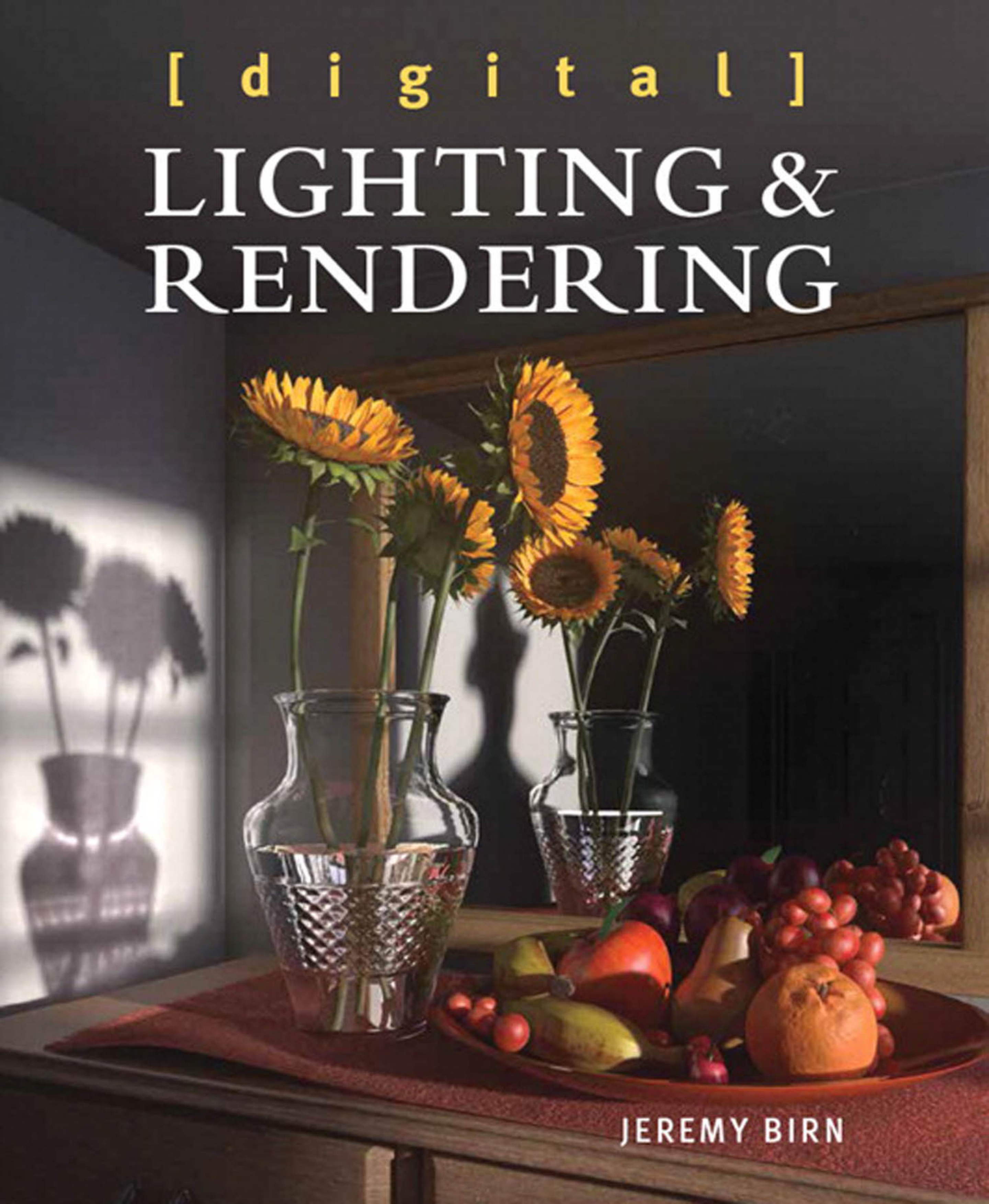
[digital] LIGHTING & RENDERING



JEREMY BIRN

[d i g i t a l]
LIGHTING & RENDERING

Third Edition

New Riders
VOICES THAT MATTER™

Jeremy Birn

Digital Lighting and Rendering, Third Edition

Jeremy Birn

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Introduction

To help you make better 3D renderings, this book fuses information from several fields. In these pages, you will find practical advice based on professional film production experience, concepts and techniques from live-action cinematography, design principles from traditional visual arts, and plain-English explanations of the latest science behind the scenes.

Who Should Read This Book?

You should read this book when you have at least a working knowledge of how to use a 3D software package and are interested in taking your 3D rendering further.

- For professional users of 3D rendering software, this book is designed to help with real-world production challenges and contribute to the ongoing growth of your lighting and rendering work.
- For students of computer graphics, this book will help you develop professional lighting and rendering skills.
- For dedicated 3D hobbyists, this book can help you improve the artistic quality of your 3D renderings and learn more about professional approaches to graphics production.

I wrote this book to be clear, but not condescending. I have made every effort to define terms the first time I use them, and to illustrate every concept and technique with figures and sample renderings. This book is designed to complement, rather than replace, your software's manuals and help files. Most of the information you find here is not in your software manual, even if some of it should be.

Software Requirements

This book covers techniques and concepts that you can apply in almost any 3D rendering software. I also recommend that you have 2D paint and compositing software on hand.

3D Software

I don't care whether you use Blender (open-source software from www.blender.org), Maxon Cinema 4D, Side Effects Houdini, NewTek LightWave 3D, Autodesk Maya, Autodesk Softimage, Autodesk 3ds Max, or any other brand of software that lets you light and render 3D scenes. You can use the renderer that comes with your software package or separate rendering software like Solid Angle's Arnold, NVIDIA Mental Ray, Pixar's RenderMan, or Chaos Group's V-Ray. No single program is going to support every feature, function, and rendering algorithm described in this book, so hopefully you won't mind learning about a few functions that aren't in your particular software yet. Most sections show several alternate approaches or workarounds so that you can achieve any effect that I describe, no matter which program you use.

Being non-software-specific doesn't mean that this book doesn't discuss individual programs, though. If there's a noteworthy feature in any particular 3D program, or a technique that you need to do differently in one program than in another, I mention it when it comes up.

This book is dedicated to the idea that, if you are aware of the art and computer graphics principles that go into a rendering, and you apply a little bit of creative problem solving, you can accomplish great work in almost any rendering package.

2D Software

You should complement any good 3D system with 2D software that can create and manipulate texture maps, and composite together layers and render passes. You will find that a paint program such as Adobe Photoshop (which I have used in many texture-creation examples in this book) is useful, although free alternatives such as GIMP (www.gimp.org) or Paint.NET (www.getpaint.net) will also work just fine. You may also find a dedicated compositing program (such as The Foundry's Nuke, eyeon Fusion, or Adobe After Effects) useful when you are compositing together render passes, although you can also do basic compositing in your paint program.

About This Edition

This is the third edition of the popular book *Digital Lighting & Rendering*. The first edition became the standard text on the art of 3D lighting and rendering, and introduced many artists to the field. Since it was published in 2000, it has met with great critical and commercial success. A second edition was released with major updates in 2006. I am sincerely grateful to each teacher who has chosen to use my book, everyone on the Internet who has posted a recommendation, and every artist who has shown my book to a friend or colleague.

Now I have written this new third edition to make sure that the book advances along with changes in technology, software, and the industry. A great deal has changed since the second edition.

I have added sections to cover new technologies and growing trends, such as physically based lights, physically based shaders, Ptex (per-face texturing), and unbiased rendering. In addition, there's a new focus on the linear workflow, why you need one, and how to maintain it.

I've also updated several chapters to reflect how it's becoming common to use global illumination in feature film lighting, as a part of your character lighting, and also to light environments and architecture. I'm not trying to force everyone to use global illumination for everything, though. I have also expanded the coverage of occlusion, using the occlusion sandwich technique, and more advanced approaches to occlusion passes.

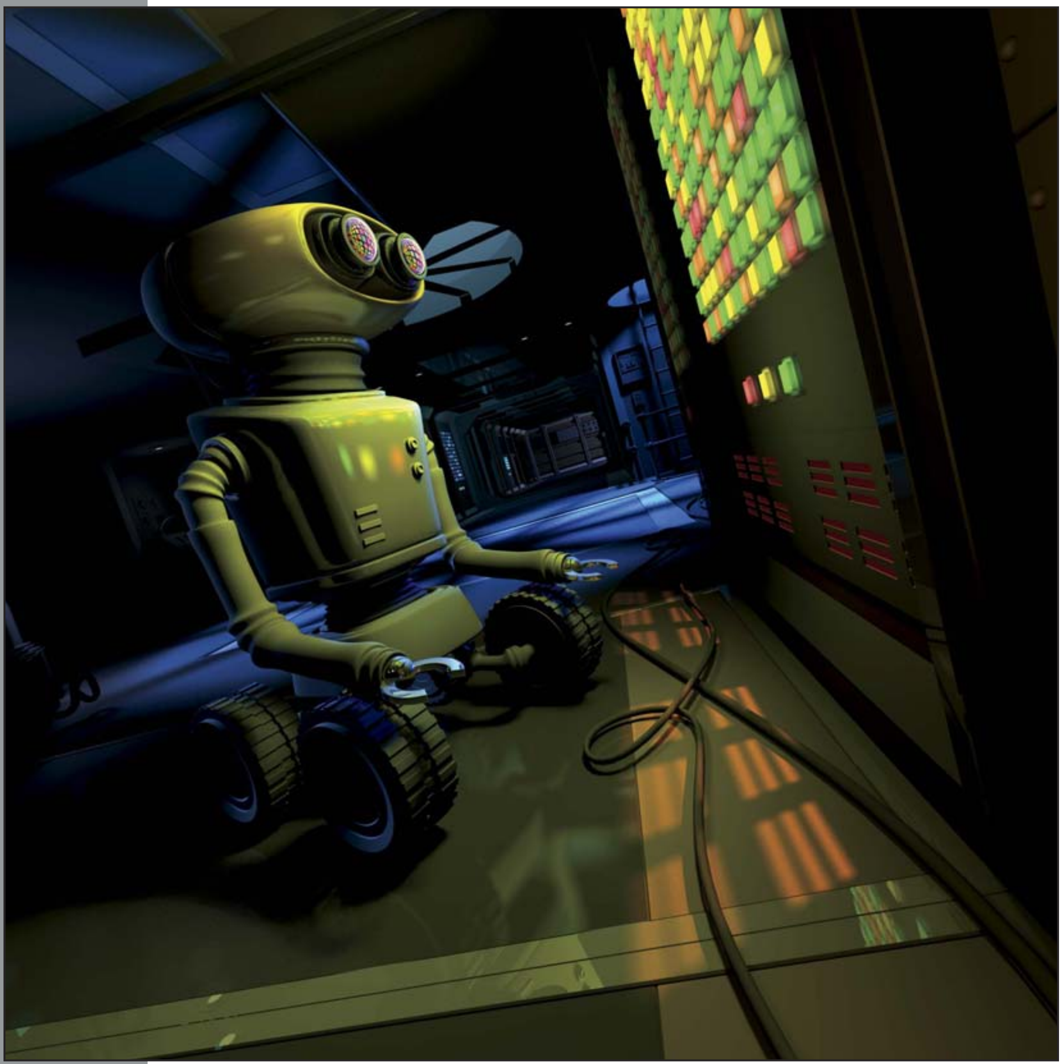
I still cover old-school lighting techniques such as depth map shadows in this edition. Although depth map shadows are going out of style for many purposes, a lighting technical director should still know what they are good for, how to adjust them, and how to fix bias issues and light leaks. Though the third edition retains the same chapter organization as the second edition, it has grown longer in places and contains new sections on lighting atmosphere, participating media, and underwater scenes; new examples of compositing; expanded coverage of simulating natural light; and new character lighting situations. I've also included new sections on approaches lighting teams can use to work together in lighting feature films, the state of the computer graphics industry, and new advice for developing your showreel and finding a job.

