

P | N | E M E T L O G R A P H Y

A Lighting Approach for Computer Graphics

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Siggraph '96 Course #30

T A B L E O F C O N T E N T S

Schedule	5
Speaker Biographies	7
Course Introduction	9
Storytelling Through Lighting by Sharon Callahan	11
Lighting from a Filmmaker's Perspective by Stephen Poster	41
Pixel Cinematography Lighting for Computer Graphics by John Kahrs	43
Lighting for Compositing and Integration by Dave Carson	69

C O U R S E S C H E D U L E

8:30 am	Introduction Kahrs
8:40 am	Lighting from a Filmmaker's Perspective Poster
10:00 am	Break
10:15 pm	Storytelling Through Lighting Calahan
12:00 noon	Break
1:30 pm	A Lighting Approach for Computer Imagery Kahrs
3:00 pm	Break
3:15 pm	Lighting for Compositing and Integration Carson

S P E A K E R B I O G R A P H I E S

Sharon Calahan, *Lighting Supervisor* Pixar Animation Studios

As the creative Lighting Supervisor for Pixar's "Toy Story", Sharon Calahan has been a member of the technical team at Pixar for the last two years. Her background and education in art and design led her into advertising, broadcast TV, video production, and eventually computer animation. With a focus on lighting direction, Sharon has worked in computer animation for over ten years. Besides "Toy Story" and various commercial work, other accomplishments have been as the computer animation Lighting Director for Hanna-Barbera's "The Last Halloween" which won an Emmy for Special Effects.

Dave Carson, *Visual Effects Supervisor* Industrial Light & Magic

Dave Carson has been at ILM for over 15 years, beginning as a storyboard artist and model maker on the second and third Star Wars films. He has worked in various roles on many remarkable films, primarily as a Visual Effects Art Director and Visual Effects Supervisor. His work in the digital realm includes acting as a Digital Artist on "Hook", "Forrest Gump" and "Jurassic Park". He also contributed character design and animation on "Casper" where he was credited as Character Design Supervisor. His latest projects include supervising the updating of work in "Empire Strikes Back" and "Return of the Jedi" for their new film releases. He is currently scheduled to begin work as a Visual Effects Supervisor on the next film in the Star Wars series when it goes into production later this year.

John Kahrs, *Animation Director* Blue Sky Productions

John has been directing lighting and animation at Blue Sky Productions since 1990. The focus at Blue Sky has been on a classic approach to character animation, combined with the very best rendering techniques. At the core of the production system is a proprietary raytracer, for which John has written much of the user's manual. John has made a priority of refining Blue Sky's lighting techniques. His lighting and animation appears in several commercials for clients including Braun razors, Chock-full-O'-Nuts coffee, and Brother laser printers. John designed and constructed the Blue Sky web site. He also has outlined the lighting direction for the CG cockroaches in the upcoming feature film "Joe's Apartment". In 1993, John won a Golden Nica Award for his radiosity imagery at the Ars Electronica festival in Linz, Austria.

Steven Poster, A.S.C., *Cinematographer*

Stephen Poster has worked on dozens of films, including Ridley Scott's "Someone To Watch Over Me", "Big Top Pee-Wee" and most recently "Roswell," about the reported crash of a UFO in New Mexico in 1947. Originally from Chicago, Poster was called upon early in his career to shoot second unit photography on "Close Encounters of a Third Kind" and "Blade Runner".

COURSE INTRODUCTION INTRODUCTION

How do you “Teach” Lighting?

Software tools and complex lighting models for computer graphics are some of the most elegant, sophisticated technologies of our time, yet the attention paid to lighting and refining the images is often minimal, and sometimes practically nonexistent. Conversely, we also see subtle, beautiful, resonant images made with computers. What accounts for this disparity?

An answer may lie in the fact that some computer artists have a deeper understanding of light and material qualities, while others may not even consider lighting as an issue. They may not have trained themselves to see and understand how light works, especially with the often incomplete lighting model in computer graphics.

This course focuses on the craft of lighting for computer graphics. Using a hybrid approach of traditional cinematography and knowledge about composition, color, balance, and the behavior of light and materials, it offers a comprehensive approach for lighting specifically in the field of computer graphics.

I think the idea for a lighting course specifically for CG is very timely. It's almost to the point where it's hard to find a sizeable Hollywood film *without* some kind of digital effect of some sort. The medium of computer animation is, I think, entering a Golden age. Software tools more powerful than ever, and elegant in their sophistication. A beautiful film called *Toy Story* has been embraced in and outside the graphics community. To just watch the Siggraph film shows from the past decade is to see technol-

ogy evolve into artistry. We hear a lot about how there's no ceiling, there's no end in sight, we're only just beginning, and all this limitless optimism can get on your nerves after a while, but the funny thing is that it's the truth.

Part of what inspired the idea for a course on lighting is the animation courses at Siggraph that seem to pop up every other year or so. I hoped to do for CG lighting what John Lasseter, Chris Wedge and others have done for computer animation. The influence of traditionally trained animators in the new medium reflected a sea change that was occurring in the late eighties: those who used the classic principles of animation applied them when using the new tools. This mood culminated in a 1987 Siggraph course: *3D Character Animation by Computer*, and more recently, 1994's *Animation Tricks*. Suddenly CG animation had grown up. The cliche of slow, computer-smooth motion became less prevalent. Now it was entertaining, exciting, and the entire medium was being taken more seriously. They succeeded because traditional techniques, hammered out over years of practical use and distilled down to a list of basic principles, were skillfully applied to a new medium.

I hoped that a similar approach could be applied to computer lighting: where the principles of traditional cinematography could be applied to the new tools. This is possible, but only to a certain extent. This is partly because, while there are many strong parallels, traditional techniques aren't so easily portable to computer techniques, as they are with animation.

As I wrote the course notes for my part of the talk, the idea of the course changed drastically. I had thought that the course speakers could teach lighting, plain and simple. I really thought, for some time, that in lighting too, much of the task could be distilled down to an essential list, and my ultimate model for such a list was "The Principles of Animation", a chapter in the indispensable book, *The Illusion of Life: Disney Animation*, by Frank Thomas and Ollie Johnston.

Then I was on the phone one day with Steven Poster, the cinematographer I asked to speak at the course to offer a look at lighting from a traditional angle. He said out loud what I had been sensing deep down more and more clearly. He said, "Oh, absolutely, no. No, you can't teach lighting. You can't teach someone how to light. You can only teach them about light and how it works, and you can give them a few guidelines, but you can't teach anyone how to light."

I realized my folly in presuming this. It was like figure drawing class in art school. No one could teach us how to draw. Only we, the students, could teach ourselves to draw better. The instructor was merely trying to get us to see more clearly: to observe and measure with our eyes and compare what we saw with what we had drawn. If the instructor was good, he was trying to teach us to see.

The process of computer graphics work is like working with a kind of complex diorama-machine. We're creating little worlds, and we can build everything almost as if from scratch, be-

cause the level of control can be so basic. There are so many different skills to be proficient in when we do this. We have to be Renaissance people.

This course isn't going to magically transform anyone's images into flawlessly refined pictures. All it can really do is offer a few guidelines, provide some important things to remember, and hopefully point you in the right direction with a solid footing about where to start.

The artistry of computer lighting has to come from your own vision and intuition about what you want to see. If it succeeds, it may help you see light in a way you hadn't before, and encourage you to teach yourself how to create truly great images.

So how to approach the task of lighting on the computer...

*John Kahrs
New York, May 1996*

STORYTELLING THROUGH LIGHTING

A Computer Graphics Perspective

By Sharon Calahan

ABSTRACT

This course is designed as a beginning, non-technical course to discuss the how lighting in computer graphics can be used to enhance visual storytelling for cinematic purposes. It collects knowledge and principles from the disciplines of design, fine art, photography, illustration, cinematography and the psychology of visual perception. Although much of the content of this course is not solely applicable to lighting on the computer, its special needs are always in mind.

1. Introduction

The desire to write these notes and to present a course on lighting for storytelling in computer animation arose from the shortage of available literature on the subject. Frequently I am asked to recommend a book or two on lighting, and although several good books are available, none are ideal. Most tend to focus on the equipment and mechanics of live-action lighting without explaining how to achieve the fundamental principles. The commonality between live-action lighting and computer lighting is chiefly the thought process, not the equipment. Computer tools vary with implementation, are continually evolving, and are not limited by physics. Tools in the future will be driven by the desire to see on the screen what we are able to visualize in our minds. This course is designed to focus on these thought processes, while providing not only practical information, but also the desire and resources to continue exploring.

The use of words alone is inadequate to describe visual concepts. Most books include many repetitive visual examples to drive the point home. Although a few crude visual examples are included in these notes, they are merely intended to serve as a reminder of the presentation of this course. These notes are also necessarily succinct, and may contain concepts which could not fit into the hour-and-a-half time allotment.

The term *lighting* in computer animation often includes the task of describing the surface characteristics of objects (often referred to as shaders), as well as compositing and the integration of special effects. For the purposes of this course, lighting is defined more in live-action terms as the design and placement of the lights themselves, but in a purely computer graphics environment.

Visual storytelling is a vast topic that reaches far beyond the realm of lighting. Most of it is not noticeable on a conscious level to the viewer, but adds depth and richness to the story and the visual experience. The lighting principles and techniques presented in this course are discussed in isolation from other visual storytelling devices. Ideally the lighting would be designed with these in mind, but would extend far beyond the scope of this course.

Cinematic lighting literature typically emphasizes live-action lighting issues and techniques, and in this discussion of lighting for synthetic cinema we will find that many live-action concepts apply. However, there are some differences in the approach, roles and responsibilities, the size of the crew, and the sequence in which tasks are accomplished.

In live-action, the lighting design, the staging, and framing of a shot are a collaborative and simultaneous effort between the director and cinematographer. Each activity affects the other, and it is important that they are fine-tuned together. Actors can rehearse the scene, staging and framing can be altered, and props can be redressed to take best advantage of the lighting design. This differs from the pipeline approach often employed in synthetic cinema, where the modeling, surface design, staging, framing, set dressing, and acting are accomplished sequentially, each usually established before the lighting designer begins to work. It should be kept in mind that the sooner in the production process the lighting can be designed, the more involved it can be in the storytelling process.

Another important difference between live-action and synthetic lighting can be the role of the art director. In live-action, the art director is absorbed in designing sets and props and is not usually involved in staging, framing, and lighting design. On the other hand, computer generated animation has a more stylized, illustrative quality, with its roots more in hand-drawn animation than live-action cinema. In addition to designing sets and props, the art director is also often heavily involved in the staging (layout) and lighting decisions. With the director, the art director is often responsible for determining the lighting style for individual sequences as well as the film as a whole.

2. Objectives of Lighting

The primary purpose of cinematic lighting is storytelling. The director is the storyteller and it is his vision that the lighting designer is attempting to reveal. To that end, it is important to understand the story-point behind each shot, and how it relates to the story as a whole. It is not enough that the lighting designer simply illuminate the scene so the viewer can see what is happening, or to make it look pretty. It is the light-

ing designer's task to captivate the audience by emphasizing the action and setting the mood.

The following six lighting objectives are important fundamentals of good lighting design. They also break down the thought process into a good course outline. They are borrowed and adapted from the book *Matters of Light and Depth*, by Ross Lowell.

- Directing the viewer's eye
- Enhancing mood, atmosphere and drama
- Creating depth
- Conveying time of day and season
- Revealing character personality and situation
- Complementing composition

3. Directing the Viewer's Eye— The Study of Composition

The primary objective of good lighting is to show the viewer where to look. Shots are often on-screen only briefly, which means the storytelling effectiveness of a shot often depends upon how well, and how quickly, the viewer's eye is led to the key story elements.

Learning to direct the viewer's eye is essentially the study of *composition*. Composition is a term which is used to collectively describe a group of related visual principles. These principles are the criterion employed to evaluate the effectiveness of an image. They are not rules to be followed, but define a structure by which to explore creative possibilities. They describe a visual vocabulary, and provide methods for breaking down a complex image into manageable characteristics for subjective analysis. Besides being of interest to artists, these principles are also an important aspect of visual perception and cognitive psychology research.

The seemingly simple act of placing lights can radically change the composition and focal point of a shot. Good lighting can make a well-com-

posed image stunning. It can also help rescue a less-than-perfect composition. The principles of composition are the tools with which the lighting designer can analyze a scene to devise ways to accentuate what is working and to minimize what is not. They are effective in both static or moving scenes. Pauses in camera moves and character poses are perfect opportunities to evaluate a kinetic composition using static techniques.

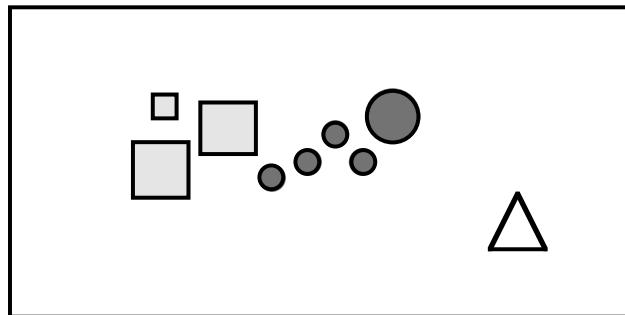
Rather than simply referring the reader at this point to consult a book on composition, a brief discussion of the primary principles needed to the lighting designer are presented here. Although each principle relates to the others, they are presented in isolation for clarity.

3.1 Unity/Harmony

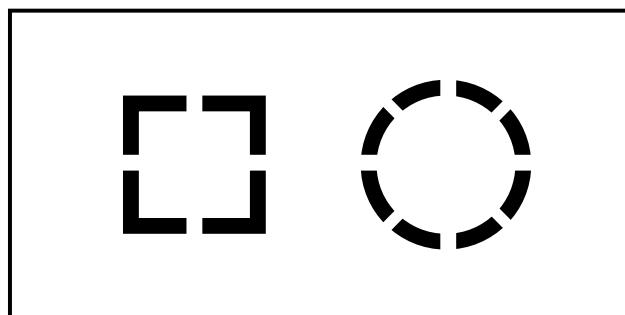
The name of this principle suggests that the elements of the composition appear to belong together, relate to each other, and to otherwise visually agree. Where other principles of composition break down the image into specific topics for study, the principle of unity reminds the artist to take a step back and look at the image as a whole.

Although most artists rely on intuition to decide if a composition is working, the cognitive psychologists offer a somewhat less subjective alternative. They study the eye and brain processes that lead to the artist's intuitive decisions. The cognitive psychologists have developed the Gestalt theory to help explain our perceptual tendencies. The term Gestalt means "whole" or "pattern." Gestaltists emphasize the importance of organization and patterning in enabling the viewer to perceive the whole stimulus rather than discerning it only as discrete parts. They propose a set of laws of organization that reflect how people perceive form. Without these organizational rules, our world would be visually overwhelming. They include:

- The brain tends to *group* objects that are close to each other into a larger unit. This is especially true with objects which share properties such as size, shape, color or value.



- Negative or empty spaces will likewise be organized and grouped.
- Elements are divided into planes, such as foreground and background planes.
- Patterns or objects that continue in one direction, even if interrupted by another pattern, are perceived as being continuous. The brain wants to perceive a finished or whole unit even if there are gaps in it.



- The brain attempts to interpret the world by finding constancies. If a person is familiar with an object, he remembers its size, shape and color and applies that memory when he sees that object in an unfamiliar environment. This helps him to become familiar with the new environment, instead of becoming disoriented, by relating the objects in the new environment to the known object.

By ignoring these principles, an artist risks creating an image which challenges the eye to organize it with little success. The viewer's eye will quickly tire and lose interest. Conversely, too much unity can be boring; if there is nothing to visually resolve, the eye will also quickly lose interest.

By understanding how the eye tends to group objects together, the lighting designer can help unify a disorganized or busy composition with careful shadow placement, or by minimizing or emphasizing certain elements with light and color.

3.2 Emphasis

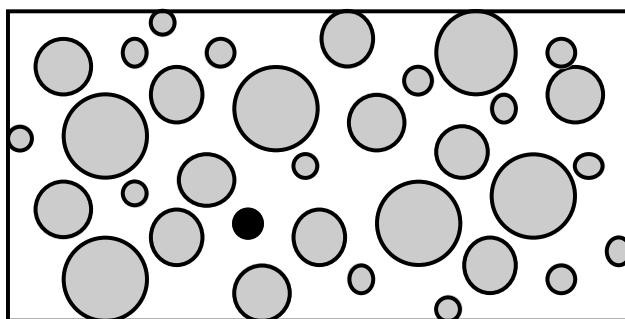
To direct the viewer's eye, an image needs a point of emphasis, or focal point. An image without emphasis is like wallpaper, the eye has no particular place to look and no reward for having tried. Images which are lit with default or uniform lighting similarly feel drab and lifeless. By establishing the quantity, placement and intensities of focal points, the lighting designer directs the attention of the viewer by giving him something interesting to look at, but without overwhelming the viewer with too much of a good thing.

