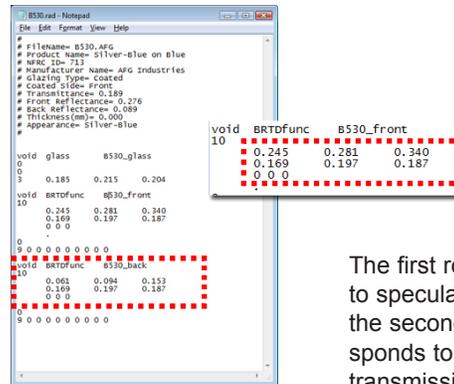
Daylight Simulation in Autodesk 3ds Max Design 2009



Export as a glazing configuration from Optics 5 as a Radiance file.

Once the file is exported on disk, open it in Notepad and search for a section that looks like this:

```
void BRTDFunc B530_front
10
    0.245 0.281 0.340
    0.169 0.197 0.187
    0 0 0
```



The color coefficients (RGB) for the ideal specular reflection corresponds to 0.245 0.281 0.340. The color coefficients for the ideal specular transmission corresponds to 0.169 0.197 0.187. Those values will need to be used as a basis for the mental ray A&D Material.

How to use the provided Microsoft Excel spreadsheet to convert to the mr A&D Material.

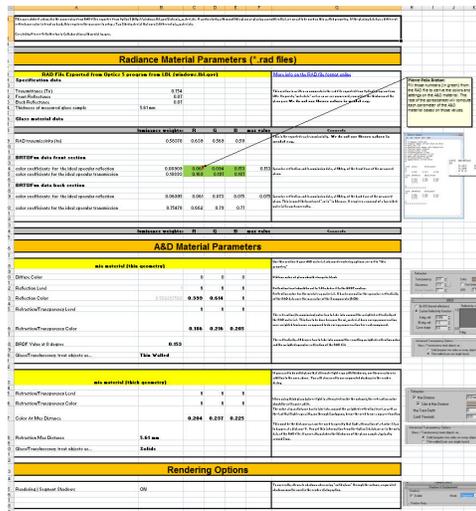
To correctly convert specular reflection and transmission from a Radiance material to a mr A&D Material, we need to take into account internal energy conservation methods that are built in the mr A&D Material that are not factored by the Radiance material. In other words, numbers can't be "plugged-in" as is.

To help you with this task, we developed a Microsoft® Excel® software spreadsheet that will let you do this precisely. The spreadsheet can be downloaded here: http://www.autodesk.com/us/3dsmaxdesign/spreadsheet/rad_glass_to_mi_material_conversion_bronze.xlsx

The first row corresponds to specular reflection and the second row corresponds to the specular transmission (in floating-point RGB color).

Limitations:

- The Radiance Materials exported from the Optics 5 database does not take into account angular dependency: A Fresnel falloff curve is assumed so metallic-coated glazing systems may be less precisely simulated.
- The Optics 5 database contains optical data measured spectrally. The exported Radiance materials and the A&D materials use RGB colors which are a crude approximation of the visible light spectrum. Therefore, lighting simulations are done within limitations of RGB colors.



The provided Microsoft Excel spreadsheet is meant to help you convert Radiance materials exported from the Optics 5 software into mr A&D Materials. Simply plug the numbers from the BRTDFunc into the green cells in the spreadsheet.

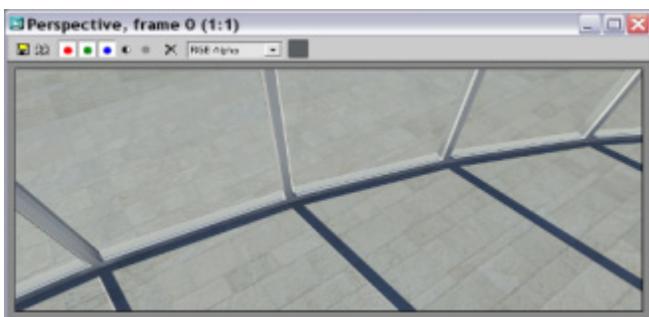
Guidelines for Your Scene Geometry

Good renderings require good geometry. Creating good geometry doesn't mean you must model everything. You can obtain many detailed effects with optimizations, such as bump maps or cut-out 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 don't have to create perfect models, but more accurate models make rendering easier and more efficient.

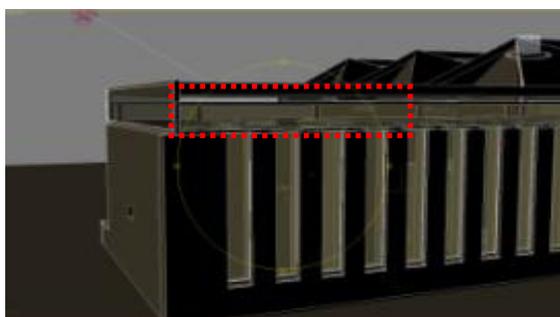
The following section describes general guidelines for your model's geometry that should be taken into account for accurate renderings and/or lighting analysis.