In computer graphics, we say our work is never really completed, only abandoned. Shots can always be better, and perfectionists can always find something to tweak and revise a little more—and of course it is the same with books. Crashing into a deadline is what finally forces us to let go of the projects we love. After releasing a book, being able to revisit and revise all the material again gives me great pleasure. It is with great pride that I abandon this new edition to you.

Download Additional Files

Throughout the book, you will find references to many of the 3D scenes used as examples. Feel free to download and experiment with those scenes for your own personal work. You can access them at www.3dRender.com.

[CHAPTER FOUR]



Lighting Environments and Architecture

To light natural environments and architectural spaces, you need to be aware of the environment around you. Direct light from the sun, soft illumination from the sky, and indirect light blend their colors and tones in subtle ways. This chapter discusses how you can use these three elements to simulate natural light outdoors and indoors, by day or by night. Different kinds of artificial light, from flashlights to desk lamps to streetlights, require equal care to simulate realistic throw patterns and illumination in your scene. You can use atmosphere, from fog and dust in the air to thicker participating media for underwater scenes, to help convey how light




travels through space in your environment. Finally, with global illumination (GI) you can simulate how all of these lights are transmitted from one surface to another, filling your scene with indirectly bounced light. This chapter explores not just how to light with natural and artificial light sources, but how to simulate indirect lighting with or without GI.

Creating Daylight

You can create a simple outdoor lighting setup by adding three elements to your scene: direct sunlight; soft fill light representing light from the sky; and indirect light, simulating light that has bounced off of surfaces in your environment. When you put these three elements together, you can simulate outdoor light at any time of day. This section will explore these three elements and the choices you need to make when creating them.

Adding Sunlight

Think about your scene. What time of day is it? Is there direct sunlight? You'll want to address the sun first, because the sun will be your *key light*—the most important, main light that defines your scene. If sunlight is visible at all, it is often the brightest light in your scene and tends to cast the most visible shadows. You determine the angle of the sun depending on the time of day you are trying to re-create, but remember that your audience doesn't usually know whether the camera is facing east or west, so you have enormous creative latitude in picking an angle for the sun that lights your scene well.

Most of the time, you will use a directional light as the type of light source for the sun. Remember from Chapter 2 that a directional light casts all light and shadows in parallel, which is appropriate for sunlight. If you are using a directional light to cover a full scene with sunlight, you should probably use raytraced shadows to make sure that accurate shadows can be cast by everything in the scene.

Sunlight does not need any decay or attenuation based on distance. The light has already traveled about 150 million kilometers (93 million miles) from the sun to reach your scene, so it is unlikely to wear out appreciably in the last few meters.

Make the sun a yellow color for most of the day; turn it orange or red only during sunrise or sunset. If you test-render your scene with just the sunlight and no other lights, it will appear very yellow and stark, as in Figure 4.1. Before you add any other lights, make sure that you are completely happy with which areas of the scene are in sun and which aren't. In this example, I pivoted the sun around until the statue's head was lit by sunlight and the light came from the side, to bring out the shape of the face instead of flattening it with frontal lighting.

[Figure 4.1] Sunlight by itself looks yellow and is full of contrast. Here, the sun angle is adjusted to light the main subject well.

Adjusting Raytraced Shadows

The shadows from the sun are the most important shadows in an outdoor scene. Be sure to adjust and test-render the sun shadows, and make sure you like their shape and direction, before you move on to add any other lights.

Shadows from the sun are not completely sharp. Think of the sun as an area light that casts slightly soft shadows. The sun usually fills an area of about 1% of the sky around us, but the shadows from the sun can become considerably softer on a hazy day or around sunset, so you may use values between 1 and 5 degrees for the shadow's light angle.

It is best to leave the *shadow color* parameter of your sunlight set to pure black. You can add a blue cast to the shadow areas later, when you fill in the scene with skylight.

Using Depth Map Shadows

If you are using depth map shadows, you may need to approach setting up sunlight differently. In order to focus a depth map around an appropriate area, you may choose to use spotlights instead of a directional light.

If you use a spotlight to represent the sun, you need to translate the light a large distance away from the rest of the scene so that the shadows it casts will appear parallel. After you accomplish this, set the spotlight cone to a very narrow cone angle so that it only covers the area where its light and shadows are visible in the scene.

One advantage of this approach is that it is easy to aim cookies from a spotlight. If you want a cookie in the sun—to simulate dappled light shining through tree leaves, for example—you can aim and adjust that cookie by moving the light.

One spotlight might not be enough to cover a large area, however. Stretching a depth map over too broad an area can cause it to lose accuracy. If you want to work efficiently with depth maps in cases like this, sometimes you must represent the sun with an array of spotlights, and each must provide light and shadows to one region of the scene. Using multiple depth maps, each with a reasonable resolution such as 1024 or 2048, is usually more efficient than cranking up the depth map resolution above 4096 or 8192.

In some environments you may have no choice but to use depth maps. Complex elements such as grass, fur, or vegetation greatly add to render times and memory use if you try to render them in raytraced shadows. Depth maps can shadow this kind of subject matter more efficiently. Specialized types of depth maps in some renderers, such as the *deep shadow maps* in RenderMan and the *detail shadow maps* in Mental Ray, are optimized for shadowing fine details such as hair and grass.

Adding Spill from the Sun

It is often a good idea to use a second light to represent the spill from the sun. After you have your main sunlight set up and you have test-rendered it to make sure you like what it illuminates and where it casts shadows, you can duplicate a second copy of the sunlight and rename it to become a spill light. Don't rotate the spill light; leave it aimed the same direction as the main sunlight. Set the spill to have much softer shadows than the sunlight so that it spills out beyond the edge of the sunlight into shadow areas, and make the spill dimmer than the sunlight itself.

In some scenes, it is useful to give the spill a richly saturated color. Around sunset, the sun itself might be an ordinary yellow, but the spill could be a rich red or deep orange. In some midday scenes, the sun is so bright that it should appear overexposed and desaturated; in these cases your sun's color might be a pale yellow or appear almost white. If you give the spill light a more saturated color than the sun itself, then the overall impression created by your scene will be that the sunlight has a warm tone.

Figure 4.2 compares the scene from Figure 4.1 with sunlight only (left), and with both sunlight and spill light together (right).

Visually, adding a spill light around the sun extends the sunlight into more angles and helps it wrap further around round objects. Because shadows get softer the farther they are cast from the subject, you can still have black shadows close to the objects that cast them, but shadows cast from more distant objects are more filled in. Overall, having spill light around the sun can add both richness and realism to your scene, compared to the starkness of having sunlight that is not visible at all beyond the edge of the shadows.

[Figure 4.2]
Sunlight by itself (left) leaves more of the scene in black shadow. Adding a spill light (right) fills in the edges of the shadows with a warm glow.

Adding Skylight

The soft blue light from the sky is another main aspect of your outdoor lighting. It helps to test-render the sky illumination by itself, with the sunlight and sun spill hidden, before you start to put them all together. A single dome light, as discussed in Chapter 2, is usually the best way to simulate sky illumination in an outdoor environment. The left side of Figure 4.3 shows the scene lit entirely by a dome light.

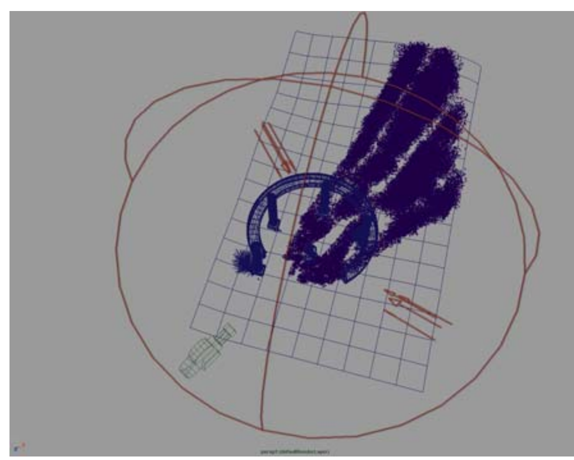
You can map the dome light with gradients to create shaping and variety in your sky illumination. Often a gradient runs from a lighter blue at the horizon up to a deeper, darker blue at the top of the sky. This simulates a bit of haze that makes the sky look brighter and less saturated near the horizon. Often you want a second gradient to run from the bright side of the sky (where the sun is) toward the darker side of the sky. This adds more variety to sky illumination.