A composition may have more than one focal point, but one should dominate. The more complicated an image is, the more necessary points of emphasis are to help organize the elements. Introducing a focal point is not difficult, but it should be created with some subtlety and a sense of restraint. It must remain a part of the overall design.

By first understanding what attracts the eye, the lighting designer can then devise methods to minimize areas which distract the viewer by commanding unwanted attention, and instead create more emphasis in areas which should be getting the viewer's attention.

3.2.1 Emphasis Through Contrasts

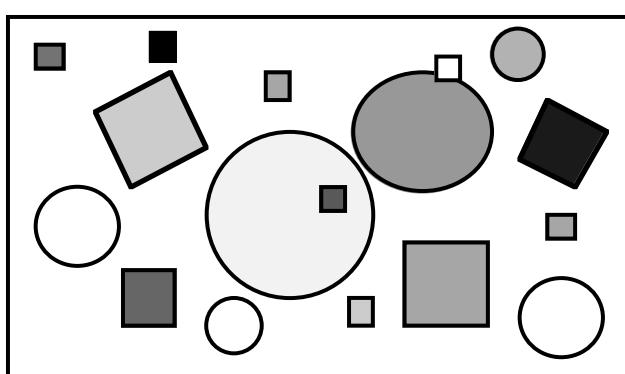
The primary method for achieving emphasis is by establishing contrast. Contrast can be achieved with shape, size, color, texture, brightness or even motion. A focal point results when one element differs significantly from other elements. This difference interrupts the overall feeling or pattern, which automatically attracts the eye. With one dark dot among thirty bright ones, there is no question which dot gets noticed, the dark one, for two reasons: it has the most contrast with its background, but also because it is the only one of its type. Unique or minority elements within larger groups tend to attract our attention.



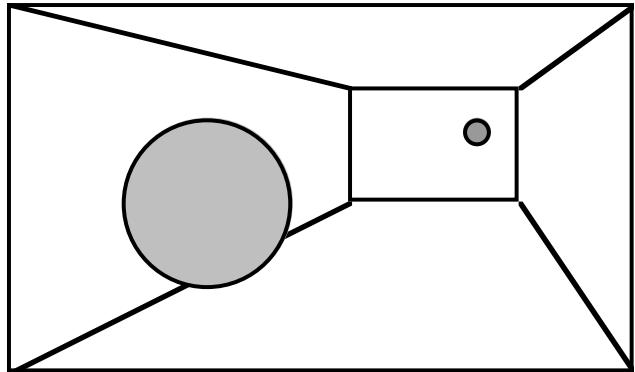
Contrast in value (brightness) is easy for the eye to see, which is why black and white imagery is successful despite its lack of color. It also illustrates why lighting is a major tool in the establishment of emphasis and directing the eye of the viewer.

3.2.2 Emphasis Through Tangents

Tangents, where two edges just touch each other, can produce a strong point of emphasis

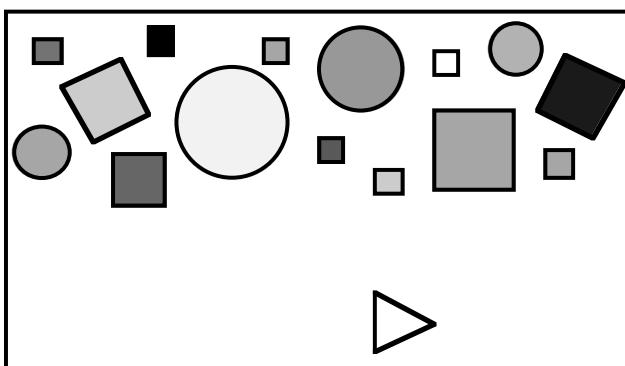


by creating visual tension. The eye is not comfortable with tangent edges and wants to move them apart. With care, tangents can be created intentionally to attract viewer interest; however, most of the time they are accidental and distracting. If a tangent is creating unwanted emphasis, it is best to try to move one of the shapes. It may be necessary to move an object in the scene if it falls tangent to another object. Another potential compositional problem is when an edge of a shadow or light falls tangent with an object or other geometric edge. In this case, it is preferable to move the shadow or light to avoid the tangency.



3.2.3 Emphasis Through Isolation

Emphasis by isolation is a variation of the Gestalt grouping concept. When an object defies grouping, by not being near or similar to any other object, it calls attention to itself and becomes a point of emphasis through tension. This tension is created by the feeling of unpredictability caused by the lone element not belonging to the group.



If this emphasis is undesirable, finding a way to link it to the larger group may help minimize attention. Using an edge of a shadow to point to the isolated element is one way to link it to the group.

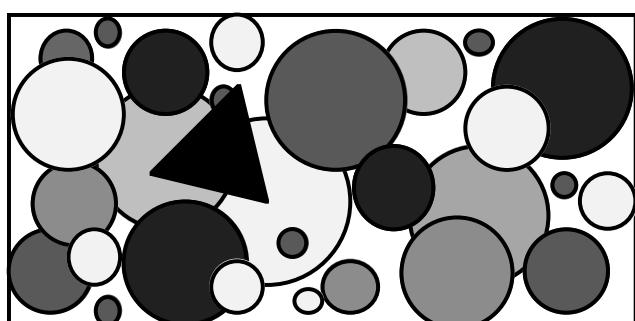
3.2.4 Emphasis Through Angles

A subtle form of emphasis can be achieved by using perspective angles and other edges which lead the eye to the focal point. However, they can just as easily lead the eye away from the intended subject. If perspective angles are leading the eye away from the focal point, it is necessary to attract or contain the eye more strongly using another method.

3.2.5 Emphasis Through Shape

The brain tends to characterize shape as either rectilinear or curvilinear. Most images are not comprised of strictly one or the other. By creating an image with primarily one type, the other type becomes a point of emphasis. In the simple example to the right, the triangle stands out from the field of circles because of its shape is unusual in this context.

As another example, a long straight shadow in an image with a lot of curves may need to have less contrast or a softer edge than usual to keep it from drawing too much attention. A busy shape among many simple ones, or vice versa, will also attract attention. This concept



may be helpful in recognizing why an object might be attracting more attention than otherwise expected.

3.2.6 Emphasis Through Recognition

Because of the human need for self-recognition, human or anthropomorphic characters will naturally attract more attention than inanimate objects. Furthermore, in our attempt to recognize a character, we naturally are attracted to look at his face, and especially to his eyes if he is speaking, to see what he is thinking and feeling.

3.2.7 Emphasis Through Motion

A static image has static points of emphasis and all principles of emphasis apply, but a moving image has the added bonus of being able to create emphasis through motion. Camera motion and character acting are topics unto themselves (see [Lasseter87]), but it helps to understand when the eye is attracted to moving objects and when it is not. If all objects are moving except one, the eye will be drawn to the one which is not moving. The opposite case, of only one object moving, is more common and even more effective in attracting attention.

3.3 Balance

When an object is unbalanced, it looks as though it will topple over. Instinctively the viewer wants to place it upright or straighten it. An unbalanced object is distracting and calls attention to itself. An entire image which is off-balance will make the viewer uncomfortable because he wants to balance it, but cannot. This discomfort can be desirable if it enhances the mood or storypoint. By knowing ways to balance or intentionally unbalance an image, the lighting designer can affect the mood of the scene.

A scale is balanced by putting equal weight on both sides. It doesn't matter how large or dense the objects placed on the scale are, they will bal-

ance as long as they have equal weight. The balancing of a composition is similar except that visual interest becomes the unit of measure. Visual interest comes in many shapes, sizes, values, colors and textures, each with varying density. The principles of emphasis and balance are therefore related since points of emphasis carry visual weight which must be considered when evaluating the balance of an image.

Visual balance is achieved using two equations. The first balances the image around a horizontal axis, where the two halves, top and bottom, should achieve a sense of equilibrium. Although it is desirable to have a sense of equal distribution, because of gravity, the viewer is accustomed to this horizontal axis being placed lower than the middle of the frame.

Besides helping to create a pleasing image, the top/bottom weight ratio can also have a storytelling effect. The majority of constant factors in our visual life experience tend to be horizontal in nature—the groundplane beneath our feet, the horizon in the distance, the surfaces of water. Where these horizontal divisions are, relative to where we are, tells us how tall we are, how far off the ground we might be, or whether we might bump our heads on something. Because we are accustomed to making these comparisons, the placement of a character within the image format and the angle that the camera sees him can imply the height of a character. And since we tend to associate height as a dominating physical characteristic, it can say something about the importance of the character in his current situation. In one shot a short character is placed high in the frame, in the next shot a tall character is placed lower in the frame. The shorter character in the first shot feels taller and more important to us than the character who is actually taller but is visually subservient. A character's eyes are usually placed above the center line, unless the character is looking up.

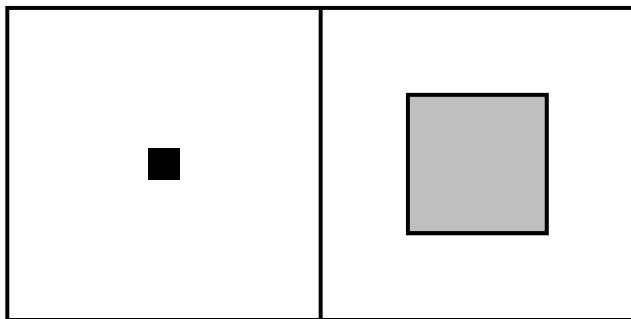
The second equation of visual balance divides the image around a central vertical axis. The horizontal format of cinema is most affected by this left/right ratio. And with the possibilities of action entering and exiting the frame, or camera pans and dollies, this ratio has the potential to be very dynamic.

The simplest type of left/right balance is *symmetrical* balance, where the two sides are mirror images of each other. Symmetrical balance is discussed here primarily because it is easy to understand and to achieve. Heavily used in architecture, symmetrical balance feels very formal, permanent, strong, calm and stable. In other forms of art, perfect symmetry is rarely seen. One distinct advantage of symmetry is the immediate creation and emphasis of a focal point. With two similar sides, there is an obvious visual importance to whatever element is placed on the center axis. Another asset is its ability to easily organize busy, complex elements into a coherent whole. In film, symmetrical balance is sometimes used to help portray a formal, official, or religious environment or mood. The Ingmar Bergman film "Winter Light" uses symmetrical balance to impart stiff, claustrophobic formality to the church setting in the opening sequence.

In contrast to symmetrical balance, *asymmetrical* balance is more commonly used, more natural in feeling, and much more challenging to achieve. Although asymmetry appears more casual and less planned than symmetry, its visual ease belies the difficulty in its creation. Balance must be achieved with dissimilar elements by manipulating the visual interest of each. Some of the variables to manipulate are value, color, shape, texture, position and eye direction. Each are discussed here individually for clarity, but keep in mind that the interplay of these variables will affect the end result. Color can balance value, or texture can balance shape, infinite combinations are possible.

3.3.1 Balance by Value

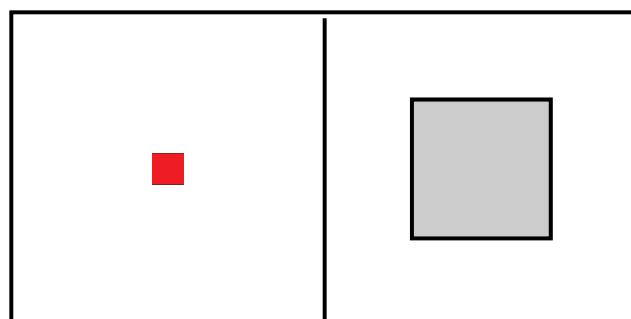
We have already discussed that the eye is attracted to contrasts, particularly that a high contrast area attracts more interest than one of low contrast. To balance the scale, a small area of high contrast will command an equal amount of attention as a large, low contrast area.



When it comes to projecting film in a theatre, the value scale isn't necessarily level to begin with. A theatre is dark to draw the viewers attention to the screen. In general, the eye is attracted to bright areas more than it is dark ones, and in a dark theatre, with our pupils dilated, a bright area will attract even more attention since it contrasts with the darkness of the theatre environment itself.

3.3.2 Balance by Color

Like value, color can be a balancing element. The eye is more attracted to a color than to a neutral image, the more saturated the color, the more attention it grabs. A small area of bright

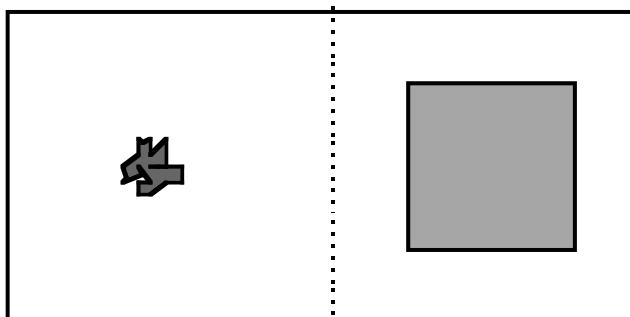


color can balance a much larger area of a duller, more neutral color. How colors are placed next to each other can also affect color balance. Complementary colors which are placed adjacent to each other will weigh more than two analogous colors would in the same situation.

If a surface color is attracting too much attention, its color saturation or diffuse light response may need to be toned down, or perhaps the surface can be placed in shadow.

3.3.3 Balance by Shape

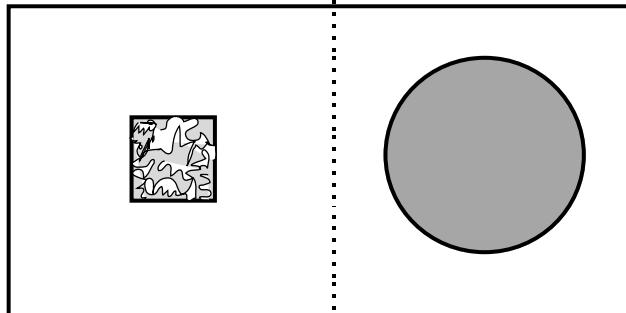
A large, simple shape can balance a smaller, more complicated one. Similarly, a large uncluttered area can balance a smaller busy area containing many shapes.



Busy areas can be minimized by placing them in shadow or enhanced with directional light placement. Large simple areas can be broken up with shadows or evenly lit depending on the visual need.

3.3.4 Balance by Texture

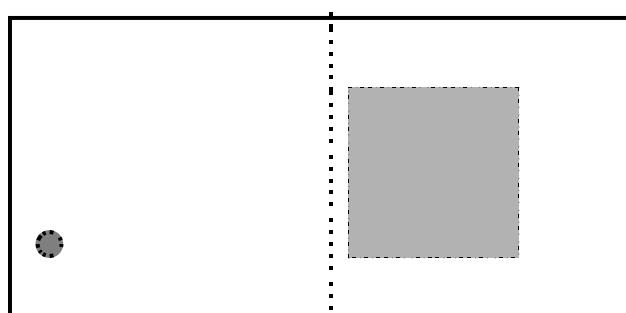
Texture and surface are similar to value, color and shape. A busy, high contrast texture on a small shape, will balance a larger shape with a smooth, matte surface.



Texture is an invitation to the audience's sense of touch. Even though they cannot reach out and feel the image, the textures in the image can trigger a sensory reaction. The surface quality of objects can help define the mood of the scene, where soft, fuzzy objects summon a warmer memory than do smooth, polished objects. Surface texture also gives the audience cues as to how close they are to the object surface, since texture becomes less apparent as the object moves farther away. A highly textured surface will attract more viewer interest than a non-textured surface, and these surfaces can be lit to highlight or minimize their respective surface qualities. A highly textured surface can be accentuated with hard light from the side or back, or it can be minimized with soft frontal lighting.

3.3.5 Balance by Position

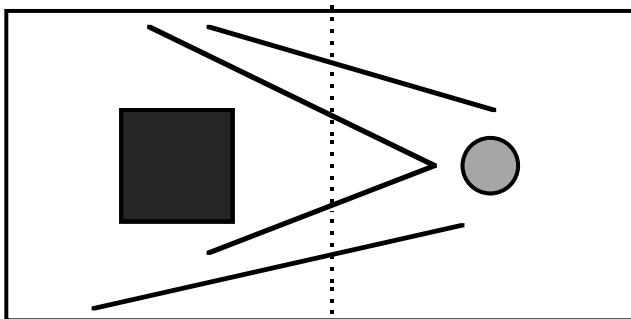
On a scale, a heavy weight can be balanced to a lighter one by moving the heavy weight closer to the scale center point, or by moving the lighter weight further away from the center. This principle is also true in composition. A large element placed close to the center of the image can be balanced by a smaller element placed near the edge.



Although it may not always be possible to move an object in the scene to balance the composition, affecting an object's visual weight can be achieved with lighting, either by changing the visual weight of the object itself, or by counter-balancing it with more visual weight elsewhere.

3.3.6 Balance by Eye Direction

Every edge, shape or group implies a direction of some kind, either straight or curved. It is the counter-balancing of one direction with another which stabilizes an image.