“Air tight” models

Sometimes, you can find models where walls and windows or roofs don't touch each other properly. This can cause lighting from the exterior of your building to penetrate without attenuation (from glazing for example) and introduce errors in the lighting analysis results.



Windows panes not touching the curtain wall frame, letting direct sun rays inside the model will falsify lighting analysis results.



This building is not “air tight.” We can clearly see a hole above the windows under the ceiling.

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.

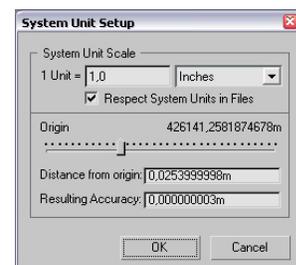
For example, a common mistake is to import an airport at the size of a shoebox or a room at the size of a stadium. In the former case, the lighting computation will be too bright. In the latter, it will be too dark.

To verify your scale settings, check the “System Unit Scale” settings in the “Customize | Units Setup | System Unit Setup dialog box.”

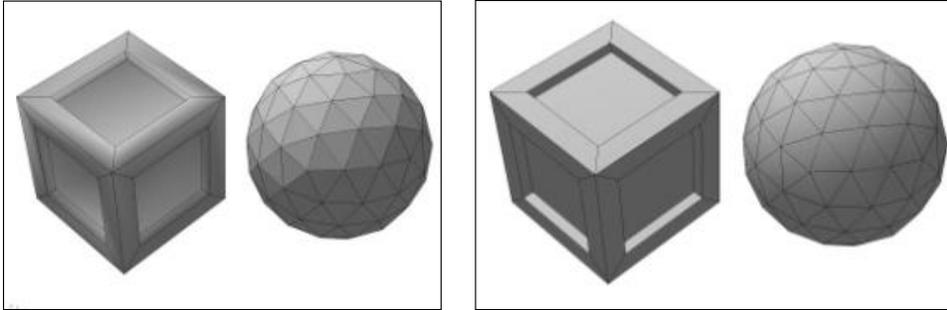
You may also want to use the “Tools | Measure Distance” tool to verify known dimensions in the scene, as well as set the “Unit Conversion” function in the Import menu when, for example, importing a DWG™ file from AutoCAD software.

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.



System Units Setup of 3ds Max Design 2009.



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

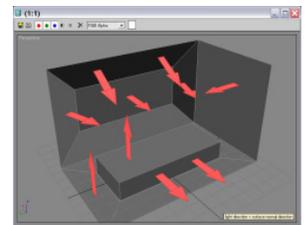
This is how the cube and the sphere should look according to smoothing groups.

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 distinguishing the front from the back of the face, which is done by the surface normal as well. For lighting analysis purposes, this is critical because light energy will be bounced in the direction of the surface normal.

When importing a model from a CAD package, you may find that direction information for some face normals gets "lost" or "corrupted." Usually, the modeling package in which the geometry was created may not have provided this information as the entities were created. For instance, SketchUp needs to be set in a special display mode to visualize face orientation and flip them.

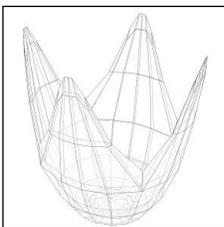
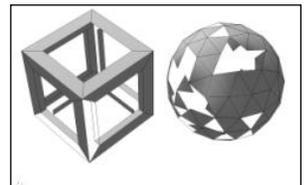
If there are only a few faces with the wrong orientation, you can add an "Edit Poly" modifier in 3ds Max Design and use Flip on the affected faces.



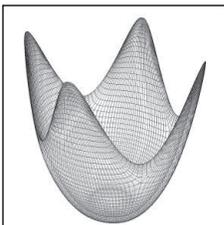
Light is bounced from the direction of surface normals. For accurate lighting analysis, this is a critical aspect.

Polygon count

It is good practice to consider 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.



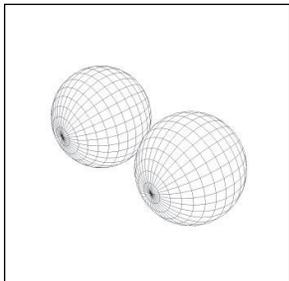
In this example, the bowl's appearance is improved because the shape allows for additional faces without destroying the bowl itself; you could simply add a "TurboSmooth modifier."

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 but, usually, the modeling program did not take them into account.