In some programs, the sky dome is just the top half of a sphere and does not include the portion of the sphere that would be underground. In other programs, dome lights wrap all the way around your scene, with half of the dome below the ground. Because the ground shadows any illumination that comes from below it, the color of the bottom half of the sphere shouldn't make a visible difference in your scene. However, you can map the bottom half of the dome to black to prevent potential light leaks if you have holes in your geometry, and possibly to save rendering time in some renderers in case the renderer is optimized to take more samples toward brighter parts of the dome light.

[Figure 4.3]
Sky illumination from a single sky dome softly fills the entire scene (left), whereas adding a kick light (right) adds definition to the shadow side of the objects.

Including an Extra Kick from the Sky

Sometimes you can add more shaping to your scene by augmenting your sky illumination with an extra light. You can use a directional light, set up just like the spill light from the sun, or you can add a spotlight if you want to be able to aim it and focus it on one area. You might give this extra light a blue or gray color, matching whatever colors you see in the sky. This technique not only adds an extra kick of illumination that comes from the sky behind your subject, often on the opposite side from the sun, but it also adds variety and shaping to the side of a subject that isn't lit by the sun and sun spill, as shown on the right side of Figure 4.3. Notice how the dark sides of the statue and columns are better defined when the kick is added.



[Figure 4.4]
This wireframe view shows the sunlight and sun spill (lower right), the sky dome, and the kick from the sky (upper left) positioned around the scene.

Let's make all of our lights visible now, as shown in Figure 4.4. We now have two directional lights in the same place for the sun and the sun spill (shown in the lower right), a dome light for the sky, and another directional light for a kick from the sky.

Adjusting Color Balance

In a sunlit scene, the warm color of the sun and the cool color of the sky should balance out so that they appear almost white where they overlap. Areas where the sun is blocked so that you see only skylight may look blue. If you render your scene with the sun and all of your skylights visible, you can see the overall color balance of your scene.

You might want a golden yellow overall tint for your scene for a late afternoon or sunset, or a blue tint for dusk or a gloomy overcast day. For a normal daylight balance, however, you don't want your full scene to look blue tinted or yellow tinted overall. You may need to go back and adjust the sun's brightness or color to achieve a natural-looking balance and make it cancel out the blue of the sky.

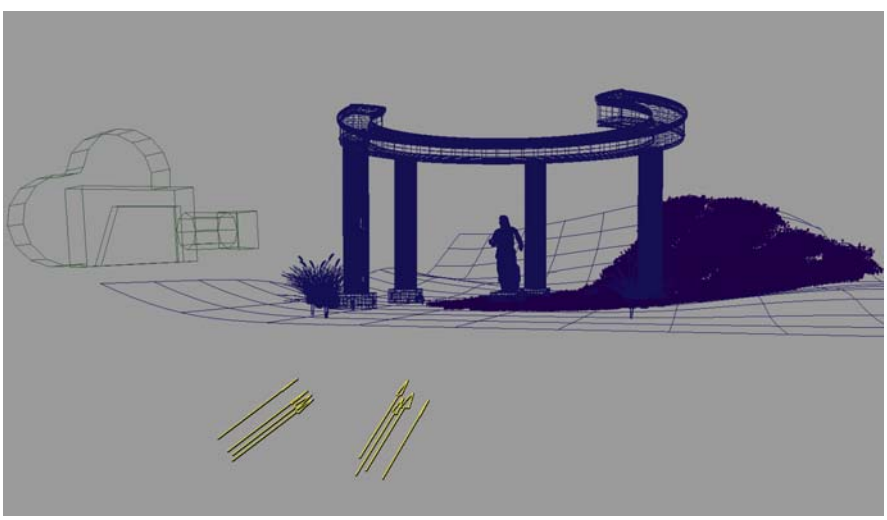
Figure 4.5 shows the result of rendering with the sun, the spill from the sun, and the sky illumination, all together. Although it still lacks the bounce light that will tie it together, you can see the overall daylight look already appearing in the image.

[Figure 4.5]
Sunlight and skylights are combined to create balanced daylight illumination.

Adding Indirect Light

The sunlight and skylights give you most of your illumination, but a realistic daylight scene also requires *indirect* or *bounce* light. Light that reflects off the ground and other surfaces back up into the scene is called indirect light because it doesn't come directly from a light source. Where sunlight and skylight illuminate the ground and other surfaces in your scene, the brightly lit surfaces themselves need to act like light sources. If light has bounced off the ground, then in many scenes most of your indirect light is aimed upward from the ground, illuminating the bottom of other objects.

You have two basic choices for how to simulate indirect light in your scene. You can add your own bounce lights to simulate indirect illumination, or you can use GI to simulate indirect illumination for you. GI adds indirect illumination to your scene automatically, so you don't need to add any more lights as bounce lights. However, this type of illumination also takes a lot longer to render, especially for scenes like this example that feature grass and vegetation. We'll come back to GI later in this chapter. For now, the straightforward approach to simulating indirect illumination in this scene is to add some bounce light, aimed upward at the scene through the ground, as shown in Figure 4.6.



[Figure 4.6]
Bounce lights (shown in yellow) shine up through the ground to simulate indirect light.

The bounce light makes the biggest difference on the bottoms of objects, brightening up the surfaces that face the ground. Figure 4.7 shows the difference that bounce light adds, if you compare the scene without bounce light to the scene with bounce light.

[Figure 4.7] Adding bounce light (right) fills in the dark bottom surfaces of objects and visually connects the light colors from the sun and the sky.

To simulate indirect light, you need to make some delicate adjustments:

- Most of the time, you should set bounce lights not to emit any specular illumination; you don't want unmotivated specular highlights to appear on the bottom of objects.
- Give your bounce lights colors similar to whatever surface motivates the indirect light. For example, to simulate light reflected off of a green lawn, use a green light.
- To simulate light bouncing off of the ground, position your bounce lights underneath the ground, aimed upward. Use light linking or shadow linking to make sure the ground itself doesn't shadow the light.
- Sometimes bounce lights don't need to cast shadows. If your bounce light casts shadows, then the shadows should be very soft and indistinct. Check inside the mouths, noses, and ears of characters to make sure you don't have unshadowed bounce light visibly shining through them.
- In most scenes, you need more than one bounce light, with different angles and different colors. Even if there's only one ground color, you

can use different colors based on the colored lights that hit the ground. For example, if yellow sunlight and blue sky fill both illuminate the grass, then you can have a yellow-green light and a blue-green light bouncing back from the grass onto the rest of the scene.

- Whereas most bounce light in many scenes is light aimed upward, you can actually aim bounce lights in any direction. If bright light is aimed at a wall, you can add a bounce light simulating light bouncing off of that wall. If a floor lamp is aimed up at a ceiling, you can aim a bounce light from the ceiling down onto the rest of the scene.

Because bounce lights are dim and subtle, it's usually a good idea to hide all of your other lights and test-render an image with only the bounce lights so that you can see that they uniformly cover the surfaces of your scene. Make sure you don't see any harsh shadows or sharp highlights in your bounce lighting, because that would give away the illusion that it comes from indirect light reflecting off large surfaces.

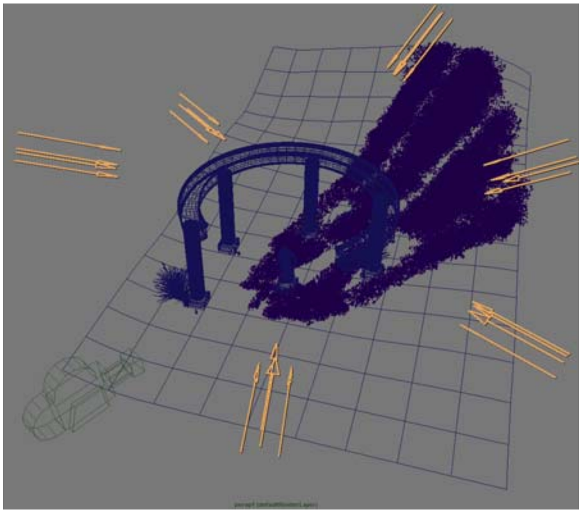
Alternate Approaches

You can simulate sky illumination in three alternative ways in modern software: You can simulate the sky with an array of lights coming from different directions instead of using dome lights; you can use a unified sun and sky shader that is available in many programs; or you can use image-based lighting to illuminate the whole scene with a High Dynamic Range Image (HDRI).

Doing Without a Dome Light

If your renderer doesn't support dome lights, or you want a solution that renders faster, use a set of multiple lights to simulate sky illumination.

Start with a directional light that casts very soft raytraced shadows (a light similar to your spill light), but give it a blue color. Test-render your scene and see how it looks with one skylight; then duplicate the light so that lights illuminate your scene from all directions. In an open scene you probably need between four and eight lights to represent fill from the whole sky. Figure 4.8 shows a collection of directional lights arranged to simulate sky illumination.



[Figure 4.8]
As an alternative to a sky dome, add several directional lights around the scene.

The lights don't need to have the same brightness and color. You can vary the brightness and color of the lights so that the sun side of the sky is brighter, and the darker side of the sky is a more saturated blue. The lights don't need to be spaced at equal angles, either. Adjust them however they look best in your particular scene. If you see any visible edges to shadows, use softer shadows, or add more directional lights from more angles, to fill in the unlit areas.

Unlike when you use a dome light, using an array of directional lights does not look very good on shiny or reflective objects. If you used six directional lights to simulate light from the sky, you don't want six bright highlights to appear on each shiny object. If you have any shiny, reflective objects in your scene, your best bet is to set the lights not to emit specular illumination and then use a separate environment map for their reflections.

For the very cheapest results, you can use an array of spotlights with depth map shadows instead of directional lights with raytraced shadows. This may not look as natural as other approaches, especially for wide-open scenes surrounded by sky, but it can render very quickly without raytracing. And in situations where only a smaller amount of sky is visible, such as within a canyon, a few spotlights may be all you need to create some sky illumination.

Sun and Sky Shaders

Available at the click of a button in many programs, linked sun and sky shaders allow you to create a sunlight and sky fill all in one step. These shaders simulate many effects for you automatically. For example, when you move the sunlight lower in the sky, it automatically changes color to simulate the color of the setting sun, and the sky's color and brightness changes to match it.