Directional lines, such as perspective angles, are a simple example of how eye direction can be used to balance a heavier side by pointing toward the lighter side, transferring visual importance. Perspective angles are an example which tend to be fairly subtle. A linear object, a shadow edge or the edge of a light can achieve a stronger directional effect. Eye direction also occurs when the eye is led from one side of an image to the opposite side when it finds the same color, or when the eye follows the gaze of a character.

3.3.7 Balance by Physical Weight

The perceived physical weight of objects in the scene also contributes to the sense of visual balance. An object known to the viewer to be heavy in physical weight will impart more visual weight than it would otherwise due to our tendency to factor mass and gravity into the equation.

3.4 Scale and Proportion

The term *scale* refers to overall size, whereas *proportion* is used to describe relative size. Scale and proportion principles help the viewer organize an image. They can also be used to create or minimize points of emphasis.

Scale and proportion are connected to emphasis and balance. If an object is out-of-scale or is oddly proportioned, it can create too much emphasis. Large scale elements, especially those large in proportion to the other elements, also create obvious visual weight. The brain automatically reads larger objects to be nearer and more important than smaller objects. As an example, in a close-up shot of a character, the viewer is rarely distracted by the background. But in a wide shot containing many elements, the viewer must create relationships between elements to establish perspective and to find a focal point. In addition to mere size grabbing viewer attention, the brain will notice an object which appears out of proportion, or unnatural in size, compared with other objects.

The lighting designer may need to minimize large objects which should not be the focus of attention.

In a purely computer generated environment, the viewer works harder to establish and maintain size relationships since there is no direct comparison available to the real world. In "Toy Story", the architecture, furniture, props and characters were modelled and textured with an appropriate amount of detail for their relative size as well as to the distance they would be viewed from the camera. Great care was also taken in the staging and editing processes to avoid disorienting the viewer with unexpected changes in apparent size relationships. A consistent use of lenses for close-ups, medium shots and long shots helped to ensure spacial continuity.

Besides being useful for describing relative size, proportion also pertains to the pleasing design of objects and their placement in the overall image frame. Placing the focal point dead-center in the frame is not usually a very interesting or pleasing placement. The eye naturally prefers the focal point to be located within one of the four quadrants. This is especially true if the image contains another strong point of emphasis. This is only a general rule of thumb, however. Sometimes the lighting designer will be given a shot where the focal point is intended to be in the center of the frame. If the shot is a wide shot with many elements, the eye may have difficulty remaining in the center of the screen. It may be necessary to minimize other points of emphasis on the periphery to keep the eye from wandering.

Much study has been devoted to deriving ideal proportions for an individual entity as well as how to portion an image in the most pleasing form. The use of aesthetic formulas has a long history. Even before the Renaissance, when there was more overlap between the arts and sciences, artists and mathematicians perfected what they believed were the ideal proportions for human form, design and composition. One of the formulas they derived is the *golden section**. Once used heavily in architecture, painting and sculpture, it is described as "Traditional proportion which is supposed to express the secret of visual harmony. In its simplest form it consists of a line divided into two so that the smaller part is to the larger as the larger is to the whole." This proportion is expressed in mathematics as a Fibonacci sequence of numbers, or as a ratio roughly equivalent to 8:13 (j). The golden section is frequently found in nature and is very pleasing to the eye. When deciding where to place an edge of a light or

shadow, formulas like the golden section may be useful to keep in mind.

3.5 Repetition and Rhythm

3.5.1 Repetition of Shape

The use of similarly shaped elements in an image, however subtle, is a strongly unifying force, as a product of the Gestalt grouping principle. Repetition is an aspect of visual unity which is exhibited in some manner in every image. The human eye is very good at making comparisons and correcting minor differences to equate two shapes as being essentially the same, and then grouping them together as a unit or connecting them in some way. Because of this tendency, two similar objects, even at opposite sides of the image, will lead the eye from one shape to the other.

Also, the shape of an object can acquire more visual weight if it is repeated, by its own shadow for instance. By looking for ways to repeat shapes with light and shadow, the lighting designer can help unify an image or redistribute visual weight

3.5.2 Rhythm

Visual rhythms are plentiful in nature: a stand of trees, a flock of birds, ripples in the sand, raindrops in a puddle. A person is so accustomed to natural rhythm that they *feel* it more than they *see* it.

As a design principle, rhythm is based on repetition, although just because something repeats itself doesn't mean it has rhythm. A small number of repeated or similar elements become visually grouped together to form a unit. To achieve rhythm, a larger number of elements are required, enough elements so as to discourage grouping as a single unit, but several. Groupings of three or more start to introduce rhythm, but only if they are not exactly the same. Rhythm also requires variation within its repetitive groupings.

*p. 90; The Thames and Hudson Dictionary of Art Terms, by Edward Lucie-Smith: Thames and Hudson, 1984.

Rhythm can be established using colors or textures, but shapes and their arrangement are more common repetitive elements. Rhythmic patterns can help lead the eye through a composition, but they can also evoke an emotional response. A succession of curvilinear forms can be calming, whereas a pattern of angular lines may be stimulating.

3.6 Line and Contour

The human eye is very sensitive to change, and can find even very subtle distinctions. It then mentally connects these demarcations to create a line or boundary. The imagination and past memories then quickly fill in missing details in an effort to recognize these lines as a known shape. In addition to filling in the missing bits, the brain also ignores visual stimuli which may be competing for attention.

The careful placement and emphasis of edges and linear elements play an important role in leading a viewer's eye through a composition, directing it to the intended subject. A practical example of how lighting can be used to control the placement and emphasis of edges might be the angle of a shadow, highlighting the edge of an object, or even deliberately allowing the edge to blend with the background.

There are three types of edges or lines, an *actual* line, an *implied* line, and a *psychic* line. An actual line is the easiest to recognize because it usually defines a shape. A line is implied by positioning a series of points so that the eye tends automatically to connect them. A psychic line is not a line which is seen, but one which is felt as a mental connection that exists between two elements. The eyeline of a character is a good example. If a character looks toward an object, the viewer will also look. These psychic lines are very powerful and can be difficult to minimize if they are distracting.

How and where a line is terminated can also affect its importance. A line which points to an object, but doesn't quite touch it will create tension and attract attention more than one which continues.

The boundaries of shapes and other linear elements portion a composition for proportional analysis. They also have an emotional role. Horizontal lines imply stability, vertical lines imply potential motion, and diagonal lines imply dynamic motion and depth. When working within the rectangular cinema format, horizontal and vertical lines work as stabilizers and reduce feelings of movement since they mirror the format boundaries. A common camera technique is to roll the camera to introduce a feeling of instability.

3.7 Shape

The computer animation environment is three dimensional as it exists within the computer. Three dimensional objects move and deform freely, changing shape and position, in their three dimensional world. And although the sculptural form and motion of the objects affect how light is reflected and shadows are cast; ultimately, it is the placement and definition of the resulting two dimensional shapes, within the image frame, that becomes the final product. Camera placement and lighting are what control this transition from the original design space to the image the audience sees projected on the screen. This may seem obvious, but it also appears to be forgotten at times.

A composition is primarily an arrangement of shapes. The brain not only strives to recognize shapes, it also attempts to organize them into *figure and ground* relationships, or positive and negative space. This happens on several levels. Just as the brain distinguishes between background and foreground planes, it also looks for positive and negative relationships within each plane. The focal points and busy areas of the plane become the positive space, while the other areas become relief for the eye, or nega-

tive space. Negative spaces are not necessarily empty flat areas, but they do not tend to attract attention. In a well crafted image, as much care is given to the shape and placement of the negative spaces as is given to the subject itself. However, the shape of a negative area, particularly an enclosed one, can be so interesting that it may take on a life of its own, attracting attention instead of deflecting it.

A lighting designer is constantly balancing the need for readability and the need for integration. An image which has all of its shapes clearly defined is easy to understand. However, it is not as interesting as an image where shapes fall in and out of definition, by falling in and out of light and shadow. Similarly, clear definition between foreground/background, and positive/negative space is easy to read, but is not a particularly interesting spatial solution. It is often desirable to blend together, or integrate, the spaces in some way to avoid the harsh juxtaposition of forms as is evident in a bad matte. The use of a similar color or value along an edge can help the eye travel more easily between the spaces.

An important concept for the lighting designer to keep in mind, is that the brain is very good at recognizing shapes with a minimal amount of information, especially if this shape is already familiar to the viewer. By just hinting at a shape with a minimal amount of light, the viewer's imagination becomes engaged, and a mood of mystery and suspense is evoked. This is a concept that is apparently foreign to advertising agencies who want to see the entire product label evenly lit.

Shape distortion can be a powerful emotional tool. The viewer is so accustomed to seeing the world in a natural fashion that when shape is distorted in an image, it signals an altered state of reality. An emotional response will range widely depending on the shape being distorted and its context. The baby in "Tin Toy" is dis-

torted, using refraction through a cellophane wrapper, with comic relief to the plight of Tinny. In another context the same technique may be eerie and unsettling. The individual parts of the mutant toys in "Toy Story" are not themselves distorted, but in combination they represent a distorted vision of a life-like toy. The combined effect is disturbing and repulsive, which helps us believe that they may indeed be cannibals.

3.8 Value

A black and white image can often work as well as a full color image because enough visual information exists for the viewer's imagination to fill in the missing color information. In fact, a black and white image can sometimes be more powerful than color precisely because it requires the use of imagination.

Contrast in value provides spatial cues for depth perception. Areas of greater contrast appear to advance into the foreground, while areas of lesser contrast tend to recede. The angle and direction of a shadow helps define the location and orientation of the surface on which it falls. If a shadow does not fall as expected from its source, the result can be disorienting as the viewer tries to reconcile the surface plane to the shadow.

Lighting is ultimately how the values of the scene are controlled as the camera will see them. In live-action, the aperture of the camera lens will also affect the final result by selecting a tonal range within the capabilities of the film stock.

The interplay of light and shadow and the relationships of tonal values is a major contributor to the style and mood of the scene. This is discussed in more detail in Section 4.

3.9 Color

Value and color are related to each other since the light which falls on reflective surfaces, or shines through translucent materials, produces various brightnesses. On black and white film

they are reproduced as gray values. On color film, the apparent brightness is greatly influenced by the hue and saturation of the colors, but the final outcome is still a range of values. Every color has a value, but color, which is based on wavelengths of light, offers a much broader field of visual differences and contrasts.

The color of a surface is determined by how it reflects the light that illuminates it. The apparent color of a surface depends upon the lighting situation. Unfamiliar objects appear just as the eye perceives them, that is the apparent color and value are determined by the actual wavelength of the reflected light. For familiar objects, the principle of *color and brightness constancy* takes effect. Here the brain uses previous experience to augment the strictly physical perception of the eye. If the color of a familiar object differs from that in memory, the brain assumes that the color of the object is affected by its environment. For example, if the viewer sees a purple apple, chances are they have never seen an actual purple apple, and will assume they are viewing a red apple as seen under blue lighting or through a blue filter.

A color is also perceived as a certain hue, saturation and brightness as it relates to the color next to it. A color on a neutral background may appear very different than it would in context with other colors. Similarly, two complementary colors, when juxtaposed will accentuate each other and appear more intense than they would if either were placed adjacent to an analogous color. Neutral colors can be heavily influenced by a stronger color next to them, where the neutral color will tend to go toward a hue which contrasts the strong color. In other words, a grey square next to a red one will tend to go a little greenish.

Color can play a big part in visual storytelling, both in terms of the set, props, and wardrobe design, but also in the lighting. Section 4.7 contains a brief discussion on color and our emotional responses to it. An exhaustive discussion of color, however worthy, is beyond the scope

of this course. Many books on color theory and the psychology of color exist for the reader who is interested in exploring these subjects in further detail.

3.10 Compositional Mood

A pleasing composition evokes a sense of well-being, a feeling that everything is happy and going to stay that way. A composition which is a little unbalanced, or otherwise feels awkward, can create a feeling of tension and apprehension. This feeling can be useful if the intent is to build story tension or to portray the emotional state of a character. A progressive building of visual tension can foretell that something bad is going to happen whether it actually does or not. A sudden change in visual tension can accentuate the shock of a dramatic change. Sometimes the composition and lighting design will intentionally be in contradiction with the subject matter. Soft, warm, beautiful lighting can be used to light a violent, ugly subject matter. This contradiction can aid in viewer discomfort because it feels especially out of context and shocking.

Whether or not the composition is busy or simple will also have some emotional impact on the viewer. A well-composed simple scene will feel elegant and noticeably beautiful compared to a cluttered scene. An element in a simple scene will also feel more important than the same element in a busy scene.

3.11 Transitions

While it is necessary to direct the viewer's eye to the intended subject within a shot, it may also be desirable to "lead" the viewer's eye into the next shot. An effective transitional device is to use lighting and compositional elements from the current shot to transition into similar elements in the next shot. The audience is already visually prepared for the next shot before the cut or dissolve occurs.

3.12 Putting it Together

Even with the intent of discussing the principles of composition as isolated topics, it is easy to see how they interrelate. Figures 3.12a, 3.12b and 3.12c illustrate a few examples of using a few of these techniques together to direct the attention from one character to another. Figure 3.12a shows a simple shot of Woody and Buzz over a plain grey background. The same basic lighting is applied to both Buzz and Woody, the direction of which is arbitrary. If you were to guess which character is supposed to hold our attention, which would you choose? Initially we may think that it is supposed to be Buzz because Woody is looking at him which naturally draws our attention to Buzz. Ordinarily we would consult with the director to find out his intention, but for the purposes of our example, we will light one to highlight Buzz and then relight it to focus our attention on Woody. In these examples, only the background has been relit, because the result is clear to see.

Figure 3.12b uses several techniques to help draw our attention to Buzz. A shadow line was introduced on the background to reinforce the eyeline from Woody to Buzz. It is sharper behind Buzz and softens as it reaches Woody to provide more contrast near Buzz. The contrast of the shadow line is low enough so that it does not attract attention to itself. This dark shadow area behind Buzz allows him to “pop” from the background while Woody tends to blend into it. Also, this shadow line is positioned so that it is almost tangent with Buzz’s head to add tension to that area. Woody does not have a rim light to aide in his blending into the background, while Buzz has a nice bright one which helps him separate.

Figure 3.12c shows the shift of attention toward Woody. For this image, we will use the proximity of the grey wall to help us. The shadow of Woody on the wall provides us with more contrast areas around Woody’s head and the repetition of his shape on the wall gives him more visual weight and drama. The wall behind

Buzz is lit to help him blend into it. The rim light on Buzz has been toned down while the rim on Woody has been brightened. As you can see in this image, the psychic line created by Woody looking at Buzz is very difficult to overcome.

Exaggeration is a familiar device used by character animators to enhance the life-like quality of a character. Purely natural or physically correct lighting is often not interesting enough to create drama and captivate the audience. Pushing the limits of reality can create magic and beauty that connects the imagination with the story being told.

It would be possible to fill volumes with examples, but let’s move on. The next five lighting objectives draw upon our knowledge of these principles of composition and illustrate further how they can be used in lighting for storytelling.

4. Enhancing mood, atmosphere and drama

Many aspects of an image affect its mood and dramatic qualities. The sets; the costumes; the actors and their acting; the staging; the score; the weather; the time of day; and the lighting, are all components which can illustrate the mood of the story being told. Lighting design can pull it all together into a cohesive mood, or it can provide a contradictory mood of its own for the sake of contrast.

The emotional role of lighting is not always obvious, even though it is profound. This emotional effect can be accentuated by juxtaposing complementary lighting situations. An overcast day will evoke vague feelings of oppression and melancholy, but might not be noticeable until it is compared with the uplifting quality felt at the first brightness of a spring sun. It probably wouldn’t be appropriate to light a sad and gloomy scene with lots of bright light, nor

would it seem right to light a comedy with harsh high-contrast light.

Lighting vocabulary is based on studio lighting. This long-established vocabulary breaks down the infinite possibilities of light into manageable topics for discussion. It is therefore useful to take a look at the studio method of explaining lighting design and relate it to our synthetic tools.

The establishment of mood and drama through lighting is the sum of the properties of the lights themselves as their motivation, purpose, placement, direction, range, color, quality, quantity and intensity. This section is primarily devoted to the discussion of these light properties, how they relate to each other and how they influence the emotional qualities of the scene. Each property is presented in the logical order that lighting decisions are usually made.

Often, the first decision to be made is to determine the *style* of lighting to be used for the scene.

4.1 Lighting Style

An infinite number of combinations of lighting properties can be created for a wide range of visual and emotional effects. In order to simplify the endless possibilities, some generalizations have been drawn which are used to label and describe lighting in terms of style. Lighting styles are described by their tonal range, which is the range of values from the darkest dark to the brightest highlight and the grey values in between. Lighting styles are also described in terms of the overall color, motivation, placement, and quality of the lights and shadows.