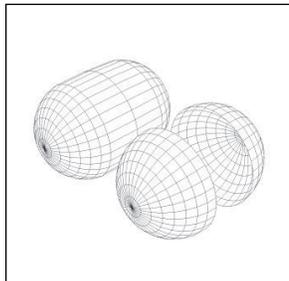
Unwelded vertices

In some cases, a model might look as if it is closed, but instead each face is separated and the vertices of neighbouring 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 place in front, and a black pattern artefact will appear. Worse, in the case of lighting analysis, you may end up bouncing more energy than received (double the energy) and get incorrect analysis results.

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, or by creating a ground plane across your entire model at the same level of the floor finish.



Unlike unwelded vertices, overlapping surfaces are easy to spot.

What is Exposure Control?

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

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: 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.

Daylight Simulation in Autodesk 3ds Max Design 2009

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.



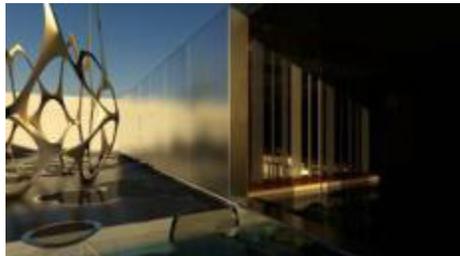
Moonlit backyard, luminance on the roof
of the garage: 0.22 cd / m². Kids' play
set luminance (brightest): 0.1 cd / m².

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 be beyond the range of what a monitor can display.

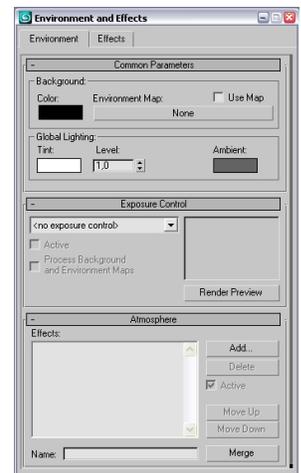
Therefore, it's necessary to compress the calculated image (ranging from zero to infinity) into a displayable image (ranging from zero to 255). This process is called *tone mapping* or *exposure*.

To enable exposure control in 3ds Max Design, 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 sensitivity 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 adjust your camera's aperture or shutter speed than wait for the sun to set. The exposure controls control light in the same way.



The left image is exposed toward the inside of the room, and the right image is exposed toward the outer courtyard. Both are correct and the light levels in the scene did not change; the direction of the exposure is up to you. Images courtesy of (c) 2007 Electric Gobo / Karcher, www.electricgobo.com



Exposure Control Rollout in 3ds Max and 3ds Max Design

External Links

Autodesk: Ecotect Wiki

<http://squ1.org/wiki/>

Energy Plus: Weather Data Files

http://www.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm

Autodesk: 3ds Max Design White Papers

<http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=11360846>

National Research Council of Canada: Introduction to dynamic daylight metrics

<http://irc.nrc-cnrc.gc.ca/pubs/fulltext/nrcc48669/>

X-Rite: GretagMacBeth Color Chart

http://www.xrite.com/product_overview.aspx?ID=820

Windows Group, Lawrence Berkeley National Lab

<http://windows.lbl.gov/>

Radiance Material Definition

<http://radsite.lbl.gov/radiance/refer/ray.html#glass>

CIBSE: Surface Reflectance and Colour

<http://www.cibse.org/index.cfm?go=publications.view&item=164>

About the Authors

Marion Landry

Marion Landry has over 10 years of experience in Architecture Visualization, working with a wide range of software including Autodesk 3ds Max and Autodesk Maya. She has worked on numerous projects from concept design to high-end pre-visualization.

Some of her recent projects include the innovative Ritz Carlton Residence Vancouver (Arthur Ericson designed tower), and the Hyatt Hotel, Vancouver. She contributed high-end animation packages to the Four Seasons Hotel, Whistler, and to a number of Intrawest Resorts. She has participated in a range of sustainable building projects, including the LEED-certified Vancouver Convention Centre, built for the 2010 winter Olympics, and the Abbotsford Regional Hospital and Cancer Centre.

As a Technical Marketing Specialist for Autodesk Media & Entertainment, she now focuses on the creation of demonstrations for an AEC- wide audience as well as being involved in the development of Autodesk 3ds Max and Autodesk 3ds Max Design products.

Pierre-Felix Breton

Pierre-Felix Breton is senior software designer and lighting consultant specializing in the field of physically based and artistic lighting simulation. His professional background includes electrical engineering, computer programming, and theatrical lighting.

Currently employed by Autodesk Media & Entertainment, he participates in the creation of products such as Autodesk 3ds Max and Autodesk Revit where he focuses on the integration of the mental ray rendering engine as well as daylight simulation technologies.

Pierre-Felix also consults regularly on various architectural lighting design projects as a designer, technical coordinator, and simulation specialist where he is involved in the entire lighting design and specification process.