When choosing approaches to lighting, you need to think ahead, beyond the first version that you render. After you render version one, chances are that you will need to show your work to your client, creative lead, director, or art director. At that time, you will get notes on how to proceed to the next version. Even if physically based sun and sky shaders saved you time on lighting the first version, they can sometimes limit your ability to adapt to art direction after that. For example, if you are asked to make the sun a little pinker as it sets, it's easier to directly adjust the RGB color of a light than to look through options labeled "Turbidity" and "Ozone" and adjust them to see how the sun's color happens to respond. Time saved up-front on an easy, preset setup does not always speed up your overall workflow in the long run.

Image-Based Lighting

Image-based lighting (IBL) provides an alternative approach to simulating skylight. With IBL, you map an image to a sky dome surrounding the scene, and the colors and tones from that image are used to illuminate the scene. Figure 4.9 is a test-render of the scene lit only by a texture map of a sky and clouds.

[Figure 4.9] This test-render shows a scene lit entirely by IBL instead of lights.

When you use a High Dynamic Range Image (HDRI) format, all of the colors and tones from a real environment can be included in one map for IBL. A huge range of HDRI maps are available for free or for low prices over the Internet, or you can make your own. (Chapter 6 describes how to make your own HDRI.)

IBL holds the promise of great convenience and realism if you happen to have a texture map that perfectly matches the environment you are simulating. IBL also lets you use whatever map you make to represent the environment in reflections, potentially increasing the realism of any shiny or reflective objects in your scene.

In a few ways, it is possible to adjust the lighting on a scene lit by IBL: You can adjust the overall diffuse and specular brightness emitted from your dome light; you can rotate the whole map around to face a different way; you can adjust its overall tint; and you can add conventional lighting to it, aiming extra lights into the scene wherever the illumination from the IBL itself doesn't meet your needs. However, lighting your whole scene based on a premade map is still creatively limiting compared to lighting your scene with fully adjustable individual lights. As with the sun and sky shaders described earlier, sometimes taking this approach makes it easy to create the first version of your lighting, but makes it more difficult to iterate your scene into different versions and adapt your lighting based on creative notes from the director or art director.

Working with Indoor Natural Light

Indoor light can be a mix of natural light that comes in through windows, doors, and skylights, and artificial light sources. The artificial light sources simulated in the scene are called *practical lights*, and those are discussed in the next section. As a first step in moving indoors, start with the natural light—including sunlight, skylight, and indirect light—which you can add to interior scenes in almost the same way as you did outdoors.

Adding Skylight

When adding natural light to an indoor environment, it sometimes makes sense to start with the light from the sky rather than the sun. Sometimes you see a sunbeam coming through a window, other times you don't. Direct sunlight only enters a window when it happens to come from the correct angle. Skylight, on the other hand, always enters through every window, as long as it is daylight outside and you can see out the window.

As it was when we were working with lighting outdoors, sky illumination is a broad, soft light that simulates all of the light coming from every visible part of the sky. It is possible (but not efficient) to put a full sky dome outside of your 3D building and let some of the light from that dome enter through the window; however, this approach can lead to very slow render times, because light from every possible direction is computed, even when most of the sky dome is not visible through the window.

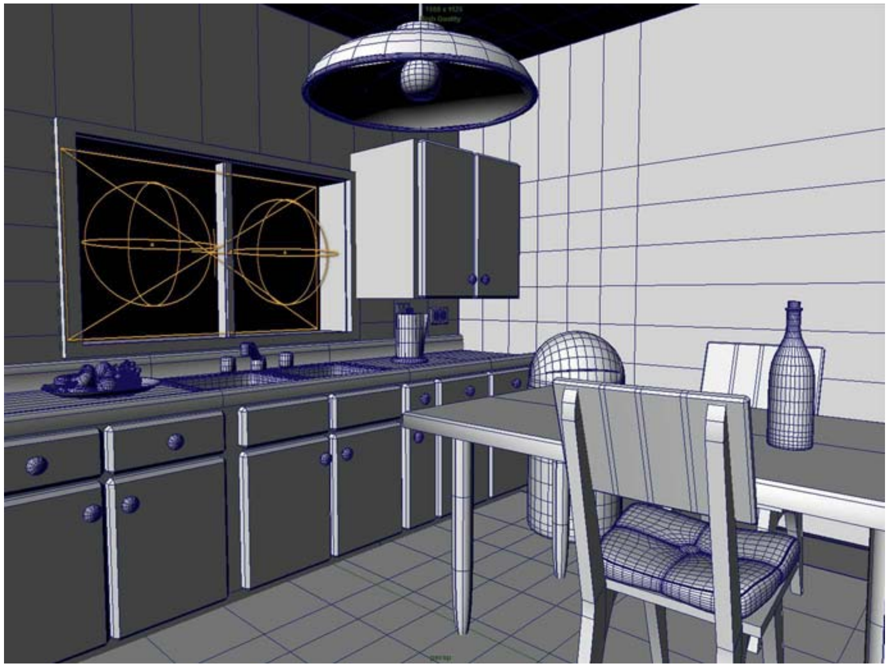
Area Lights in the Windows

Area lights aligned with a window are often the most natural way to simulate sky illumination coming inside. Place a rectangular area light just outside of a window, door, or skylight, and give it a color matching the sky. Of course, if the window is round, you can use a disc-shaped area light, and you can use multiple area lights for more complex groups of windows.

If a background image is visible through the window, then use the color of the sky visible outside to guide the color of your area light. If the outdoor area is a 3D scene, use the color from the outdoor sky fill for the area light in your window.

Some renderers have a special kind of area light called a *portal light*, which is like a regular area light except that it gets the brightness and color from a corresponding sky dome that surrounds the scene. A portal light simulates getting light and color from a sky dome without the inefficiency associated with sampling a full sky dome when only a tiny part of the dome is visible.

Even if you only have one window in the scene, it's OK to use more than one light to simulate skylight from that window. A rectangular area light, matching the shape of the window, is technically a good fit, but sometimes you want to use more lights to help fill more of the room with soft illumination. A spherical area light can create a nice, soft ball of light, emitting soft illumination from just outside the window. In the example kitchen scene, two windows are side by side, so two spherical area lights have been added outside the window, as shown in Figure 4.10.



[Figure 4.10] Rectangular and spherical area lights are both added to each window. This kitchen model is from Lighting Challenge #2, which you can download from www.3dRender.com/challenges in multiple file formats.

The spherical area lights in this window overlap with the rectangular area light, and they are partially inside the room to help the fill light spill out to a broader angle. Figure 4.11 shows what the window fill looks like from the rectangular area light by itself (left) compared to how the scene looks with the spherical area lights extending the sky illumination (right).

[Figure 4.11] Rectangular area lights in each window (left) simulate sky illumination around the window, but adding the spherical area lights (right) extends the illumination to fill more of the scene.

Usually it's best to test-render the skylights without any GI activated. The scene will have high contrast but images can render faster, and such an image shows you what the sky fill looks like by itself, without any light in the scene. You may come across exceptions to this rule if a technical option on the area light or portal light requires GI to be turned on, but in general it's best to get a clear look at what the light does by itself when you are first setting it up.

Check the area immediately around the window and make sure surfaces near the window appear to be convincingly lit by the window light. The light should spill out into the room so that any surfaces immediately above, below, or beside the window receive some light from outdoors.

Excluding Window Geometry

If you have a 3D model of glass in the window, then use light linking to remove the glass from your lights. Otherwise a light very close to the glass itself or intersecting with the glass might create unnatural highlights on the glass, or the glass might block or shadow the light.

You can sometimes use shadow linking to remove thin pieces of geometry in the window itself (such as window frames, bars on the window, or blinds) from the fill light's shadow. When a soft area light illuminates the whole room, the shadow of a thin bar on the window spreads out so that it no longer looks like a shadow of a bar; instead it just creates extra noise in the area light, and can require more shadow samples if it isn't removed from the shadow completely.

You may wish to set the clear glass in the window so it does not to cast any shadows. You should not do the same thing for window frames or other opaque geometry, however. Even if you prevent this geometry from casting shadows in the sky fill, you still want it to be able to cast shadows in a sunbeam if sunlight enters the window.

Adding Sunlight

Check your background image (or whatever you see through the window) to see what direction the sun seems to be coming from and if it's sunny outside. Windows don't always have a sunbeam, especially if the sun is coming from the other side of the building.

Create a bright, warm directional light, just as you did for sunlight outside. If you don't want to use a directional light, a spherical or disk-shaped area light can work just as well, but make sure to position it far away from the window to achieve the kind of distant perspective that people expect from sunlight. Test-render your scene to see where the sunbeam is cast into your room, and rotate or move the light until it hits where you want. Figure 4.12 shows the room with a sunbeam added.

[Figure 4.12]
A directional light adds a sunbeam to the room.

Adding Spill Light

The sunlight shouldn't cut off completely at the edge of the sunbeam. Just like when you were working outside, the spill light should be outside the sunbeam, simulating the extra light that comes from the bright parts of the sky around the sun itself. Figure 4.13 shows the difference that spill light can make.

[Figure 4.13]
Compare the sunlight by itself (left) to the addition of a spill light (right)–the spill light adds a warm outer glow around the sunbeam.

If you are using a directional light for your sun, then to create a spill light, you only need to duplicate the directional light, modify the shadows to be much softer, and reduce the intensity of the light. Often it looks good to use a rich, saturated color (more saturated than the sunlight itself) for the spill from the sun.

Adding Indirect Light

When light hits each surface in your interior scene, any brightly lit surface essentially functions as a light source, illuminating other objects with indirect light that has reflected off of it. The floor, the walls, and certainly any object hit by a sunbeam motivate indirect light that needs to illuminate the rest of the scene.