The character and mood of an image is dramatically affected by the range of tone values from light to dark and by their distribution within the frame. This tonal range is decided early in the lighting process. This decision is usually motivated by the dramatic quality of the story and can be consistent throughout the entire movie or vary with the location and time of day.

A light-hearted or comedic story might dictate a *high-key* lighting style. High-key lighting is characterized by a scene that is mostly well lit with a lot of soft fill light and no heavy or hard shadows. The sets and costumes also tend to be light in color. This doesn't mean that there aren't any dark areas, but the overall brightness tends to be light, contrast is low, and the dark areas are soft and few. The result minimizes suspense since nothing is left to the imagination of the audience.

At the other end of the spectrum is *low-key* lighting. In a low-key lighting situation, most of the scene is darkly lit, with the emphasis on the few areas which are brightly lit. The sets and costumes are also usually dark in color. The overall impression is dark but not murky. What is seen is equally important to what is not seen. The detail only hinted at is much richer than it would be if it were well lit. Light is used to direct the viewer's attention, the darkness to stimulate his imagination. Of course, these are the polar opposites, with many possible tonal ranges in between.

Aside from the overall brightness or darkness of the style, its contrast range can evoke mood and meaning. Unlike a low-key scene where most of the frame is dark, *high-contrast* scenes contain a wide range of light and dark areas with a narrow middle range of greys. A high-contrast image, with many hard edges of light and shadow, has a dramatic graphic quality and can evoke a sense of energy or unrest. A low-contrast image, composed of a range of shades of middle tonality, can convey a feeling of calmness or bleak oppression.

Even before the viewer has understood the story-point, the lighting style can suggest a feeling for a scene, especially in comparison with adjacent scenes. Or within a single shot, one character may be modeled in bright tones and another in shadows and dark tones to suggest their individual personalities or their emotional or dramatic situations.

4.2 Quality of Light

The creation of varying degrees of softness and directionality are important aspects in creating mood through lighting. In addition to considering the tonality of image, lighting style is also often defined by the *quality* of the lights, especially the key source. The quality of a light is comprised of three characteristics, the primary one being its hardness or softness, with the other two being its angle of throw, and its color. A soft source is diffused which scatters light in many directions and creates very soft shadows, whereas a hard source is not diffused and casts very crisp shadows. A light source, even a soft one, will become harder as it moves farther away from the subject. The apparent size of the source becomes smaller, and as its rays become more parallel, causing its highlights and shadows to become more crisp.

In addition to the actual hardness or softness of the sources themselves, the contrast range of the resulting image also contributes to the overall feeling of hard or soft lighting. Subjects of limited tonal range, with middle tones of gray, appear softer than subjects with deep blacks and brilliant whites.

The quality, or character, of light will initially be influenced by the scene location and the time of day but may vary to accentuate mood or story-points. Daylight scenes are usually softly lit except for direct sunlight. Night scenes, especially exteriors, tend to be lit with harder lights. The character of a light is also heavily influenced by the *motivation* of its source.

4.3 Lighting Motivation

Once the character of light is chosen for a given scene, the next task of the lighting designer is to decide the practical and hypothetical sources of light and their orientation to the set and subject. These decisions will be influenced by the script, the set, and the camera locations within the scene. Lights are characterized as being either *logical* or *pictorial*. A light is logical if it appears to be motivated by an actual source of light (practical source) that the viewer can see

or is implied, such as a window or table lamp. Logical lighting, also called naturalistic, motivated, or method lighting, generally follows the natural, logically established visible sources in a scene. On the other hand, pictorial lighting generally uses lighting directions simply because they produce a pleasing picture.

Most of the time, there is a compromise between the logic of the source and the compositional requirements of the frame. Sometimes the light direction is established by what feels natural, even if the logic of the source is slightly violated. It is the overall character of the light, its color, softness and direction, that matters. The exact angle and intensity of the light will never be scrutinized by the audience as long as it is not disorienting.

Practical sources which are visible to the viewer need to be well placed. If there is a visible source of light within the image frame, the viewer expects the overall light direction to emanate from the source they see, even if the lighting originated from a different source in the previous shot.

4.4 Quantity of Lights

The number of logical sources chosen will also help determine the mood of the scene. A soft one-light scene, for instance from a candle, can feel very warm and romantic. A big bank of fluorescent lights can feel sterile, cold and over-lit. There are many possibilities in between, but in general, the number of logical sources are usually kept relatively few to be able to establish overall direction.

The number of logical sources may be small even though the actual number of lights used to achieve a look may be many. This is true in live-action and even more so in synthetic lighting since no ambient or bounce lighting comes for free (unless of course a radiosity renderer is used). In general a light should not be added to a scene without an intended purpose, and the temptation to use one light to serve two purposes should be avoided.

4.5 Quality and Quantity of Shadows

The number and quality of light sources also help determine the number and quality of shadows. This is one area where synthetic lighting has a great advantage over live-action. In a live-action situation, each hard light casts a distinct shadow. Great care is taken to minimize multiple shadows and to establish one dominant shadow. Conversely, in synthetic lighting, it takes effort to create multiple shadows and penumbra effects, and the tendency is to overdo it. One shadow should still dominate, but it is usually necessary to introduce a secondary or contact shadow to help ground a character onto the shadowed surface.

Also in live-action situations, the quality of the shadow is determined by the placement and quality of the light. A hard or distant light will cast a crisp shadow. The softest light will not cast any shadow. The density of the shadow is determined by the amount of bounce and fill light in the scene. In synthetic lighting, shadow direction, quality, color and density controls can be independent of the light attributes, but they should still feel naturally motivated by the sources in the scene.

4.6 Light Type, Purpose, Placement, Direction and Intensity

The desired tonal range of the image, and quality and motivation of illumination have now been established. The next task to consider is the specific type, purpose, placement, direction and intensity of each light.

4.6.1 Types of Lights

Three basic types of lights are used for live-action lighting. The spotlight, the floodlight, and the area light. The spotlight has a narrow beam and is usually used as a hard light source. It casts crisp shadows and a crisp bright highlight. The floodlight has a broader beam and is usually diffused and used as a softer source. It casts a soft shadow and a broader diffused highlight. An area light is either fully diffused through a diffusion material or is bounced off another surface such as a white card. It casts very faint shadows, if any.

The use of diffusion and focusing materials creates a wide range between a very soft scattered light and a very hard directional light. Light placement also affects the apparent hardness of the light, since even a soft light will appear harder as it moves farther away from its subject, as its rays become more parallel. These three types of studio lights are designed to emulate nature. Sunlight is an example of parallel rays which cast very crisp shadows. An overcast sky is an example of very diffused light casting soft shadows. And the shadow areas under a clear blue sky is an example of a big area source which casts faint shadows.

The synthetic lighting designer attempts to recreate these real light properties with a different set of tools. Many renderers currently support all three basic light types. Spotlights (point) and solar (parallel, infinite, or distant) lights are pretty standard stuff, area lights are more difficult to find since they are more computationally expensive.

Without the availability of area sources, the overall soft look can be emulated using more standard techniques. The parallel rays of a solar light have a softer feel than a spotlight because the illumination is more evenly distributed over a surface. And since the shadows can be controlled independently, a blurred shadow with partial density can help this cheat. The specular quantity and quality from a source also describes its apparent softness. By using an environment map, with blurring and color filtering controls, to define the highlights, the cheat can be taken a step further.

Many renderers support control for diffusing the specular highlight for each source independent from the surface roughness, but specular highlights are really just a cheat. It is often more convincing to use an environment map which contains representations of the sources instead. Gratuitous specular highlights impart a plastic, computer-generated quality; highlights should be placed, shaped and colored with care.

The quality of a light's shadow provides the most information in describing the quality of the source. In computer lighting, much control and creative freedom can exist for manipulating shadows. The color of a shadow can be enhanced, and the density and softness of a shadow can be set uniformly or be varied across its surface.

The softness of the shadow suggests the softness of the source as well as the distance of the source from the subject. But, even though a hard distant light will cast a hard shadow, softening the shadow can suggest atmospheric diffusion. The softness of the shadow also gives us visual cues about the distance from the shadow-casting object to the surface on which the shadow falls. The nearer the subject to the shadowed surface, the more dark and crisp its shadow will appear.

4.6.2 Light Functions and Placement

The function of a light is independent of its type, its quality and even its placement. A light's function is particularly meaningful for describing how it is used on a subject. For this reason, light function and placement are discussed here together.

4.6.2.1 Ambient—or base lighting

The overall brightness of the shadow areas is usually determined first by the use of base lighting. In live-action this might be achieved by suspending a white cloth over the set and top-lighting it, bathing the entire set in a wash of light. In the computer this is accomplished by using a combination of an ambient light and diffuse lights. The ambient light adds a slight amount of light everywhere to prevent any absolute black areas, but is extremely flat. The use of a few diffuse lights can add a little bit of directionality to ambient base lighting. A radiosity renderer eliminates the need for adding a flat ambient light, but does not necessarily eliminate the need for base lighting.

4.6.2.2 Key light—for modeling of surface and setting of mood

The key light is the brightest light striking a subject. It defines the brightness and shape and texture of the subject.

As the dominant source, the placement, color, intensity, and textural quality of the key light are important attributes in setting the mood for a scene. But it is the placement of this light that most affects the mood and dramatic quality of the image by controlling the direction of the light as it strikes the subject. The direction of the light can vary the apparent shape and volume of the subject, by accentuating or minimizing certain features. This is referred to, in lighting terms, as surface modelling. The character of this modelling is also affected by the softness of the light and its shadows.

Although there are no hard and fast rules for the placement of the key light, it is conventionally placed 30-45 degrees to the side and above the subject relative to the camera axes. However, this light can be effectively placed as far back as 135 degrees from the camera as a *three-quarters-back* key light. Another convention is to place the key light so that it is on the opposite side of the actor's eyeline from the camera. These conventions are interesting, but only serve as a loose guideline since the direction of light is usually dictated by the relationship of the subject to the motivation of the source, the chosen style of lighting, and the mood of the scene.

By controlling the direction and quality of the key light, it is possible to change the appearance of the subject as well as to suggest something about the subject's personality or dramatic situation. A beauty-shot of the heroine may have a softer, more frontal key light than the villain who is chasing her.

In live-action lighting, the addition of a *filler* light is often added to fill in the key light shadows. This light is placed near the key light, but a little lower. On the computer this light is not

usually added since the same effect can be achieved by lessening the density of the key light shadow.

4.6.2.3 Fill light—*for subject contrast control*

A fill light is a low-intensity, diffuse light used to fill in shadow areas. This light does not call attention to itself. In pure terms, it does not cast noticeable shadows, nor does it produce a noticeable or sharp specular highlight.

Although a fill light can be placed almost anywhere, it is traditionally placed nearer to the camera axes than the key light. Since the fill light is often near the camera, it tends to fill in the key light shadows and reduce the surface modelling created by the key light.

The ratio of the key light plus the fill light to the fill light alone is called the *lighting ratio* and is one way of controlling the contrast range of the scene. In a high-key lighting situation, a lot of soft fill light is used to bring up the overall level of illumination. In low-key lighting situations, the fill light is frequently omitted.

4.6.2.4 Backlight—*for separation from background and setting of mood*

Also referred to as rim, hair, or separation lights, backlights are traditionally used in black and white cinematography for foreground separation. In color cinema they are needed less for separation, but they are also effective for creating a romantic mood.

A true backlight is traditionally placed behind the subject so that it is pointing directly at the camera resulting in a thin rim of light around the edge of the subject. They are also placed at higher angles to highlight hair and clothing. Back cross-lighting is frequently used to put a rim on both sides of the subject. A soft backlight can look natural even if it has no obvious motivation. A hard backlight, unless it is motivated by direct light, will look unnatural, but they are still often used anyway. Backlighting should be used with thought since it tends to be overused.

Backlighting is easy to achieve in live action, often with one light. However, many shading algorithms ignore light which strikes the back of an object and do not try to simulate the halo effect that results from backlight hitting a surface which is not mirror smooth. Without special shaders which comprehend backlighting, creating this effect in CGI requires a bit of cheating and patience. It helps to have roughness controls on the specular highlight of each light source, so that the backlights can have as broad a highlight as possible. Exact light placement can be tricky to control especially with moving or multiple characters, and multiple sources. If a localized effect is desired, a spotlight may be easier to control than a solar light which is more effective over a broad area. Consistent backlighting is also tricky to achieve in a wide-angle shot, especially if a character is moving across the frame. It may be necessary to animate backlights in these situations.

4.6.2.5 Kicker—*for surface modeling and character enhancement*

A kicker light is an *optional* light usually used to define the non-key edge of a subject. This light typically works from a three-quarters-back position and is placed nearer to the floor than the backlight. This light can be soft and diffuse or hard and specular, depending on need and the intended lighting style.

A kicker light is a more general name for a variety of lights which perform slightly different functions. The three main types are a kicker, a liner, and a glow light. When used to create a sheen (specular light), on a cheek for instance, they are frequently referred to as a kicker light. When far enough forward to contribute more diffuse light, it is sometimes referred to as a liner light. A glow light is a little farther forward still and is softer, non-specular, and shadowless. On people, it is usually desirable to avoid having a hot kicker light hit the tip of the nose.

4.6.2.6 Specials—to accent an area for either subject or background

A special is any type of light that is used for background and set lighting, or for highlighting an area on the subject.

4.6.2.7 Bounce Lights—to simulate radiosity effects

In computer graphics lighting, unless a radiosity renderer is used, extra lights usually need to be added to simulate the light that normally bounces off nearby surfaces. These lights are usually localized, non-specular, low-intensity and colored to mimic to the surface they are reflecting.

4.7 The Color of Light

4.7.1 Color Palettes

A lighting style is described as a chosen tonal range, but it also includes a color style as well. Color style is often discussed in terms of palette, consisting of hues and tones. In order to set a style, a fairly small selection of colors are chosen according to how they relate to each other. This selection, or palette, may consist of complementary colors, analogous colors or another of an infinite variety of combinations. The sets and costumes already have an established palette which the lighting designer may try to accentuate or minimize.

Naturalistic lighting mimics the complementary palette found in nature. The range is from yellow/purple to orange/blue to red-orange/blue-green in varying degrees of saturation. For a daytime scene, the key light is warm, simulating the sun, while the fill light is cool, simulating the natural fill of blue sky. A nighttime scene might reverse this sense with a strong blue key light acting as moon light with a soft warm fill emanating from incandescent indoor lighting. The eye is accustomed to seeing this warm-cool relationship in a wide range of color intensities. The contrast between warm and cool is minimized during the early to middle part of the day, and grows as the day nears

dusk as dust particles in the atmosphere filter the color of the light. A natural feeling still can be maintained even when using a strongly colored light which falls outside of this natural palette, as long as it appears to emanate from a visible practical source.

The similarity or contrast between lighting hues and saturation can help suggest the mood of the scene. Scenes which are lit with similar colors tend to be more somber than scenes which use extremes. The color of individual objects, sets and costuming evoke emotional responses of their own. The combination of these elements into a whole image also presents an overall color for emotional consideration. Lighting can be used to accentuate or minimize individual areas of color as well as setting the tone for the overall scene.

The placement and intensities of the lights also have an effect on the overall color. A low-key, almost black and white effect, can be achieved by minimizing object color saturation with the use of strong directional lighting. The emphasis falls on the shapes of objects rather than their surface colors.

Many new lighting designers are intimidated by using and mixing brightly colored light sources because they don't do what the designer expects. Most people have had experience with *subtractive color theory* since they have mixed colors together as paint or other pigments. It is called subtractive because if you mix the three primaries (red, green, blue) together, the result would be black. If you mix the three primaries of light together, the result is white light. This is called *additive color theory*. A quick study of additive color theory would give the new lighting designer confidence to explore the mixing of colored lights.

4.7.2 Color and Emotions

Early man's use of color was largely symbolic and emotional, based in mysticism and religion, and not necessarily chosen for aesthetic reasons. The palette for a culture was estab-

lished and adhered to within that culture, and was used to identify themselves by dynasty, race or tribe. Not until the Renaissance was color appreciated as an aesthetic choice.

Colors evoke physiological, psychological and emotional responses. These responses are a reaction to associations we make with our past experiences and cultural heritage. Two people can have very different reactions to the same color, and one person can have a varied reactions to the same color depending upon its context. Even so, there are enough common life experiences and contexts within which to draw some generalizations about how color affects us emotionally, especially in American culture where many of them have been stereotypically reinforced by advertising.

Colors are often referred to as being *warm, cool or neutral*. Warm colors are generally agreed to be those which fall within the red-orange-yellow spectrum, and cool colors to be within the green-blue-violet range. Neutral colors are those which are near grey in saturation value. Cool hues tend to recede and induce calm. Warm hues stimulate the nervous system and raise the heartbeat. Pure, saturated colors tend to advance and excite, while duller neutral colors tend to recede into the background.

Specific colors evoke more specific associations and responses. Red, for example, is an emotionally charged color which has many associations: anger, passion, fire, blood, violence, sunset, sex, adultery, aggression, power, creativity, embarrassment, and courage. It is also used as a universal symbol to stop or to denote when an error is encountered.

Green recalls calmer memories: nature, water, trees, mountains, meadows. It is an introspective, reserved color which evokes feelings of security, constancy, normalcy, balance, civility, convention. It is a suburban color for active healthy people. It is the color of money. Green is generally a positive color, although it does have negative associations, we have all

heard the expression "green with envy". Green lighting can look eerie, chemical, artificial and unhealthy.

Blue can feel heavenly and religious and is associated with Western culture weddings. It feels spacious as it reminds us of the sky and oceans. It is a rational, conservative color which symbolizes authority, loyalty, order, peace, conformity, success, caution, and patience. Blue lighting can look gloomy, electric, and cold if there is no warm light to counterbalance it.

Violet and purple have been associated with royalty since the Roman Empire when only the emperor was allowed to wear it. It can feel magical, exotic, sensitive, sophisticated, idealistic, and cultured. Violet lighting in shadow areas can be very beautiful.

Yellow feels sunny, happy, and reminds us of summer days and flowers. It is also associated with intellect, wisdom, timidity, cowardice, and hunger. Yellow lighting is associated with mid-day and interior settings.

Orange is the social color, full of fun and cheerfulness. It is urban and outgoing. It has also recently become known as the safety and construction color due to its visibility. Orange lighting is associated with evenings, and interior lighting.

Brown is a homey and down-to-earth color, full of duty and responsibility. It is often associated with poverty and the lower class and is easily disliked. It is also associated with the past since objects tend to turn brown with time and exposure.

Pink packs more punch than other pastel colors. It can immediately portray someone as feminine, silly, delicate, floral, pampered, tender, healthy, wealthy, vain, and indulgent.

Black can look formal, elegant, and sleek. It can feel evil, empty, mysterious, anxious and fearful. It is associated with night, death, and inevitability.

White can feel pure, virginal, innocent, classical, and youthful; but it can also feel sterile and emotionless. White lighting is associated with high afternoon sunshine and daylight interiors.

Grey is the color of oppression and isolation. It can feel institutional, indifferent, sad, cold and heartless.

A person's response to a color is immediate, but is usually short-lived. After continued exposure to a color, the effect wears off or sometimes even reverses itself. It is the change from one color to another which triggers an acute response.

Researchers who study human response to color have established that people remember skin tones as being warmer or pinker than they really are. Human skin (real or computer generated) is more appealing in warm light and we like to remember it that way. Films are usually lit and color-corrected during printing to make skin tones look "rosy", and in general, films are usually color-corrected for the skin tones rather than for other colors or objects in the scene. Overall skin tones which are colored more realistically tend to give an image a documentary feel.

4.7.3 An Example Palette and Usage

The movie "Crimson Tide" is a terrific example to illustrate these points because it takes them to the *extreme*. The chosen color palette is pure saturated primary colors, red, blue, yellow, with the addition of pure green. The set and costumes are dominated by neutral tones with accents of these primaries. The main part of the submarine is lit with nearly neutral light as well. The overall intensity is fairly dark, with hotter rim lights, giving it an enclosed, submerged feeling. The intensely colored lights are used to place the viewer in different locations

within the sub. Green light is used near the sonar screens, blue light in the transition areas, red light in the weapons room, and yellow hazard lights flashing everywhere to heighten the sense of urgency. The brightly colored scenes intercut with the neutral ones, which can be somewhat jarring, but you never get confused about where the shot is taking place (even with the sound turned off watching it for the first time). This intercutting also tends to heighten tension, mimicking the attitude of the flashing hazard lights.

4.8 Shaping and Controlling Light

Of equal importance to the placement and direction of light, is shaping and controlling it, illuminating the intended subject without spilling into unwanted areas. It is sometimes also desirable to create a defined light shape, either to mimic a logical source, or for dramatic or compositional purposes.

Many of the techniques used to control and shape light synthetically can be similar to those of live-action because the problems are also similar. These problems include controlling the light's size, shape, distribution, isolation, and coverage over distance.

It is desirable to break up large or even surfaces with varying light and shadow. Sometimes this can be achieved with deliberate, recognizable shadows from actors or props and sets, other times a more subtle overall variation will be appropriate. Barndoors, the four flaps attached to the sides of a light, can be used to shape and trim a source. The use of freestanding flags to block lights, can be used to shape light at various distances from the source, which allows control over the hardness of softness of the shaping. A cucaloris (or cookie), a rigid board with squiggly holes cut into it, can be used in front of a light to create a more random, organic light pattern.

A good computer lighting toolkit will offer a variety of light shapes along with sizing and soft barndoor controls. Further light shaping

can be accomplished with the use of blocker flags, slides and cookies, as well as light attenuation over distance.

Computer lighting has several benefits which do not exist in live-action. Lights and flags can exist anywhere in space without interfering with the camera or subject. It is also possible to illuminate a subject and not have the light affect other characters or the background, negative intensity lights can be used to softly subtract illumination and shadows can be independently colored, blurred, and given an arbitrary density value. The apparent softness of a light can be independent of its distance from the scene, and resulting shadows do not necessarily have to be projected from the source point of the light.

Shadow quality and shadow placement to remove light from certain areas are methods for controlling light, creating emphasis, and establishing mood. The "Film Noir" lighting style often used superlative examples for controlling light to establish mood and influence composition. The film "Mildred Pierce" offers wonderful examples of not-so-subtle plays of light and shadow on both subject and background.

5. Creating Depth

The film medium is a two-dimensional surface through which light is projected. Any feeling of depth and three-dimensionality achieved is merely an illusion. This implied depth must be created; it does not happen automatically simply because the subject matter is three-dimensional.

5.1 Planes of Light

The separation of planes is a significant aspect of achieving depth through lighting. Most literature on live-action lighting discusses the necessity of creating *planes of light*, often without really explaining what it means or how to achieve it. A lighting plane is essentially a col-

lection of objects or subjects which are parallel with the camera plane and are lit as a unit to contrast with other planes. These planes can be any distance from the camera and are defined with light for the purposes of creating the illusion of depth through layers.

As an example, a simple scene might nicely break down into four planes, from back to front: the view out a window, the wall of the room, the subjects, and a near-foreground object such as a vase of flowers. Lighting each of these planes in reference to each other will enhance depth. The foreground vase of flowers could be dark in silhouette, the subjects brightly lit, the background in partial shadow, with a bright view out the window. Each plane is clearly defined by its brightness.

This separation can be further accentuated by color variations between planes, with the subjects being in warm light while the background wall is lit with cool light. The subjects can also be further separated from the wall with a little backlighting motivated by the window. And as another step, the vase of flowers and the view out the window might be out of focus.

By finding ways to create planes of light, a scene becomes easier to visually organize. It also gains much added richness and beauty.

5.2 Volume and Space

Depth is also implied by feelings of volume and space. Volume can be created for individual subjects or other objects in the scene. Space is created by how these subjects and objects are compared to each other.

For individual subjects, volume can be accentuated using back and side lighting, by highlighting prominent features, and leaving the rest in shadow. In contrast, any light which emanates from the general camera direction tends to reduce the illusion of volume.

The three-dimensional quality and the feeling of space in a set can be augmented by using pools of light separated by dark objects or areas. For example, a long hallway has more apparent depth if only a few parts of it are lit with shadow areas in between. A subject which moves in and out of light imparts a greater feeling volume as the light travels over its surface, and a greater feeling of space as the subject travels over distance.

5.3 Perspective and Depth of Field

The motion picture image is a window into a world where the viewer makes intuitive comparisons to determine what they are seeing. Some of these comparisons are easy. If an object is bigger than another, it is probably nearer. If an object overlaps another, it is decidedly closer. At this point, the comparisons start to become more complicated. Does the object appear small because it is a small object or because it is far away? The brain looks for other monocular and binocular clues to establish size and distance. The converging lines of linear perspective are very helpful, but can be altered with the use of various camera lenses. As an example, a long telephoto lens tends to condense distance, making faraway objects appear very near. Focus and depth of field are also important clues, but are dependent on the lens focal length and aperture used. Aerial perspective is helpful, but it can vary depending upon atmospheric conditions. The brain also uses the angle between a light source and where its shadow falls to help determine object-to-object proximity. The viewer uses all of these comparisons to organize the image and to establish depth.

Depth of field is an inherent feature of binocular eyesight, hence it feels natural in a monocular camera lens. With a live-action camera, depth of field is determined by the focal length of the lens as well as the aperture used. Each lens has its limits within which it can operate effectively. With these limits in mind, a lens is chosen depending on the story-point, mood,

filmstock, available lighting intensity, the actor's features, and compositional reasons. The choice is a technical decision as well as an artistic one. A synthetic camera has the technical restrictions removed, which makes the choice a purely aesthetic one. This doesn't mean that the choice becomes any easier. The lens and its depth of field determines how the viewer interacts with the subject. Two close-ups with similar subject framing can have dissimilar effects resulting from the perspective and focal depth caused by the choice of lens. One lens can place the viewer uncomfortably close to the subject while the other places the viewer at a more detached distance simply through depth of field. A close-up where the background is out of focus will feel more intimate than one where the background is sharp.

Depth of field is also important in establishing depth. A shot with varying levels of focus will have more apparent depth than a shot which is uniformly crisp. In addition, depth of field is useful for directing the viewer's attention to the subject which is in focus. Depth of field rendering is very convincing, although it can be expensive and is not supported by all renderers. Pseudo depth of field can be created by rendering the scene in planes and then blurring them by varying amounts during compositing. This solution is adequate for many close-ups where it is more frequently used. Another solution is to use a depth buffer image of the camera view and blur the final pixels based on their distance from the camera. It is even possible to pull a convincing rack-focus with these techniques, although it should be kept in mind that some blurring filters are more convincing than others.

5.4 Atmosphere

The use of atmospheric effects can enhance both depth and mood. Except for a windy day or immediately following a rain storm, some dust and water particles hang in the air which reflect and scatter light. These particles are particularly noticeable in direct sunlight where they create shafts of light. The mood these

shafts create depends largely on context and light color. Bright, warm shafts of light feel warm and cozy while cool shafts feel misty and foggy. Dingy, warm, irregular shafts feel smoky.

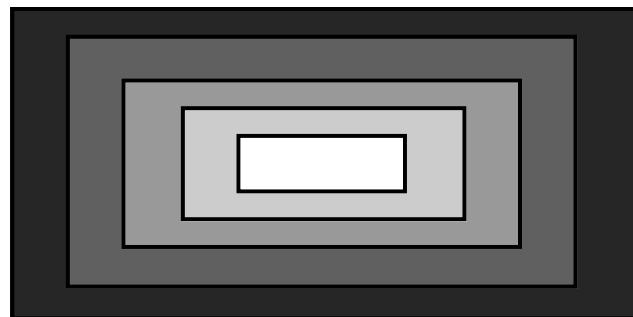
Atmospheric effects are also noticeable over distance where they create aerial perspective by minimizing color saturation and contrast. Smoke and fog machines are heavily used in live-action cinema to heighten these effects. In the computer aerial perspective can be created simply by adding a percentage of a fog color into the shading calculation for each pixel based on surface distance from the camera. For more complicated, three-dimensional effects, volumetric light shaders can be used.

5.5 Lens Effects

Other effects that enhance atmosphere and depth which are often used in live-action are lens effects. Diffusion filters or nets can be used to slightly soften a scene and glow the highlights. These filters can be used overall or just around the edges leaving the center clear. On the computer, gaussian filters and other image processing techniques can be used to reproduce these effects during compositing. Lens diffusion effects create a soft, sensuous, romantic quality. They are often used in close-ups to beautify actors, with less diffusion on medium shots, and none on long shots. Other filters frequently used are grad filters which darken or alter the overall color or density as a ramp across the lens, or as a vignette.

5.6 Depth Using Color and Value

Depth can be enhanced with chromatic and luminance separation. A warm subject over a cool background will impart more apparent depth than a subject and background with the same color temperature. Similarly, if the brighter side of a subject is placed against a dark background area, it will help define the shape of the subject, and keep it from blending with the background.



A further feeling of depth can be achieved by lighting the background more brightly than the foreground, with a blending of tonal ranges between. This is especially effective in a dark theatre environment.

6. Conveying time of day and season

Conveying the time of day and season is important to place the story and to illustrate passages of time. The time of day and season are major factors in determining the quality, quantity, motivation, direction and color of light sources for a scene. They also are major components in setting the mood.

For daylight scenes, being too literal about placing lights for the hour's sun position is not necessary and is often not aesthetically desirable. A general feeling for dawn, morning, afternoon or dusk is usually sufficient since light positions often need to move to be able to light subjects attractively, and the subtle time distinctions would be unnoticeable by the viewer.

At dawn, the light is blue, warming as the minutes pass. Slightly later, in the early morning, the rising sun casts long shadows, and the color of the light is slightly blue. At noon, when the sun is overhead, the lack of shadows tends to flatten the images and make color appear less vivid and interesting. The light tends to be very white in color, becoming more warm as the day progresses. In the evening, at sunset, the shad-

ows are long, and the color of the light appears more red. The low sun at both dawn and sunset rims figures and objects with light that separates them from the background and, depending on the position from which the scene is photographed, creates dramatic or romantic effects. For winter scenes, the light is usually colder all day and the light angles remain more horizontal. Light nearer to the poles tends to be cooler than light nearer to the equator.

Morning light feels optimistic and cheerful. The day is beginning with high hopes for what it will bring. The air is fresh and you feel rested and rejuvenated. Evening light is romantic, but it is also a little melancholy. The day is coming to an end, slowing down, and you are getting tired. These daily cycles are repeated on a yearly scale as well; spring is a new beginning and the light is clear and cool, autumn light is warmer and nature is winding down for the year. An old person portrayed in a morning spring setting will feel more energetic and youthful than when the scene is set in afternoon autumn.

Day interiors are usually lit with soft lights except for any direct sunlight which may be shining through a window. The light sources are usually motivated by windows rather than practical sources in the scene. Day exterior lighting is motivated by the weather and the setting. There is much more license to modulate the light outdoors. Dappled lighting effects through trees or a cucaloris are frequently used, especially on the background.

For night scenes, hard, directional lighting is more justified, although soft light is also frequently used. The practical sources which are visible in the frame should determine the quality of the light. The illusion of night is created by the angle and the distribution of light. The angle of the light tends to be less frontal for a night effect, a three-quarters-back key light is frequently used with little frontal fill. Because there is less ambient and fill light in general, the percentage of well-lit areas in the frame is smaller, and specular glare becomes more noticeable.

7. Revealing character personality and situation

The quality, color, and direction of light can indicate to the audience impressions about the personality or character of the subject. It can also say something about the dramatic situation, or emotional state of mind, in which the subject currently finds himself. When a character is narrating a scene, he can describe his thoughts and how he sees the world; visual representation of his thoughts is not necessary. Most of the time, however, we require the use of our imagination to decipher the motivations and feelings of the characters by observing their actions, watching them emote, listening to them interact with other characters, and surveying their surroundings. It would be confusing to listen to a movie with the picture turned off, we rely so much on our vision to tell us what is happening, which is probably why we "watch" television or go to "see" a movie.

Visual clues are an aide for the viewer to help him understand the story more quickly or completely, getting him emotionally involved with the characters and their predicaments. Visual clues are comprised of tangible elements such as location, sets, props, wardrobe, time of day, time of year, that are almost taken for granted, but without which the viewer would have no context. Is it Elizabethan England in the dead of winter, high noon on the chaparral, or a humid summer night in New Orleans?

Besides establishing context for scenes, visual clues can also impart an emotional impression on the viewer by employing symbolism. My on-line computer dictionary describes symbolism as "expressing the invisible or intangible by means of visible or sensuous representations" as "artistic imitation or invention that is a method of revealing or suggesting immaterial, ideal, or otherwise intangible truth or states". Some of this is absorbed on a conscious level (the good guys wear white hats, right?) while much of it is subliminal.

Light itself expresses symbolism as life, freedom, clarity, hope, enlightenment, truth, and guidance. Darkness represents the opposing forces. The source type can also express emotion.

Candles, for instance, are associated with happy occasions such as weddings and social dinners, as well as contemplative locations such as church. They are also nostalgic since they remind us of times before electricity. Warm, soft, flickering candlelight is sensuous, flattering, seductive and romantic. Windows and doorways represent transitions. Our hopes "fly out the window", and "opportunity knocks" on, and comes in through, the doorway.

Light placement and direction impart emotional significance as well. Hard underlighting is commonly used to signify an evil or criminal character or situation. Soft underlighting can look very sensual. Lighting from directly overhead can look dreary when the subject is looking down, but spiritual, uplifting and hopeful as the subject looks up toward the light. Completely illogical lighting is often used in dream sequences or hallucinations, the more illogical, the better.