Adding Global Illumination

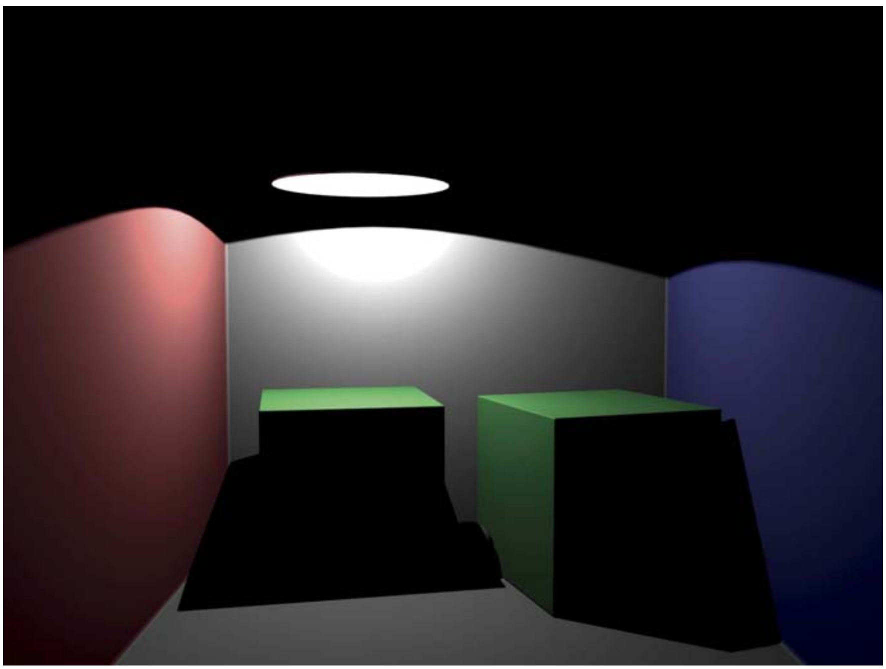
By far the easiest and most realistic way to render indirect light indoors is by using global illumination (GI). Turning on GI in your renderer allows the color and brightness of each surface in your scene to help illuminate other surfaces around it; this gives you naturalistic results without your having to work to set up extra lights to simulate indirect light.

Figure 4.14 shows the difference that GI makes to the scene. Using only the sky fill, sunlight, and sun spill lights coming through the window, GI extends the natural light from the window to fill the entire room.

[Figure 4.14] The sunlight and skylights through the window (top) are augmented by indirect light bounces (bottom) when global illumination is turned on.

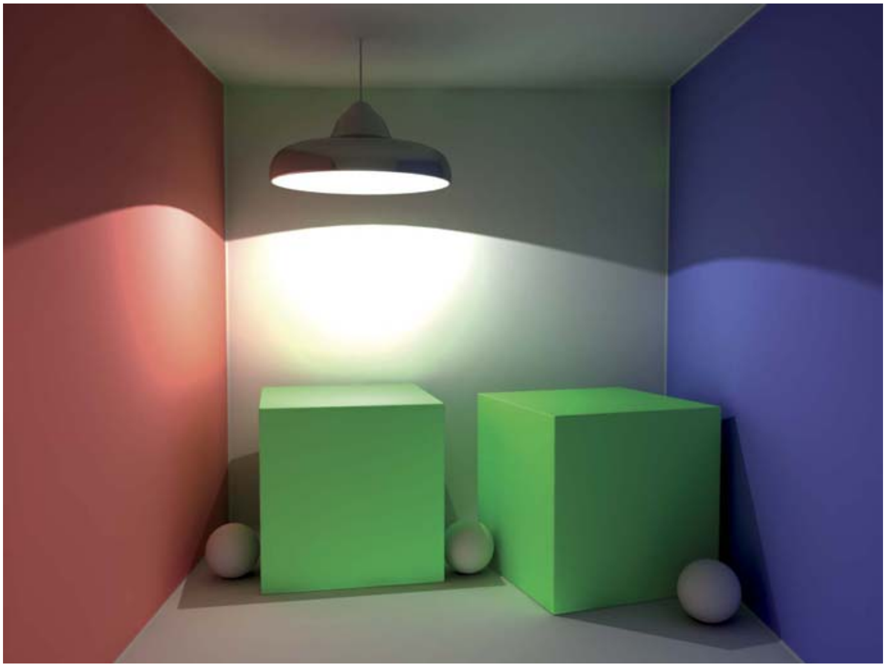
When you turn on GI, it is not just another source of fill light. When you activate global illumination or indirect illumination in your renderer, you are fundamentally changing how the lighting in your scene works.

Consider a test scene illuminated by a single light source, as shown in Figure 4.15. Without GI, surfaces are only lit by the light source itself. Parts of the scene that don't directly face the light remain black.



[Figure 4.15]
With no global illumination, a scene lit by a single light source contains solidly black shadow areas.

Figure 4.16 shows the same scene rendered with GI. When you use GI, surfaces are lit by other surfaces. One brightly lit surface can indirectly brighten other surfaces that face it. This is why shadow areas of the scene are brightened and filled in.



[Figure 4.16]
Global illumination adds indirect illumination bounced from the walls that fill in shadow areas, as well as adding secondary shadowing and color bleeding.

One nice feature you can achieve through GI is secondary levels of shadowing, where shadows are created even within other shadows. Look at the three balls in Figures 4.16. Without GI, there you would have only a single level of shadowing, and the balls would be hidden in the shadows cast by the cubes. With GI, you get secondary shadowing, even though the scene only has one light. Not only do the indirect light bounces make the balls visible, they also provide secondary shadowing, casting soft shadows from the balls onto the floor.

Also notice the colors of light that illuminate the three balls: The first ball appears red because of the light that has bounced off of the red wall; the second ball appears green because of light that has bounced off the two green cubes; and the third ball appears blue from the light that has bounced off the blue wall. This feature of GI, the way the indirect light picks up the colors of surfaces that it bounces off of, is called *color bleeding*.

One area where you can inspect any architectural rendering for quality is in the corners, where two walls meet, or where a wall meets the floor or the ceiling.

Corners are the areas where light most closely inter-reflects between walls. As a result, your scene should show continuity at the corners—a continuation of tones from one wall to another, rather than a sudden jump in brightness. GI tends to provide this, so that you can see a smooth, continuous sharing of illumination where two walls meet. When you are lighting without GI, even if you add extra bounce lights to the scene, you need to put in a lot of effort to achieve really convincing corners.

We use the term *local* illumination to describe rendering without GI, and call GI *global* illumination, which refers to how many other surfaces in the scene are taken into account when a surface's illumination is rendered. Without GI, each surface is rendered by itself; this process takes the light sources into account but not the brightness of nearby objects. With GI, illumination is computed taking all the geometry in the scene into account, so light hitting any surface may indirectly brighten other surfaces in the scene. The inclusion of all the geometry in the scene is what gives the "global" perspective to the illumination process.

GI rendering allows indirect light to contribute to diffuse illumination. In other words, GI can indirectly brighten even matte-finished surfaces—surfaces that are not shiny or reflective. With GI turned off, you can still use conventional raytraced reflections for reflective objects, but raytraced reflections by themselves don't transport light from diffuse surfaces to other diffuse surfaces. Only GI gives you true diffuse-to-diffuse light transport. Only GI allows any brightly lit surface to brighten other objects, not just as a reflection but as a light source.

[Figure 4.17] Reflectors are used to bounce light onto actors or sets.

The idea that reflected, indirect light can function as a light source is something that GI lighting has in common with live-action filmmaking. Especially when working outdoors, where bounced sunlight can be a brighter light source than many types of artificial light, filmmakers often use bounce cards or reflectors to light their scenes, instead of doing all of their lighting with lights. On a sunny day, reflectors, as shown in Figure 4.17, can provide all of the fill light filmmakers need when filming scenes outdoors.

Chapter 9 will come back to global illumination to discuss the different types of GI algorithms that your software may support. Although these algorithms can add to the quality of your imagery and may save you many hours of work as a lighting artist, they all come at the expense of slower overall rendering times. As computers get faster and software becomes more advanced and efficient, there are fewer and fewer reasons to render architectural interiors or realistic indoor scenes without using GI. However, for some extremely complex scenes, short-deadline projects, and some types of subject matter—such as hair, fur, grass, and vegetation, which are difficult to include in a full GI solution—the limited nature of rendering time still makes some people work without GI.

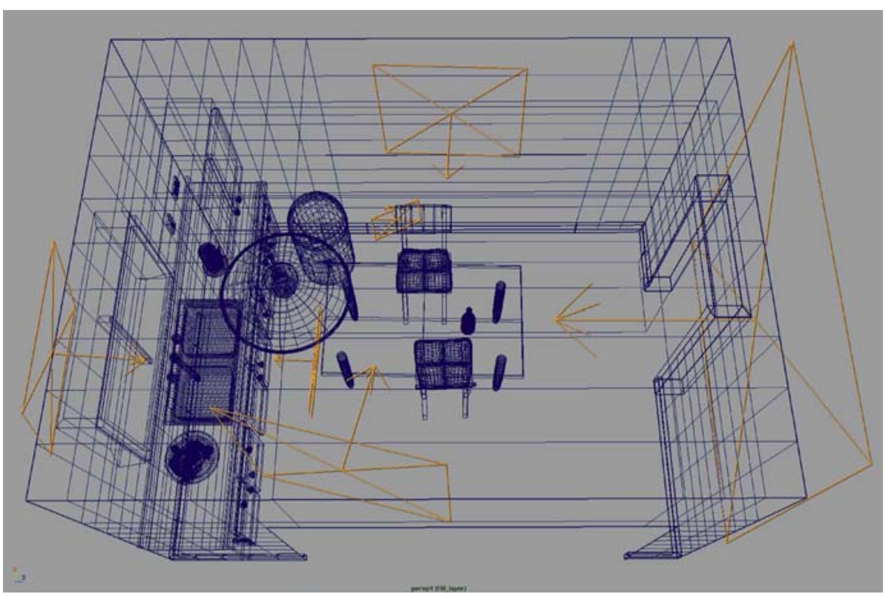
Working Without GI

If you want to simulate indirect light without using GI, often the easiest starting point is the *occlusion sandwich* approach, which was discussed in Chapter 3.

Figure 4.18 shows a fill light layer that includes two light colors: Blue light is coming from the window area and warmer light is coming from inside the room where the sunbeam would be hitting.

The fill light layer is a great place to add bounce lighting, because it does not need to include shadows. The occlusion layer adds shading later, but for this layer you can use area lights positioned outside each wall to light the scene. A blue area light is positioned outside of the window and warm colored lights illuminate the scene from other directions. The bright area where the sunbeam hits the table and walls motivates extra bounce light, so extra area lights are added coming from those parts of the scene. Figure 4.19 shows the area lights used in rendering the fill layer.