Whether we realize it or not, we attach symbolic meanings and react emotionally to virtually everything. Some reactions are innate, others are dependent on our culture, and still others are uniquely personal.

As a lighting designer (and visual storyteller) we can take advantage of these emotional reactions in how we choose to portray characters in a scene. The best way to learn how to do this is to study films (with the sound off) to experience how you are emotionally affected by what you see.

8. Complementing composition

The seemingly simple act of placing lights can radically change the composition and focal point of a shot. Good lighting can make a well-

composed image stunning. It can also rescue a less-than-perfect composition. As an example, start with an unlit, staged scene and add just one light with its shadow. Move this light around the scene and change its direction, observing how the composition changes. As the light moves, shapes transform into different shapes as they become defined by light or lost in darkness.

Every shot is unique and requires its own analysis, particularly considering that each shot has its own story-point to convey. What works well for one shot might not be the answer for another shot. Most of the time, a shot will require the lighting designer to address several problems. The background is too distracting, too busy or too plain, the main compositional lines all point to a different character than the one with the dialog, or maybe it needs special care for it to cut well with the next shot. Trying to figure out where to start is often the most daunting dilemma for a new lighting person. The establishment of the focal point is the best place to start. In the process of creating emphasis for the focal point, distracting elements will need to be minimized. Once this has been achieved, how the remainder of the scene is lit will largely be determined by the lighting style.

9. Continuity

It would be wonderful if there were enough time to craft each shot as its own masterpiece, capable of surviving scrutiny on a gallery wall. But there isn't enough time, and sometimes it is also not appropriate. A complex composition takes time to study, and the eye can take its time meandering to various points of emphasis. A thirty frame shot needs to direct the eye quickly. The audience does not have time to guess where to look, the shot needs to have immediate impact.

The desire to craft each shot as a masterpiece also needs to be balanced with the necessity of a consistently lit sequence. It is very important to constantly check the lighting progress on other shots being lit in a sequence, especially if they are being lit by other people. Lighting will inevitably and necessarily vary from shot to shot, but the overall feeling of the shot should be consistent with its sequence and especially with its adjacent shots. Sometimes this means that lights need to be brighter, darker, warmer, cooler, or even repositioned to achieve a unified feeling as camera angles change. However, the more similar two shots are that cut directly together, the more important it is for the lighting to be same.

An establishing shot which shows a wide view of the set for a sequence, will usually require broad lighting strokes and often more light in background areas to establish the set. When the camera moves in for the close-ups, it is often desirable to darken the background slightly or move a shadow line to help the foreground subject to separate from the background. These changes should be unnoticeable to the viewer, and fortunately changes in camera angle and cut-away shots help hide these alterations. You can get away with more than you might think, but the only way to know for sure is to be able to view the shot in context. The computer lighting environment offers immediate feedback, as well as preview and comparison capabilities not found in live-action.

10. Film Considerations

Once a shot is lit on the computer, it is rendered and exposed onto film. It is then developed, printed and projected onto the screen, sometimes with surprising results. Colors and values can sometimes change drastically. Film can only capture a small range of the available light and color range of the real world. Film recorders may not even be able to reach the range of the filmstock. Video monitors vary widely and may not match the final result. For these rea-

sons, it is preferable to view lighting tests on film whenever possible.

Although it is desirable to get as close as possible at exposure time, the printing process offers great latitude in altering color and density (brightness). This process is called *timing* the print. Each shot can be timed individually, but not varied over time. The timing is applied over the entire image, it is not yet possible to tweak isolated color areas as is possible in digital film-to-tape transfer sessions. It should be kept in mind that it is usually much easier to time a print darker than brighter. By brightening a print, more light is pumped through the negative which can result in a washed-out "milky" quality.

11. Conclusion

One of the most creative aspects of lighting is in finding ways to unify a screen-full of characters, objects and sources into a readable and believable shot. This is where everything discussed thus far comes together and starts bearing fruit. But, it takes practice to be able to look at an image and quickly know how to make it better. It helps to learn from other people, and to learn to look at images objectively. In art class critiques, instructors frequently turn all of the students' paintings upside down or sideways and then start the critique. The point is to teach the students to see things they wouldn't otherwise think to look for. It also helps to study classical painting, illustration, Disney animation, still photography, and to watch movies with the sound off. Observe the world around you at various locations, times of day and weather conditions.

Learning to light is learning to see, but requires more than keen observation. The most difficult and most important aspect to learn is visualization, the ability to see the final result in your mind before you begin. It is also important to be comfortable with what your tools can do. The final consideration is one which cannot be taught as inspiration. This you must find within yourself to nurture with experience and experimentation.

12. Suggestions

- Think about the story-point of the shot and the overall mood you are trying to evoke.
- Think about what logical sources might be in the scene which can help motivate the lights you are using.
- When attempting to complement a composition with light and shadow, it might help to first break up the composition into its planes. If the foreground or main character element is working well, it may help to try to take advantage of it as much as possible.
- A large flat shape does not always need added interest, it depends on the rest of the composition, but it often adds depth to modulate or ramp off the light.
- Very saturated colored lights will particularly alter a composition as they reflect unexpected hues back to the viewer. Some colors will go very dark and murky while others will leap from the screen and steal the show.
- Avoid the temptation of lighting dark shots too dimly. At least part of the image needs to be well-lit.
- Avoid placing a bright light which emanates from near the camera lens.
- Remember that one light cannot always solve two problems.
- Think about shot-to-shot continuity, but don't be too limited by it.
- Consider that lights which animate in position, unless they are attached to a moving object, will not look natural, use with care.
- Don't be too literal about the physics of it, go with what looks and feels right.
- Remember that there is *always* more than one right way to do anything.
- Investigate new ways to do things.
- Ask for new features in your tools.
- Experiment and get a second opinion.
- Share your successes and discoveries.
- Keep it as simple as possible.

13. Bibliography

[Lasseter87] *Principles of Traditional Animation Applied to 3D Computer Animation*, by John Lasseter, Pixar; SIGGRAPH 1987.

Matters of Light & Depth, by Ross Lowell; Broad Street Books; 1992.

Logic & Design in Art, Science & Mathematics, by Krome Barratt; Design Books; 1980.

Painting with Light, by John Alton; University of California Press; 1995.

Film Lighting, by Kris Malkiewicz; Prentice Hall Press; 1986.

Cinematography, Second Edition, by Kris Malkiewicz; Simon & Schuster Inc.; 1989.

Design Basics, Third Edition, by David A. Lauer; Holt, Rinehart and Winston Inc.; 1990.

Psychology in Action, Second Edition, by Huffman, Vernoy, Williams and Vernoy; John Wiley & Sons; 1991.

Elements of Film, Third Edition, by Lee R. Bobker; Harcourt Brace Jovanovich; 1979.

Introduction to Film, by Robert S. Withers; Barnes & Noble Books; 1983.

Color & Human Response, by Faber Birren; Van Nostrand Reinhold; 1978.

Design and Composition, by Nathan Goldstein, Prentice Hall; 1989.

LIGHTING IN THE REAL WORLD

A Traditional Filmmaker's Approach

By Steven Poster

I think that I had my first conscious thoughts about light as a pre-teenager. I had become interested in Photography at ten years old. By twelve I knew that this would be my life's work.

I learned at first how light reflects off of surfaces.

I knew that light was crucial to my life, but I didn't learn how to control...no, how to see it until my first six weeks at Los Angeles Art Center College of Design. These were extraordinary times for me. A man named Charles Potts was my lighting instructor. From my first lecture with him I felt that I was having a religious epiphany. His explanation of what light was taught me how to see for the first time. If I can give you just a small portion of what he gave me I will feel that this was a successful seminar.

The first thing the soft spoken Mr. Potts taught us was that light was a law: There were five components that always existed when a light source was shined on a subject.

These were:

1. The Highlight Side
2. The Shadow Side
3. The Core
4. The Cast Shadow
5. The Incident Highlight

The qualities of these components on the subject helped define the direction of light, the size of the source of light, the shape of the subject, the material and surface of the subject.

Charlie, as he was affectionately known, also said another startling statement during our first lecture; "There are only two kinds of light. When It's sunny and when It's cloudy". This deceptively simple statement defines the quality of all light sources in the universe.

We will spend the next couple of hours examining how these five components of light and these two qualities of illumination are the basis of learning to see light. Once this visceral connection is made, you will have to tools to be able to then learn to control lighting in all of your work. Whether it is in the real world or the many fantastic virtual worlds that you will create. And once you can begin to control light you may be able to develop the spiritual connection to seeing how this seemingly simple element of our lives controls much more than our just our ability to see.

PIXEL CINEMATOGRAPHY

Lighting for Computer Graphics

By John Kahrs

Introduction

As Computer Graphics increases its sophistication, the craft of creating the images has come into its own. The tools have gotten easier to use, allowing the user to concentrate less on technology, and more on content. In the same way a writer forgets the computer keyboard he or she types on, animators, technical directors and artists can think less about operating systems and Cartesian coordinates. They can start to concentrate on the lighting, the animation, the refinement of the image itself.

With computer lighting, there has been a thrust towards creating ever more accurate models of light, recreating the effects of light, and improving the tools for lighting, but there has been little attention paid to how to best use these often very sophisticated toolsets. We also see a great disparity in the quality of the images. There is work that is simply astounding in its excellence (the T-Rex night attack in *Jurassic Park*, *Toy Story*), and yet conversely, one can open any magazine on 3D computer graphics and see images in which the lighting seems to have been given little or no attention. Hopefully, these notes pinpoint why some images succeed, help identify common mistakes.

The idea is not to concentrate on the physics and science of lighting (although this has to be addressed, it's unavoidable), but to get a better idea of how light works, and also how light and materials are reproduced with computers. This information is directed toward the users of software. The focus is on the craft of image-making with computers.

A logical place to start would be to find traditional principles in similar disciplines that apply to the new medium. This would including live-action cinematography, still photography, and even painting and illustration. These art forms evolved to a high degree long before CG was even a concept, so it should pay to examine these areas closely.

The special considerations for computer lighting are numerous, and an attempt to address them has been made for these notes. One of the most troublesome issues is that computer models of light usually give only a raw, rough outline of the way light behaves. The complexity and subtlety of light that is the free, real time toolset of a live-action director of photography (DP) is, in the computer model, just a slow, crude approximation. It is the digital artist's task to bring some semblance of this richness to the antiseptic CG world. Also, artists must also specify and tune material qualities. This task of creating materials is just as crucial as placing the lights, yet it often happens that material qualities are given only minimal attention, and without knowledge that they have limits and relationships to one another.

Some of the concepts covered here may seem very basic, but in practice they open up to a complexity of variables. Overall, the aim is to concentrate on concepts and principles: problems and solutions, not how to use this or that software's menu cells.

There is a misconception that you need a high-end, expensive renderer to do really good lighting. Actually, a good renderer does help a lot. It

makes things easier, but it's not necessary. If the software is merely *adequate*, experienced users can push the software further than the designers ever envisioned. Where you run into trouble is when some basic capability is simply missing. Then the workarounds become an onerous task, and a good workman *can* blame his tools.

Whether you drive a Yugo or a Rolls Royce, you can still get to places. The Rolls will be a pleasure to drive, and the Yugo you might have to jerry-rig along the way, but you can still go places with it. And conversely, you can drive the Yugo with style and skill, and abuse and ignore the quality of the Rolls Royce.

Anyone who claims that they are "stuck" with the limitations of low-cost software should take a look at a few images from the CDROM game MYST, which used an inexpensive, off-the-shelf

Macintosh software called Strata Vision 3D™. With limited tools, MYST's creators defined the standard for CDROM games to follow. This probably had less to do with the software itself than with the authors' solid grasp of image contrast, composition and sensitivity to ambient light issues.

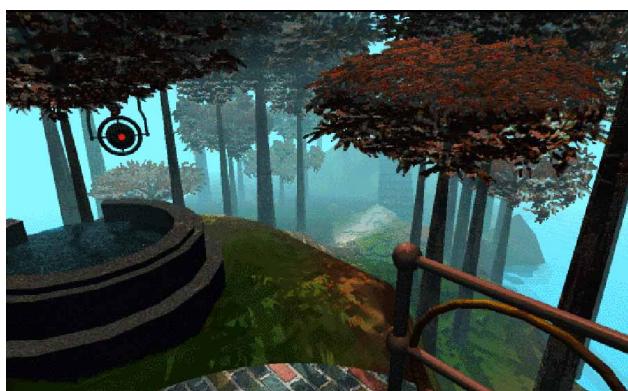
To illustrate the points in this course, many of the images were rendered with Softimage's original renderer, a sort of middle-ground renderer: the Ford F-150 of raytracers. Otherwise, Blue Sky's *CGIStudio* was used to create the images.

Video 101

Whenever I've tried to learn about lighting from a book on filmmaking, I come across a chapter on "Basic Lighting Techniques", and I've been presented with a "basic lighting setup". This invariably consists of a key light, a fill light, and a back light, or "kicker".

When I walked into Video 101 in my first year of art school, this three-light technique was dropped on us right away, and when we tried it, it looked awful. It looked cheap and plastic. Now that I think back on what we were doing in that little studio, I realize that my class, and those books were all just scratching the surface of a more complex set of issues.

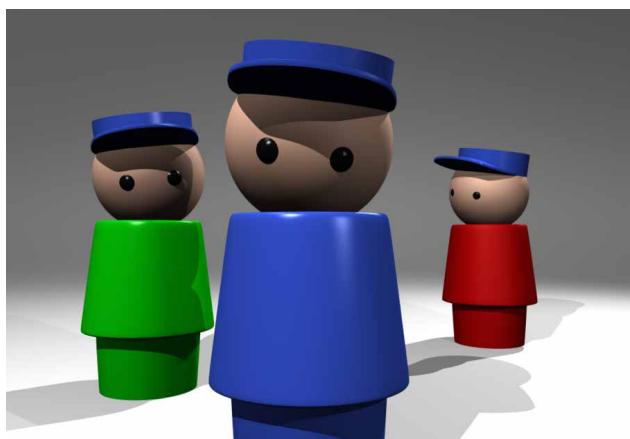
When I began working with computer graphics, I had no experience with any kind of studio lighting except for that bad experience. I had some background in painting and photography, so to a degree, I understood how light worked. I shunned this standardized 3-light approach because of its canned quality. So, at that point, I didn't have any approach, I just looked at reality and tried to observe what happened, to learn from it and appropriate it. I decided, not only in CG, but in general, that forcing every situation



down a constrained pathway was a mistake, and that it made everything look essentially the same. I recently discovered that many of these books and classes were being written and taught by people who worked in television from the 60's and 70's, and their concerns with light were less about motivation than about ease of use, simplicity and low production costs. I wanted to start from a different state of mind: which I later discovered was to let the characteristics of the scene dictate the lighting.



The standard 3-light studio setup: key light, fill light, and kicker.



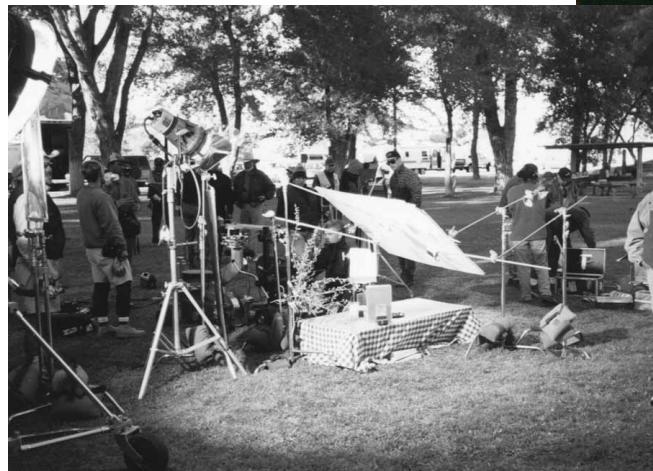
Which usually gives a TV-studio look to even the most innocent, unsuspecting subjects.

As I worked over time, I saw that the way a lighting setup evolves in computer graphics is very different from one on a live-action set. Most of my time was spent trying to balance the ambient light, or just trying to get the overall image to have some kind of balance, or maybe it just felt right. A lot of effort was spent on the backgrounds and environments. I saw that the figure/ground relationship was completely different, because, for example, ambient light was controlled solely (and often arbitrarily) by the user. The overall balance of the image depended heavily on how I adjusted the ambient light. In the computer lab back in school, many of my classmates didn't realize it was there to be adjusted.

When I started lighting at Blue Sky, I began to use reference more and more. When I strayed from the reference, the image quickly got lost. When I didn't have any reference, I never even knew what I was looking for. I kept playing around with our radiosity model when I had free time, (a switch in our renderer that recreates the complex diffuse reflection that occurs with real light). This allowed me to see how light behaved when the computer model was more in line with what the real-life scene would look like. It was like taking picture of a real-life model of your scene. Slowly I got an understanding of how light works in the CG realm, in the same way that a photographer can call out the *f*-stop and shutter speed of a scene simply by looking at it. Many of the things I learned made their way into these notes.