[Figure 4.18]
A fill light pass is evenly lit, but it does feature some color variation.



[Figure 4.19]
Area lights from every major surface are used to illuminate the fill pass.

As a quality-control check on your fill light layer, take a look at the corners where two walls meet, or where the walls meet the ceiling or floor. The illumination on the different surfaces should be roughly equal, without any big jump in brightness between the connected surfaces. Although some variation in color and tone is good, the fill light pass should be smoothly, evenly lit, without any high-contrast jumps in the brightness.

Also check your fill light layer to make sure no noticeable specular highlights or extremely bright spots are in the scene. By using broad, soft area lights as fills instead of tiny point-source lights, you help avoid unmotivated highlights that come from what should be bounce light from a wall. The fill layer also should not have any completely black areas unless you are sure an area in your scene would receive absolutely no fill or bounce light.

The middle layer in the occlusion sandwich is the occlusion pass of the room, as shown in Figure 4.20. Note that corners are softly darkened, and alcoves, such as the area under the upper cabinets, go much darker. This shading helps your bounce lighting look more like real global illumination.

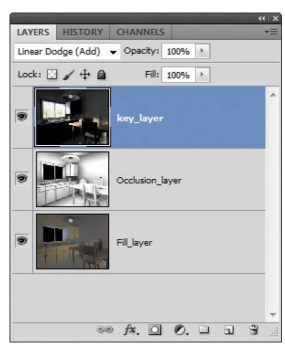
[Figure 4.20]
The occlusion pass is the middle layer of the occlusion sandwich.

We already have the lights that go into the key layer of the occlusion sandwich. We render an image lit by the sunlight, sun spill, and sky fill lights, all as described earlier. The result still has dark areas because of the lack of GI, but otherwise it should be a fully lit scene, as shown in Figure 4.21.

[Figure 4.21]
The light pass is mainly just the sunbeam and other direct illumination.

Assemble the occlusion sandwich in your compositing software or a paint program starting with the fill layer as the base. *Multiply* the occlusion layer and then *add* the key layer on top. Figure 4.22 shows the occlusion sandwich assembled in Photoshop.

The result is shown in Figure 4.23. Although it might not match the output with global illumination, it gets pretty close, and the scene can be rendered much more quickly.



[Figure 4.22]
The occlusion sandwich assembled as layers in Photoshop. Blend modes are Normal for the Fill layer, Multiply for the Occlusion layer, and Linear Dodge (Add) for the Key layer.

[Figure 4.23] The result of the occlusion sandwich looks somewhat similar to global illumination, but it is produced in a fraction of the rendering time.

Practical Lights

Practical lights are the light sources that are visible as models within your scene. Indoor examples of practical lights include lamps, light fixtures, television sets, or any other model you've built that emits light. Outdoors, practical lights include street lamps, vehicle headlights and taillights, illuminated signs, and lights on buildings.

There are two different aspects to simulating the illumination from a practical light. You need to light the source itself (such as the actual lamp or lightbulb), and then you need to light the surrounding set as if the lamp is casting illumination into the scene.

Lighting the Light

If you want to illuminate a bulb model using a light, you can position a point light in the middle of it where a filament would be located, and give the outside of the bulb a translucent shader that gets brighter when backlit by the interior light source. As discussed in Chapter 2, inverse square (also called a quadratic decay rate) is the most physically correct setting for a light. To get realistic variation in brightness across the bulb's surface, give the light source inverse square attenuation.

[Figure 4.24]
A bare lightbulb can feature a gradient making it brightest in the center.

As an alternative to adding a light within the bulb, you can shade 3D models of lightbulbs with a luminosity, ambient, or incandescence map so that they appear bright without regard to the local lighting. The real drawback to adjusting the shader to make the bulb bright is that when you try to isolate your lights and render with only a single light visible, the glowing shader is still present, even when lights around it are hidden. Bulbs need to be texture mapped if they are to be seen up close. A lit bulb may have a bright middle area, but it can become less bright where the glass is attached to the metal base and near the top, as shown in Figure 4.24.

The immediate area around a light source often requires some dedicated lighting. For example, a lamp surrounded by a lamp shade receives a great deal of bounce light as light is reflected off the interior of the shade. With GI you can allow the lamp shade to bounce light back onto the lamp, or you can add bounce lights to illuminate the lamp itself with simulated indirect illumination.

If you are positioning any light inside a 3D model of a lightbulb and that light casts shadows, then you may want to unlink the light from the bulb model so that it can shine through the bulb and illuminate the surrounding area. Otherwise the bulb model may cast a shadow that effectively blocks any of the light from reaching the rest of the scene.

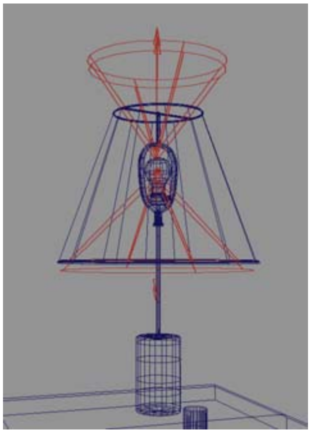
Set Lighting from Practical Lights

Just because you are simulating a single practical light source doesn't mean that you need to light it with a single light in 3D. Often you will observe several different effects on the set from a single practical light and use a light in 3D for each of these effects. For example, the lamp in Figure 4.25 emits a soft glow through the shade, a cone of light aimed up through the top of the shade, and a cone of light aimed down from the bottom. You simulate this using a point light that shines out through the shade, plus spotlights aimed upward and downward to simulate the upward and downward cones.

[Figure 4.25]
The lamp casts a dim glow through the shade, plus harder illumination through the top and bottom openings, and a little spill around the hard circles of illumination.

Adding Spill

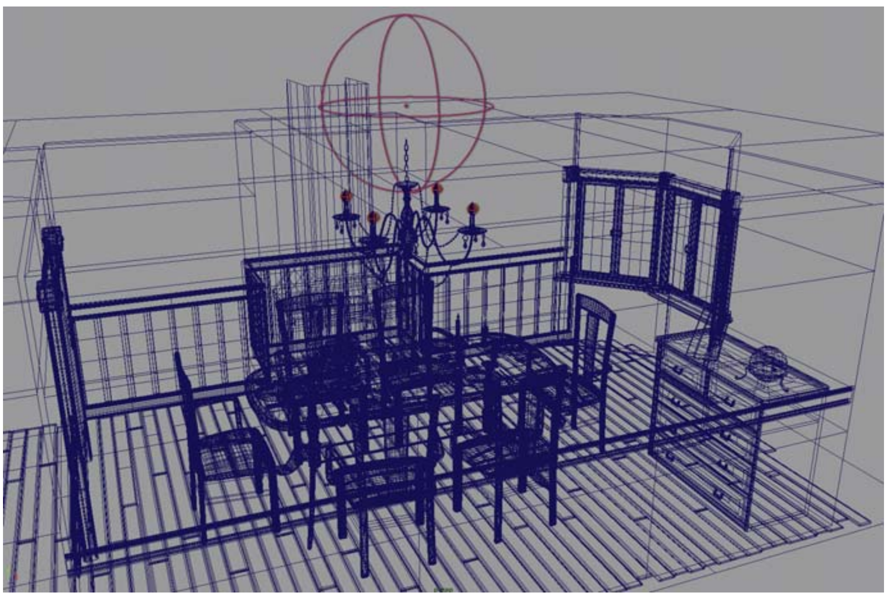
Often, projecting one spotlight in a particular direction isn't enough. You usually see a broader, dimmer cone of light around the main light source, which is a kind of spill light. For example, if you use one spotlight for the illumination cast upward from a lamp, you may need another spotlight, with a broader cone angle and a much dimmer intensity, to add a spill around the area. Figure 4.26 shows how the lighting in Figure 4.25 was created: Two spotlights aim upward and two aim downward, including the main cones and the outer spill lights. The outer spill lights can simulate light that bounces off the lamp shade instead of being aimed directly from the bulb.



[Figure 4.26]
A pair of spotlights are aimed upward, and two more are aimed downward, so that spill can be created around each circle of light.

Lighting Larger Areas

When you want to add illumination to larger areas of your set, sometimes individual lightbulbs in a light fixture just aren't enough. For example, suppose you have a chandelier in the middle of a room. It may have many individual bulbs within it, and you need one practical light for each bulb in the chandelier. However, turning up the brightness of these lights too high can spread hard-edged shadows all over the set and cause bright highlights on any surface that is shiny or reflective. Instead, you can create a softer type of light motivated by the chandelier, as shown in Figure 4.27, by adding a larger spherical area light above the chandelier.



[Figure 4.27]
One of the "secrets" of lighting design is that the actual light source doesn't have to come from the practical bulbs themselves. Here, a spherical area light (the large orange ball) is responsible for most of the illumination motivated by a chandelier.

You can use shadow linking to prevent the ceiling, and the chandelier itself, from casting shadows in the large area light. This way, the area light fills the room with soft, even illumination, without lots of noise from sampling soft shadows through the complex geometry of the chandelier.

Throw Patterns

The *throw pattern* is the shape or texture of the light that is cast into the scene from a light source. We can recognize distinctive throw patterns from car headlights, flashlights, burning torches, and many other light sources. In real life, often a complex throw pattern is caused by reflection or blocking by structural elements within the light fixture. Figure 4.28 shows a throw pattern cast by a flashlight. Interestingly, when you study different flashlight throw patterns, you see that no two models of flashlight cast exactly the same pattern into the scene.

In 3D graphics, you can create throw patterns by applying a cookie or map on the light source. If you use an image such as Figure 4.28 as a cookie on a light, it will help simulate a flashlight's beam as well as its outer spill light both from the same spotlight. Another way to simulate different throw patterns is to model geometry around the light source. The shape of the geometry can cast a shadow, or the geometry can be transparency-mapped with an image, creating an effect very similar to a cookie directly mapped onto the light.

[Figure 4.28] The throw pattern from a flashlight. If you used an image like this as a cookie, then you could simulate both the main light and the spill around it all from one single spotlight.