Most interestingly, without even intending it, this basic key/fill/kicker combination began to appear in the lighting setups: both in my own scenes, and in live action environments that were duplicated for integration. I'd be working on a scene all afternoon, and suddenly, there it was: key light, fill light and backlight. The more I looked at film images and tried to understand what was being done on the set, the more I saw these same elements of key, fill and backlight over and over again.

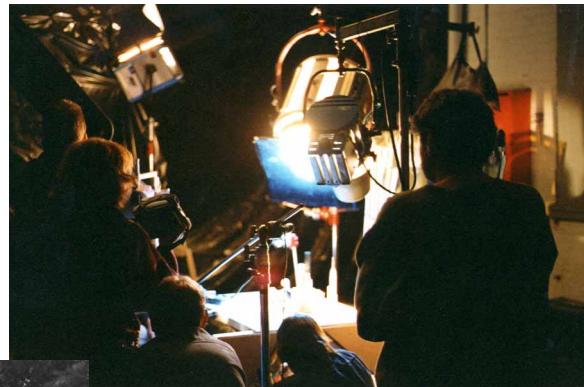
But this time, there was much more motivation and subtlety behind the placement and tuning of these lights. The lights had a logical reason for being there, not because a book or formula told someone that they were supposed to be there. The degree to which the quality of each light's contribution was refined was orders of magnitude more than I'd experienced in school. This was light years ahead of Video 101. I also saw that this general configuration was common, but by no means universal. Good lighting set-ups were developed not from some formula, but from the needs of the situation.



There were more than a few lighting rigs that had several lights, reflectors cards, mirrors and other little adjustments. And there were some lighting setups that were beautifully simple. Some used only one light.

Clearly, there's no standard, basic way to light any scene. The needs of the scene define the way it should be lit. To go even further, it's a mistake to think that this course, or some person, can teach someone how to light computer imagery. Just as in figure drawing, there is no standard, or "correct" basic approach, but there are ways of beginning, and there are common, successful techniques. The key/fill/kicker setup is one of these techniques and definitely a way to begin. I no longer see it as a confining

formula or book of rules, but as a toolkit with which to express the image. It is part of the language of lighting. In that video 101 class, we just didn't know what to say yet.



The basics

Since we now have a friendlier view of this toolkit, we can take a closer look at it. The traditional live-action approach to lighting seems to be an endless reconfiguration of the classic key light/fill light/ back light approach. Again, it is often a good starting point, but a motivated lighting setup rather than the default should always be considered. Some scenes have nothing to do with these "standard" lighting configurations.

This classic approach has a definite application in computer graphics, and the problems it solves are essentially the same as in live-action. You need general illumination for your subject, you need to fill in the shadow areas so they aren't too dark, and often, but not always, you want to separate your figure from the background, and rimlighting, backlighting or kicker lights help to achieve this. Again, this is not a rule book, it is more a way of naming certain kinds of commonly used lights and understanding what they do.

Key Light

A key light is the primary source of illumination. It may be several lights, to cover extended spaces that a subject passes through. A common key light placement provides $\frac{3}{4}$ illumination from above. " $\frac{3}{4}$ " refers to the fact that the majority of, say, someone's face is illuminated. The key light doesn't have to come from any specific direction. It may come from behind the subject, where it might be called a $\frac{3}{4}$ rear key, or directly from the side: a side key. It is usually the first light on the digital or live-action set, and other lights are added after the basic illumination of the key light is roughed out.

Beginners often place the key light close to the camera, because they simply want to see what they're doing, which creates very flat, frontal

This is why the "default" $\frac{3}{4}$ placement is mentioned and used so often as a starting point: it doesn't just illuminate the subject, it *models* it, using light with shadows.

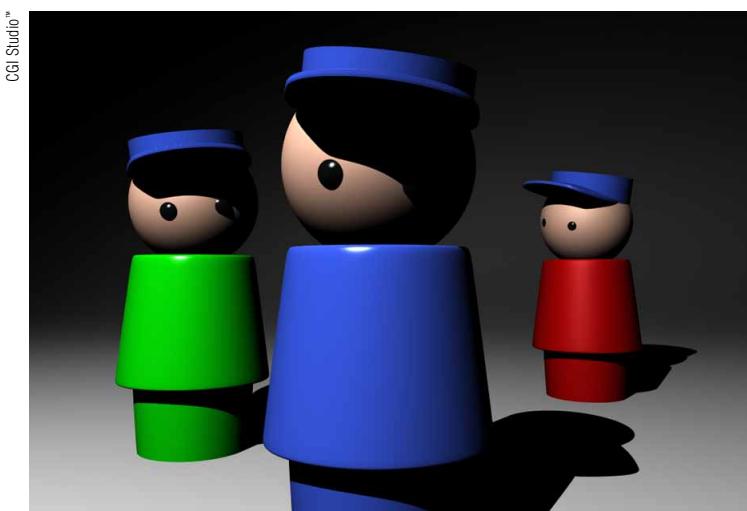
We could go into the qualities of key light like many lighting books seem to (such as whether it's hard or soft), but those qualities should be self-evident. Descriptions of this sort are usually redundant explanations of what is obvious to the eye.

Fill light

A fill light softens and fills the shadows that are created by the key light. Without fill light on a live action set, the shadows would be too harsh and dark, since the natural ambient light in the scene is usually not enough to do the work.

On a real set, for the purposes of these notes, we could say there are two different categories of fill light. One kind of fill light could be called *natural ambient*. That is, the light that reflects off of objects lit by general illumination. The other kind of fill light is *added fill*, or lights that are added specifically by the filmmaker to fill the shadows. This light from added fill bounces around the scene as well, so natural ambient is really, from a live-action point of view, a by-product of the whole process.

In the standard computer model of reality, the categories and complexities of fill light are drastically reduced. Unfortunately, this also means that a lot of the subtlety we're used to in real life ends up going out the window. There is no natural ambient in the world of computer graphics. The shadows are even darker, because there is no natural ambient light occurring in the scene.



Key Light, shown here as a broad spotlight in a $\frac{3}{4}$ placement.

light. A key light isn't necessarily a frontal light. Just because the light hits the subject, doesn't mean we've lit the subject. On the contrary, it is light and shadow we're working with. Frontal lighting is just one kind of light, and it can take skill and experience to make it work well and not look boring and flat. The quality of the shadows is at least as important as the quality of light, and it's the two elements working together that make an image.

To solve this problem, natural ambient light in computer graphics often takes the form of general ambient light, which merely provides a base of unidirectional illumination in the scene, or it can be another point or parallel light source. Sometimes this ambience is specified in the object's material. Unidirectional ambient light is the most disappointing kind of "light" in computer graphics, and it's often what makes computer graphics look so awful. It's really not light at all. It provides no modeling in the shadows, contributing to the stereotype of flat, computer-looking images. And even though this kind of light is wholly insufficient, any subtlety it may have to offer is usually nixed, since it's often the least-refined lighting component in a CG scene. On the contrary, fill light and ambient light probably should be the *most* tuned, most refined component of a scene.

Computer generated ambient light has to fill a very big gap in the computer's model of reality, because without a radiosity renderer, this model is seriously incomplete. The CG artist's task is more complicated as both kinds of fill light: natural ambient and added fill, must be duplicated.



Fill light, created with a combination of ambience and a low intensity spotlight.

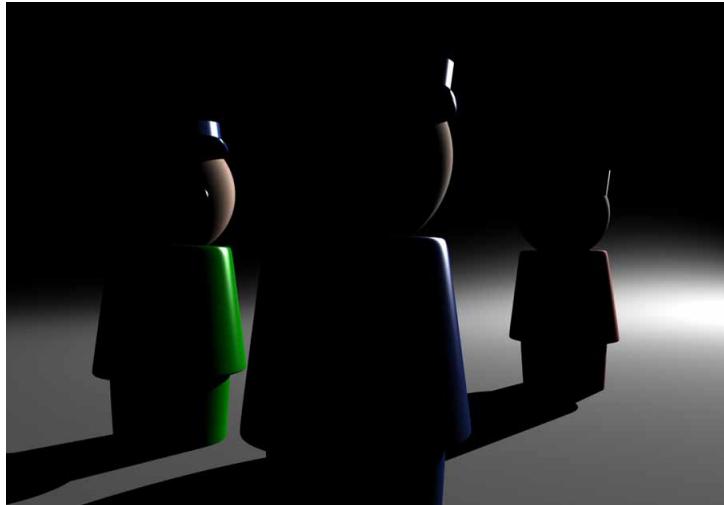
Fill light on a live action set often comes from an area close to the camera, leaving no shadow untouched, at least from the camera's point of view. Other times, a general set illumination is provided to raise the base level brightness of all objects in the scene. Screwball comedies from the forties often have this kind of high-key fill light.

In the real world you can get away with the inherent flatness that this tends to add to the image, because there is that natural ambient bouncing all over the place, adding modeling and interest. In the CG realm, this kind of subtlety has to be added by the artist, and there are different ways of tackling this.

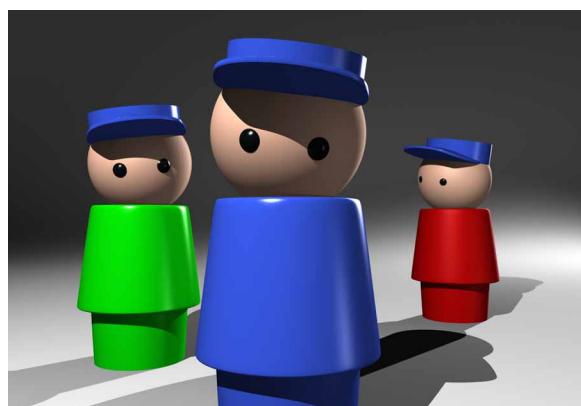
The concept of ambient and fill light is discussed again in these notes, but for now, a good place to start when adding fill light would be a combination of unidirectional ambient combined with one or more additional point light sources from logical directions, which sometimes ends up being from the opposite direction of the key. If you can eliminate the occurrence of specular highlights on objects from these sources, the ambient can look very believable. Sometimes, this simple base ambient may be all you need. Sometimes the scene may need a complex arrangement of fill lights.

Back light

A backlight provides highlights and rim lighting around the edge of the subject. The backlight is often what differentiates the subject from the background, and it's also often what separates ordinary life from Hollywood. When it happens naturally, it can be beautiful. But the situations where backlighting occurs naturally are just as often as any other arrangement. In movies, it seems to occur continuously, and is one of the things that makes movies look like movies. Backlighting tends to bring a stylized quality to the image. When it has no relationship to what might occur naturally in the scene, it looks very stylized.



A “kicker”, or rimlight, used typically to separate the subject from the background.



The key-fill-kicker lights combined together. When the lighting is unmotivated, it looks stylized and clichéd, but this combination can be used to create thousands of lighting environments.

Generally, it's a good stylization, and it has a purpose, which is to separate the figure from the ground, and define the edge of the subject.

Typical back lighting comes from behind and above the subject. A “kick” light typically refers to a light positioned directly opposite a $\frac{3}{4}$ frontal key, a technique that was very common in the 1940's. Another term called rimlighting provides illumination around the edge of a the subject, not necessarily coming from above or directly behind.

Different lights can switch roles, with the key light eliminated, for instance, and edge lighting as the dominant source of illumination. This is prevalent in night photography, since it defines the clearly against the groundplane, but the overall image remains dark, so we still think “night” when we see it. The rimlight becomes the “key” light, and where the key light used to be is now working as a fill light.

At some point, categorizing the lights with labels becomes pointless as the numbers increase and roles become more vague. But it's useful, if only to communicate ideas, to have names for lights and what they do. If we use lighting that is logically motivated and has a logical link to the situation, then formulas become obsolete. It may help to think of lighting in the sense of: “This light represents the street light in the distance. It happens to be functioning as a rimlight.”, and not: “Here is the rimlight, why is it here?”

Supplementary lights

Eyelights

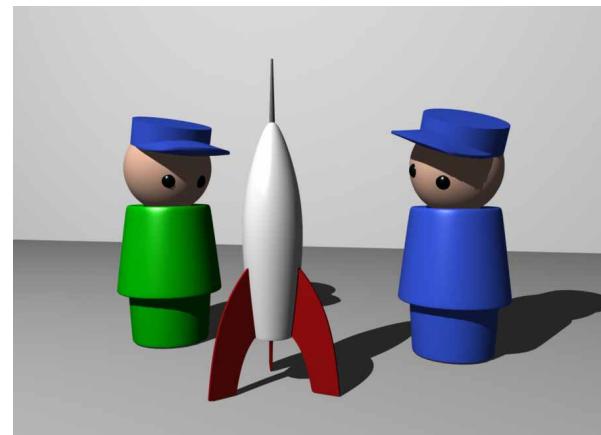
A related kind of fill light that is used often on a live action set with actors is the eyelight. It seems that whenever a subject's eyes have brilliant little highlights in them, they seem more alive, more sparkly, they "come to life". People who make movies have known this practically since movies started, and the way it's often done is by placing a small, low intensity point light source right next to the camera and pointing it at the subject. A dim light will still provide highlights in shiny surfaces such as eyes, and won't illuminate the diffuse surfaces very much. There's no reason this won't work for the same reasons for computer generated scenes and characters.

Practicals

A practical light is a light source that occurs in the frame. A lamp on a table, a candle, a flashlight, and yes, the blinding light from the mothership in *Close Encounters* are all practical lights.

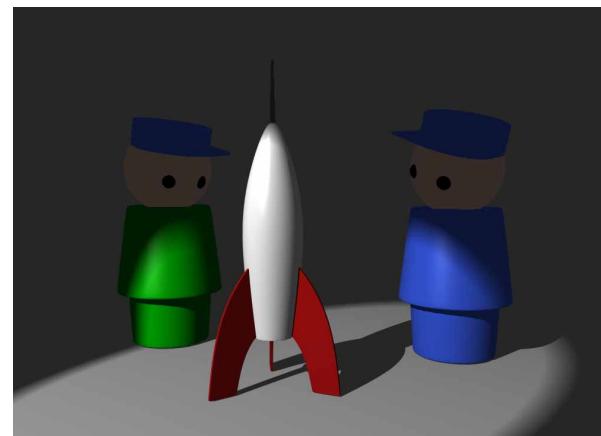
These kinds of lights are often not powerful enough to shed light on their own in the scene. You might have a memory of watching old monster movies, and figuring out that, "Hey! There's some guy with a spotlight off camera!", who is shining it on the wall next to the woman with the candle on the stairway. Film stocks were much slower back then, so light from flashlights, candles and table lamps was supplemented with off-camera lights. This often looked obvious, but as lenses and film stocks became more sensitive, the actual light from these lights could be used, probably culminating with the film *Barry Lyndon*, when the director, Stanley Kubrick, had special extra-fast lenses developed so he could film scenes using actual candlelight. The techniques that "fake" the light from a practical light are more still used often, and are much more convincing nowadays.

Thinking about ambient light



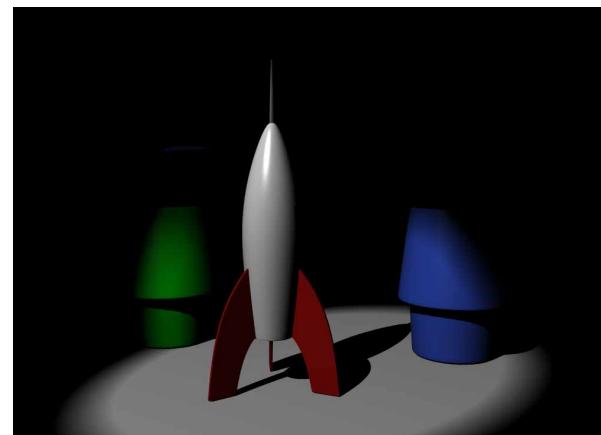
Softimage render

With a basic, $\frac{3}{4}$ key light shining on the subjects, the environment around them illuminates pretty evenly, so the default unidirectional ambient does an adequate job.



Softimage render

If the lighting moves outside of this basic situation, suddenly the basic ambient light becomes irrelevant. In the shadow areas, there's no modeling at all.



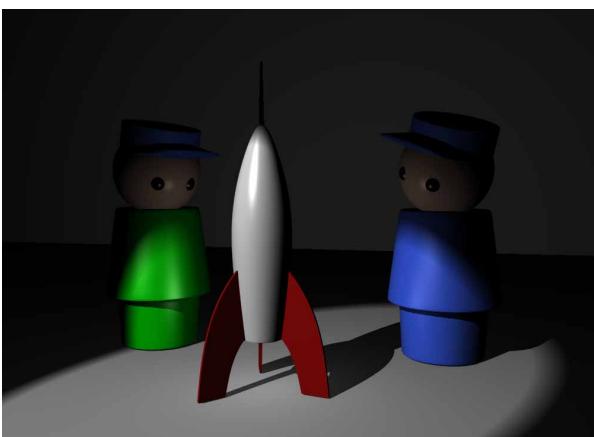
Softimage render

As an example, let's take a step back from this scene and figure out what's happening. First of all, the light has now become much more localized, so whatever ambient contribution there was from the walls and floor is mostly eliminated. Our first response for this scene would be to eliminate the ambient light altogether.