You can also use a cookie to tint the edges of a spotlight's beam. In many real spotlights, a more saturated or reddish tint appears near the edge of the beam, just before it falls off to black. A cookie with a reddish edge can help simulate this and make softer, more naturalistic throw patterns for your spotlights. If all you want out of a cookie is to tint the outer edges of a spotlight, then you can also use a procedural ramp or gradient texture, and you don't even need to paint a map.

Any time you are tempted to aim a spotlight into your scene and have it add just a plain circle of light, stop and think whether a more complex throw pattern could be more natural looking.

Night Scenes

You can create night scenes by combining techniques I have described so far in this chapter. You can create natural light coming from the moon and night sky using the same basic principles as with daylight, with just a few modifications. Practical lights, such as streetlights, light from buildings, and car headlights, also add to most nighttime scenes.

You can create light from the moon the same way you did for the sun. Usually light from the moon appears much dimmer than other lights such as streetlights. Only when you get far away from cities and towns does the moon start to become a dominant light source like the sun. Moonlight can appear either blue or yellow. Most often it appears yellow in scenes where light comes only from the moon and the night sky. If you see moonlight in addition to light from lightbulbs, the moonlight appears bluer.

At night, usually light from the sky should be a very soft blue glow. As with light from the moon, you don't want the sky to appear too bright. In cities or indoor scenes, natural light can disappear, and many night scenes are lit entirely by practical lights. At nighttime, even light coming in through a window is as likely to be light from a streetlight or car headlight as it is to be natural light.

The key to lighting night scenes is not to underexpose the entire scene, but to use a lot of contrast. The scene may be dominated by shadows, but you need to break up the darkness with bright highlights and selectively apply rims and glints of light.

You may have noticed that many night scenes in Hollywood movies feature wet pavement, making them look as if it has just rained. This is often the case even in dry cities like Las Vegas. Cinematographers are always looking for ways to capture extra glints of light and reflections in their night scenes. Since they have discovered that spraying water on the streets is a great way to get the city lights to reflect off the street, and since this makes prettier night scenes with more highlights in them, they do this even when it is obviously a cheat.

If you have any surface in your scene that can be reflective, feel free to use it wherever you need more contrast or visual interest. In Figure 4.29, for example, I added an extra light to the porch in the background. I set it to emit specular only and linked it to the street itself, so that it makes the street glisten without adding brightness to the surrounding buildings. I also used light linking to add a light that exclusively illuminates the hanging cables. These extra glints of light create interesting lines and contrast, even within a scene that is made up mostly of dark tones.

[Figure 4.29] A night scene takes advantage of a wet-looking ground to reflect the practical lights.

Distance and Depth

You can divide up space and show distance with your lighting in many ways. Instead of lighting all parts of a natural environment uniformly, you can depict natural variation in color and tone that exist in different parts of a scene.

Dividing Up Space

Many scenes let you look through a door or stairway so you can view more than one room, area, or floor of a building. Each area of a scene like this can have different lighting. If one room has a window that lets in daylight and another room is lit by a lamp or a ceiling light, then you'd expect the room lit by daylight to be brighter and have cooler, more blue-colored light, whereas the room lit by the ceiling light would appear less bright but have warmer colored illumination, as shown in Figure 4.30.

[Figure 4.30] Mixing colors of light sources with a dimmer, warmer light in the foreground hallway helps divide the space in this scene.

Even within a room, corners can receive different light than the middle of the room, or there can be a transition of color and brightness between the area around a window and the parts of the room farther from the window.

If you can create a distinction between areas that are in direct sunlight and areas that are in the shade, then that's another good way to divide up your scene. Indoors, parts of your scene can be in a sunbeam while other parts are outside of it. Often, a scene split between sunlight and shade serves to highlight the objects or characters that appear in the sunlight, but this isn't always true. It's possible to have a central subject that stands prominently, entirely in the shade, and have it set apart from a brightly overexposed background that is in direct sunlight. No matter where your center of attention is positioned, it's the contrast between the subject and the background that helps it pop out.

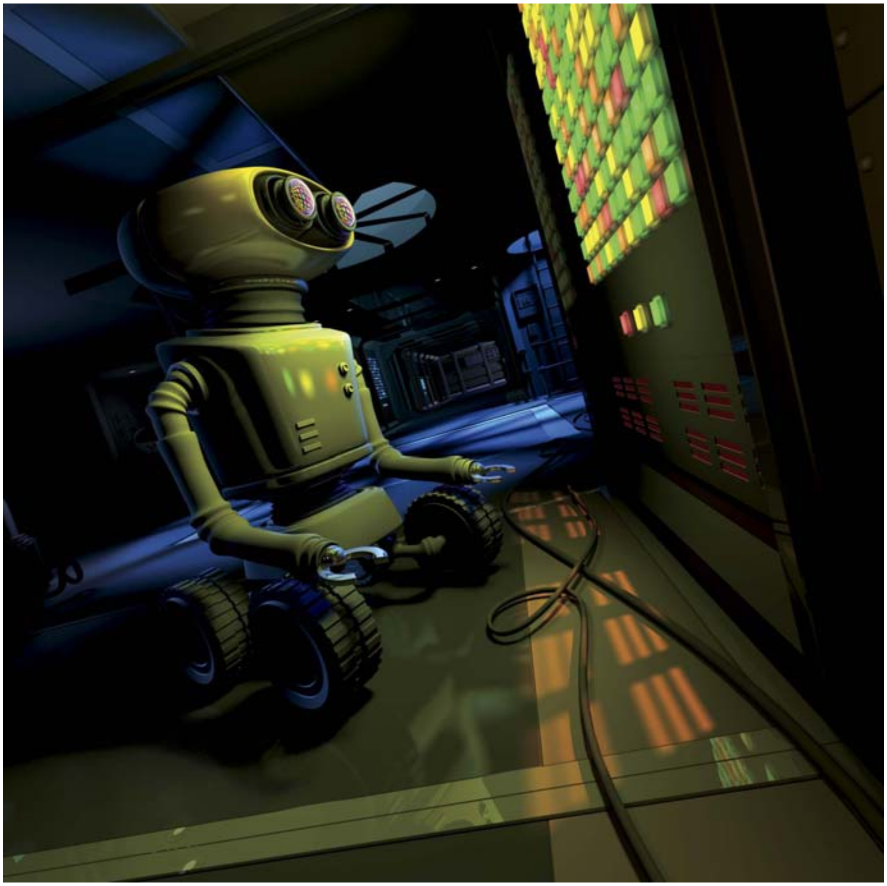
Even small differences between rooms—such as differently adjusted blinds or shades on the windows, or different color curtains or walls can lead to differences in the lighting in different rooms. Although light can flow through doors, windows, and stairways within your scene, the light cast through an opening only lights one part of a room, and where a scene is divided into different spaces you always have the opportunity to vary your lighting.

Defining Depth with Lighting

When designing the lighting for any larger set, you need to choose a strategy for how to portray the distance as you head away from the camera, into the background. Many approaches are possible: You can move from a bright foreground to a dark background, you can have a dark foreground and a bright background, you can alternate light-dark-light, or you can separate areas with color. Different designs work for different spaces. The important part of this issue is that you are creating a two-dimensional image that needs to depict three-dimensional space, so your viewers are able to see the difference between things that are close to camera and things that are farther away.

Figure 4.31 starts with a simple version of this: It has a bright, colorful foreground area, full of warm light, and a background that gets darker and uses cooler, blue tones.

In Figure 4.31, the background itself is broken up into different regions. Although the whole background is dominated by blues and cool tones, the middle hallway is lit from above, with light coming down through a fan, whereas the far background is less saturated, with more blue-colored instrument lights.



[Figure 4.31]
Space can be divided between a brighter foreground and a darker background, among other variations. This scene is Lighting Challenge #18, modeled by Juan Carlos Silva.

Whenever the background is a different color from the foreground, or you have bright light visible in the background, you can think about adding some rim light to the subjects in the foreground motivated by the background light. A few highlights or some rim light that match the background color can help tie together the background and foreground. In this case, the blue rim light along the robot's back also helps separate the robot from the darker background area behind it.

In real cinematography (unlike computer graphics) the camera is a physical object that can cast a shadow. Because of this, objects often appear darker when they get extremely close to the camera. For example, if a door is opened or closed in the foreground, the door itself often looks very dark when it shuts into a position near the camera, as if the scene itself were being wiped to black. Or if a ball is thrown directly at the camera, the ball becomes darker as it reaches the camera and fills the frame. You can avoid this effect in real cinematography in several ways (you can attach a ring light to the camera lens, brightening what's right in front of the camera, for instance), but the convention of objects in the foreground becoming darker, or turning into silhouettes, is seen in many films.

Adding Atmosphere

Atmosphere plays a role in many scenes, tinting and changing the appearance of more distant objects. In any situation in which it might be appropriate, you should look for a chance to use atmosphere to add variation with distance.

- Dust adds to the atmosphere of many outdoor environments and sometimes is visible in the air indoors in barns or old buildings.
- Any room with smoke in it, including rooms lit by torches or candles or places where people smoke or burn incense, can have a lot of visible atmosphere.
- Underwater scenes are essentially scenes with a lot of atmosphere that tints and desaturates and causes distant objects to fade away.
- Almost all outdoor scenes, if you can see all the way to a distant horizon or distant hills, have atmospheric perspective that shifts the more distant parts of the scene into a bluer, less saturated tone, as shown in Figure 4.32.
- Many kinds of weather conditions make the atmosphere more visible. Rain adds the drops themselves, plus extra mist and fog as well. Snow in the air also creates atmospheric perspective as distant objects become whiter.
- Even depictions of outer space sometimes have something like an atmosphere, in the sense that dust particles or the emissions from a rocket can float in space in between the objects in your scene.

[Figure 4.32]
Each successive mountain in this photograph has a lighter, bluer color, thanks to atmospheric perspective.

Modern rendering software offers you a whole range of different approaches for adding atmosphere to your scenes.

One simple, but somewhat limited, option is to turn on a fog effect from an individual light. This allows you to create a visible light beam easily, such as a beam of light coming through a window. However, it can sometimes look unrealistic because in real life, atmosphere tends to be spread through an entire room so that areas in the light or not in the light are all filled with the same amount of dust or smoke. If you set individual lights to emit visible fog effects, then you should also think about adding an overall atmosphere to the whole room, including the areas outside of the light beam.

An efficient approach to adding overall atmosphere to a scene is covered in more detail in Chapter 11. If you render a *depth pass* of your scene, which shows the distance from the camera to each object, then the compositor can use that information to tint, desaturate, or soften distant parts of the scene. This approach lets you simulate the overall look of atmospheric perspective in your scene, although it doesn't visibly respond to each light.

For atmosphere that responds realistically to each light, by forming visibly brighter areas or light beams in the air wherever the light is brightest, you can apply *volumetric fog* shaders, which are available in many programs. Volumetric fog makes the air (or water) in your scene respond realistically to light so that shafts of light or visible light beams can form where light and shadows cut through space, as shown in Figure 4.33. Using volumetric fog can add greatly to your rendering time, but the results often look much more realistic than what you can create in compositing software from an overall depth pass.

Finally, moving into a full particle simulation within your environment is an option that can simulate not only the presence of atmosphere, but also the movement of smoke or dust through the scene, as it responds to wind or character movements. When you fill a dusty barn with a particle system of floating bits of dust, you give a tremendous boost to the dimensionality and realism of the overall space, and you also add to the overall effect of fading out and desaturating more distant surfaces.

[Figure 4.33] Volumetric fog makes light filtered through stained glass windows visible in the air. This scene is Lighting Challenge #8, modeled by Dan Wade, concept by Gary Tonge.

You can render using a depth of field (DOF) effect that simulates selective camera focus to complement and enhance the effects of atmospheric perspective while diffusing more distant objects and drawing our attention to the foreground (or to whatever object is in focus). If your final scene will be rendered with DOF, then it's a good idea to turn it on when you test your atmospheric effects, because the two effects work together to create the final look of your scene.

Going Underwater

Being underwater is like having a very thick "atmosphere" around you. Even though we are trying to simulate water instead of air in this section, we can apply all of the same rendering techniques to create an underwater environment. Some computer scientists use the term *participating media* instead of *atmosphere* to describe whatever gas, liquid, or solid particles fill space in the scene and influence and respond to illumination.

You begin creating an underwater scene just as if it is above water. Add a directional light to simulate the sun. In a shallow pond or a swimming pool, you might need some fill light from the sky as well, although deeper in the water this might not be necessary. You can aim a bounce light upward to simulate light bouncing off the bottom of the pond to illuminate the bottom of objects. Figure 4.34 shows the humble beginnings of an underwater scene that still looks as if it is above water.

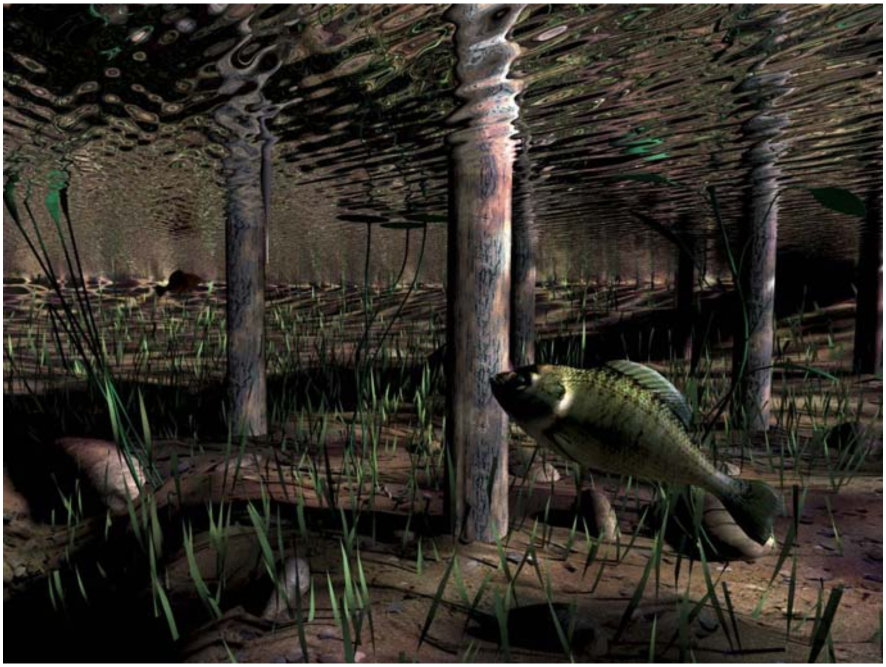
When we look out into an underwater landscape, the entire surface of the water looks just like a rippling mirror above us. Even if you make the water surface both transparent and reflective, giving it a realistic index of refraction of about 0.75 causes it to show mostly reflections. Only one area of the water surface above us, called *Snell's Window,* lets us see through to the sky and the world above the water.

The sunlight in such a scene should appear dappled, as if it is refracted caustics that have passed through the water surface. Although it might be possible to render this in a physically correct manner, you can save time by applying a cookie to the sunlight instead. If you want the sun to appear dappled below the water but not to appear dappled above the water, then you can transparency-map the caustic texture pattern onto a plane at the level of the water surface, and you can set that plane so it casts shadows but is not directly visible in the rendering.

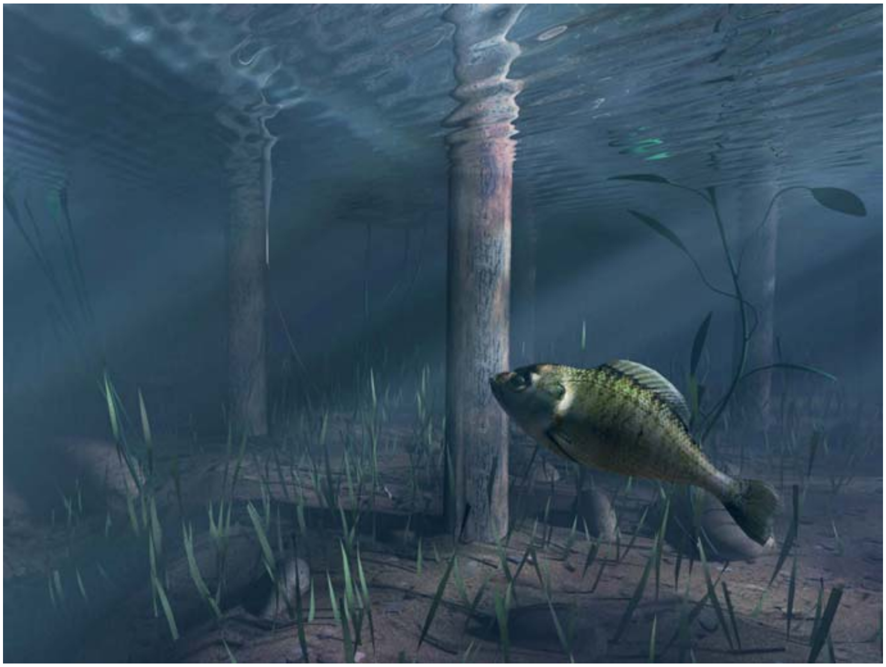
[Figure 4.34] An underwater scene without any atmosphere or water surface appears to be set on dry land. This scene is Lighting Challenge #5, modeled by Serguei Kalentchouk.

Figure 4.35 shows the scene with the water surface above and the dappled effect on the key light. However, it still doesn't appear to be underwater. What's missing is the atmosphere.

You can use a volumetric fog shader contained within a cube that fills the entire underwater area to add the atmosphere that really makes it look as if we are underwater, as shown in Figure 4.36. You need to tweak this to make sure the fog color (or scatter color) is bright enough to respond to light, which creates shafts of light where the dappled sunlight comes through the scene, and to make sure the shader absorbs light or darkens with distance enough so that the more distant parts of the water fade naturally and don't become too white. The best approach to this process is to set the resolution of your scene very low, with very low anti-aliasing quality and low quality for volumetric rendering; then you render small postage stamp–sized tests until you get the overall colors and brightness right. At this stage, the fill light can be turned down if you want to focus on the shafts of light from the key, or you can turn it up if you can't see enough of the foreground. Only once you like the overall colors and tones in the scene should you move into higher-resolution renderings.



[Figure 4.35] Adding a reflective water surface and dappled light gets this scene closer, but an essential ingredient is still missing.



[Figure 4.36] Adding atmosphere (or participating media) to the scene creates the impression of being underwater.

You can add a whole range of different effects beyond this. Sometimes you can use particles to simulate dirt and debris in the water, or add bubbles that float upward. Sometimes you can add pieces of sediment as individual polygons with transparency-mapped textures, thus scattering organic detail through the space.

In a pond, you don't want the view through the water to be too clear. Although the compositor can achieve other effects (blurring based on distance, or blurring what is seen through floating particles or bubbles), using DOF on your camera also helps blur the background and add realism to an underwater scene, as shown in Figure 4.37.

[Figure 4.37] Rendering with DOF nicely complements the underwater effect.

Exercises

There's no shortage of interesting environments to light and interesting ways to light them. I used several of the Lighting Challenge scenes as examples in this chapter, and most of them can give you experience lighting interior or exterior environments. Try to collect reference images that show a similar interior or exterior space at a similar time of day or night, and study the lighting in your reference image as you light the scene.

1. Between 1888 and 1891, Claude Monet painted image after image of haystacks. He captured the same subject over and over, in different times of day and in different seasons; he captured different lighting and colors each time he went back into the fields. If you're looking for exercises to improve your skills and your portfolio, don't be afraid to relight the same scene several times. Imagine what it would look like at night, early in the morning, or on a foggy day, and relight and rerender the scene.

2. Ambient occlusion is not dead. Some people are so accustomed to using GI that they already regard occlusion passes as a thing of the past. In reality, you will come across many situations in which you might need a faster technique than full GI. If you've never tried the approach that I call the "occlusion sandwich," try using it and see how you like the workflow.

3. Volumetric fog (also called volume shaders or environment fog) is a useful tool that's tricky to set up and adjust well in a lot of renderers. If you haven't done so before, then use your favorite rendering software to try to fill a scene with a fog or haze that responds to light.

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