Softimage renderer

So now there's no light reaching the subjects outside of the spotlight. Again, what would happen here if this was happening in reality? The bright spotlight illuminates a portion of the floor beneath the subjects. This light bounces back up into the scene from below. We could consider it a light source. We could place a point light source right where the floor is illuminated, and it does the trick.



Softimage renderer

When the two lights are combined, the scene begins to have a resonant quality to it: we start to believe in it, or at least much more than we believed in the first spotlight image. Instead of settling for simply illuminating the scene, we tried to isolate what's happening in terms of the ambient light, and create a more specialized ambient that has some relationship with what we've observed.

In computer graphics, whoever's doing the lighting has a distinct advantage in this regard, since he/she can control lights of any brightness inside the camera's view without the source being seen, eliminating the need to fake the practical's light with an off camera light of greater brightness.

Creating bright lights in the image frame brings up some points about qualities that make an object seem truly brilliant, such as diffraction or flaring. There has been some interest in recent years in ways to overexpose and flare out super bright objects in computer images. Blooming, flaring halos around bright lights offer a visual cue to the eye that makes the difference between an odd white shape on the screen and a brilliant, blinding light.

Local spots

Wherever the brightness of a localized area must be controlled independently of the entire scene, a local spotlight is sometimes used. Computer artists have the capability (if the software does also) of isolating which objects are affected by certain lights, so this local control is actually much more flexible than in live action. If those doing CG lighting would kill for the kind of interaction that live-action DP's have, they'd probably kill to have our control and isolation capability with CG lighting.

Local spots are especially handy in product shots for commercials, to insure that the labels are exposed properly, and often to simply illuminate the face of a subject, or to draw attention visually to a certain place in the frame. It's important not to let these added lights become too numerous and complex, as it make the entire lighting setup slower and harder to control.

With all our ability to twist or own models of reality into customized images, it may seem odd for live action DP's to break the rules. It turns out they can do anything, such as using tiny, isolated spotlights pointed at a tiny strip

of mirror attached to a motion control rig. This can create a local highlight on a subject just where they want it, and nowhere else. Powerful but very focussed spots can backlight just the steam from a cup of coffee, or a diamond ring on someone's hand.

This sort of very specific tuning of the light should be exercised with care. If you go too far with it, it's much like overworking a painting. There is a kind of "forest for the trees" phenomena where every little object is tuned and balanced perfectly, yet somehow the overall image lacks impact. This topic is covered in more detail in the section called "Image impact".

Ambient light

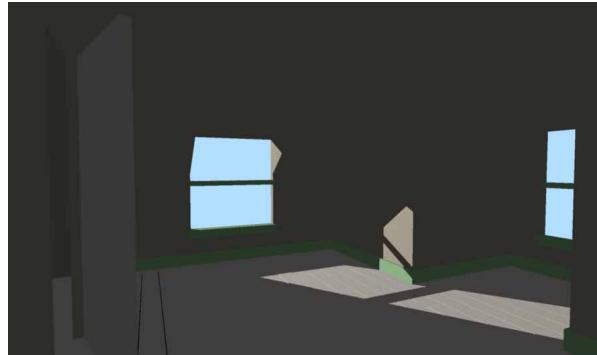
Ambient light should be considered the most crucial part of computer lighting, and though there's been a lot of improvement in the way it's used in computer graphics, its role still seems the most often under appreciated. The reason it's so important is that, in the computer world, it has to fill the role of duplicating very subtle and complex phenomena that occur in real time, all the time in the real world: indirect illumination, or radiosity.

As you read this, take a look at the environment around you. Some of it will probably be lit directly by light sources. But chances are that many areas are illuminated by reflected light. In some cases, the entire scene, such as the shady side of a daytime city street, is lit by indirect light.

Computer artists have enough trouble just recreating direct lighting, not to mention the complexities of indirect illumination. It doesn't come automatically in the CG world, and it's such a big part of the environment around us every day.

Using local fill lights to create a richer ambient environment

When light illuminates a space, it reflects off surfaces in that space. Using judiciously placed spotlights with very soft, broad cones, we can approximate this diffuse inter-reflection.



Softimage renderer

The default, unidirectional ambience offers little in the way of subtlety. As a first step, let's get rid of all the lights and consider what's going on in this room.



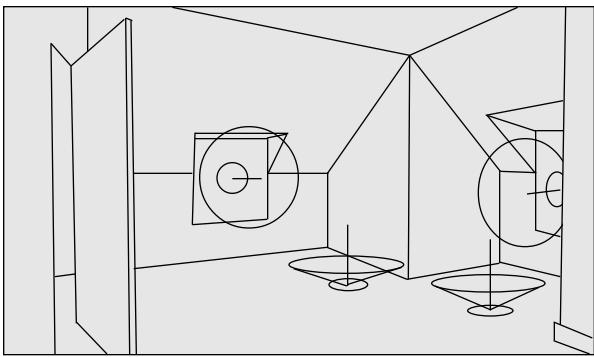
Softimage renderer

Before we work with the sunlight, what about the sky? The brightness of the light coming in the windows is an important contributor to this scene. For this room, the planes of the windows are, effectively, local light sources. Two very soft spots (over 180° of spread) are placed in each one, with significant dropoffs. The colors are on the cool side, since the light is sky blue.

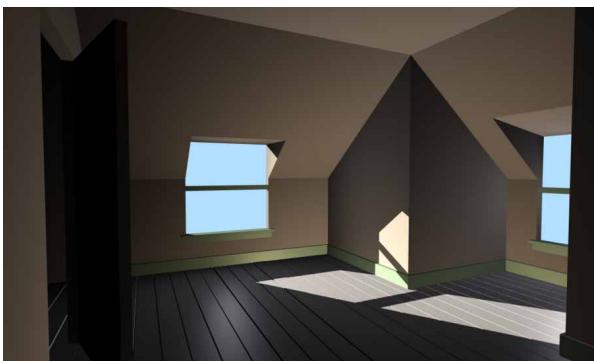


Softimage renderer

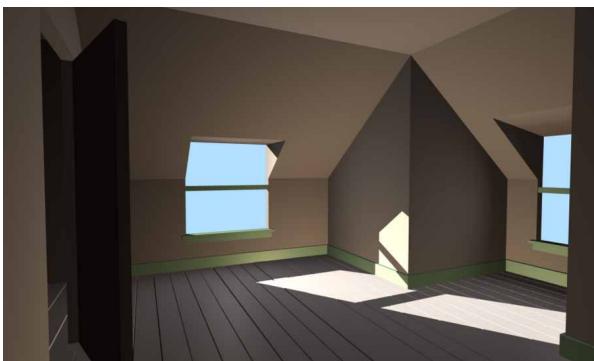
Now for the sunlight. When the sun hits that floor, it reflects up into the room. For efficiency's sake, two spotlights along the length of the patch of light and just below floor level are used instead of an expensive and (for this particular renderer, unavailable) area light. They have a similar dropoff and spread to the window spots, only they are warmer in hue. Much warmer than the sunlight itself, too.



Remember, all these fill lights don't cast any shadows. With a total of only four lights, this scene won't take too long to render.



When all the elements are combined, the image is miles ahead of where we started. Also keep in mind that these lights were isolated to show each component separately. That's not the way to work, though. Usually everything has to be up and running simultaneously to understand the image as a whole. Nothing's set in stone, either. Several materials were tweaked along the way. The floor highlights were knocked down, and the door material was made much darker, to get a more mysterious feeling that contrasts with the bright room.



To exaggerate that contrast even more, and get a more open, bright feeling, some of the dreaded unidirectional ambience was added back into the scene, in a small dosage (10%). In this role, it works well. Tweaking the hue of this ambience only slightly can drastically affect the hue of the entire image. A bit of warmth is plenty for this scene.

There are some areas in this image that feel almost like radiosity rendering. With more detailed modeling and some texture-mapping on the walls and floor, it could approach photoreal, and all with a few, ordinary lighting tools.

Live action directors spend plenty of time and effort either trying to get rid of the ambient light, or trying to direct it into the right place. On a typical set, there are large frames with black cloth stretched across it to kill the ambient reflections from unwanted areas. There are also similar contraptions with white material to reflect soft illumination back into the scene. They try to balance the look of the scene with these and other tools, and that's exactly what it's all about: balance. This balance is going to change significantly according to the situation. Usually, the more ambient light there is in your scene, the less contrast there is. The ambient light has to be adjusted to complement and logically fit into the needs of the lighting situation.

Every scene will have its own quality of ambient light, and each situation should be tackled distinctly, in terms of its own needs.

Dropoff

A crucial characteristic of light is that fact that its intensity drops as the distance from the light increases. When you hold a piece of white paper 2 inches from a 100 watt bulb (the light has to be turned on for this complex experiment to work), you can hardly look at it, it's so bright. Hold the paper 6 feet away and it seems dim by comparison. Except for the sun (which is so distant that its dropoff is negligible here on Earth) this effect occurs everywhere. Candlelight wouldn't be candlelight without it. In live action, it's a major consideration in terms of exposure.

Any self-respecting renderer or raytracer ought to have dropoff controls for its light sources, it's often up to the user to find those controls, because it tends to be turned off by default. It's cheap to compute, so why not add it to your scene? This is one lighting switch that, when you start using it, pushes the believability and subtlety of your images to another level.

It's often necessary to compensate for the decrease in brightness at the subject's location by pumping up the intensity of the light at its source. It's also useful to note that the smaller the light source, the more pronounced the dropoff is. A tiny strobe light flashing on a plane wing at night drops off harshly over a very short distance.

When lights have a pronounced dropoff, consider saving render time by excluding these lights as illumination on distant objects. (For instance, those mountains in the distance at night aren't visibly affected by the porch light of the cabin in the valley.)

Some places where dropoffs can really look great is when you're trying to recreate diffusely reflected illumination, such as the sunlight bouncing off the floor in a room. The sun wouldn't have a dropoff, but the patch of sunlight, because it is effectively a local light source, definitely has a dropoff. Consider how bland the light from this effect would be without it.

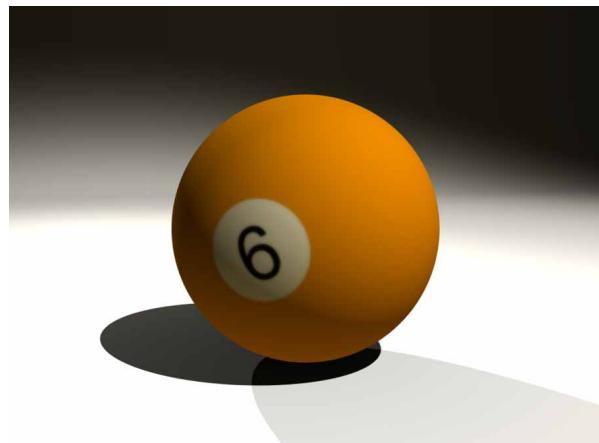
Judiciously placed fill lights with carefully tuned intensities and dropoffs can give CG images a radiosity quality. As light bounces around in a scene, that light has a rich, varied quality that rises and falls in a complex layering of overlapping dropoffs. Using lights this way can offer an organic feel that CG images often lack.

Material properties

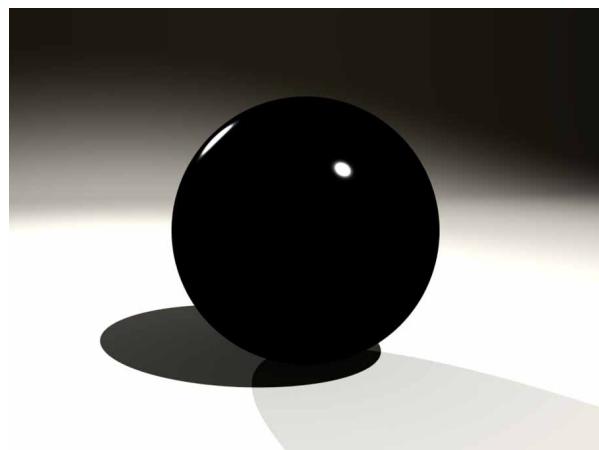
Understanding how light behaves is one part of digital lighting, but the computer cinematographer also needs to have an understanding of how surfaces react to the light. Not that we have to become part-time physicists, but this involves knowing a little about the science of materials.

There aren't really any rules for lighting, only guidelines, but there are some pretty well defined rules for the physics of materials, and it pays to rely on them, or even just use them as a starting point, because you're nowhere if you're just guessing and flailing around. Knowing about how different materials operate can make the difference between images that are just OK and images that are outstanding.

Components of Dialectric Materials



A pool ball makes a good example to explain material components. The diffuse component is the reflected energy of the flat pigment that gives the object its color.

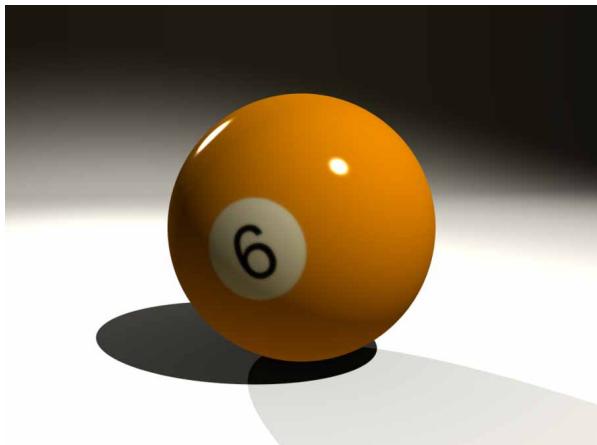


The specular component isolated. Specularity here is the neutral-colored highlight of the polished lacquer on the surface of the ball.

Specularity and Diffuse

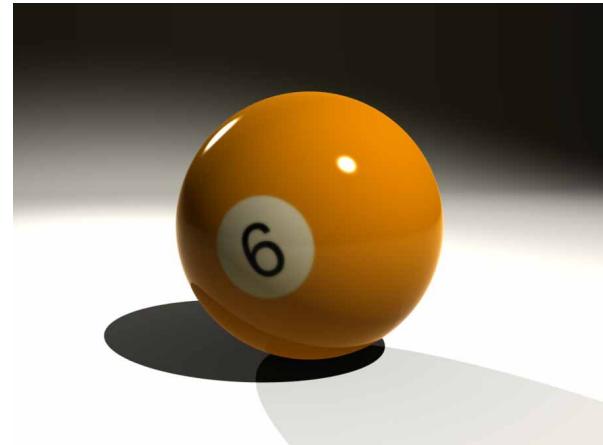
There are two major components that are used to describe materials. These are *specularity*, and *diffuse*. The color, property, and proportion of these two components are used as a foundation to describe just about any material that exists. Unfortunately, many renderers treat this simple relationship in a more convoluted way, so the better we understand these characteristics, the more effectively our materials and shaders can work for us.

When light hits an object, the energy is reflected as one of two components: the specular component (the shiny highlights) and the diffuse (the color of the object). The relationship of these two components is what defines what kind of material the object is. These two kinds of energy make up the 100% of light reflecting off an object. If 95% of it is diffuse energy, then the remaining 5% is specular energy. When the specularity increases, the diffuse component

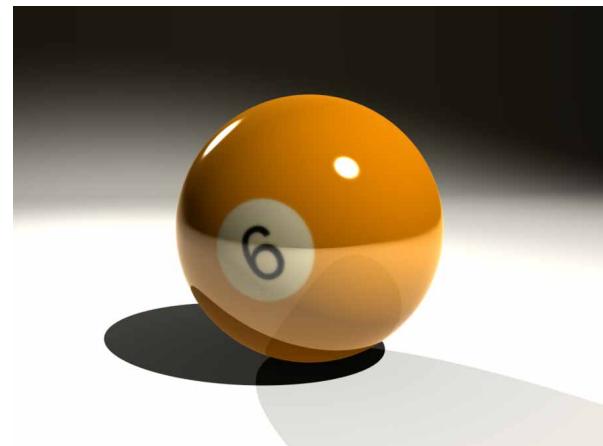


Diffuse and specular combined.

When these two elements are combined, the two reflected components are represented. This is true for any material, it's the proportion that differentiates each one on this basis.



The specular reflectance of non-metals is very mild: note how faint the reflections are. This is important to remember when creating realistic-looking materials.



A common error is to set the reflectance characteristics of non-metals too high, which isn't representative of such materials.

drops, and vice versa. A ping pong ball is considered to be a very diffuse object, with very little specularity and lots of diffuse, and a mirror is thought of as having a very high specularity, and almost no diffuse.

Nonmetals, white highlights, and 4% of the light

If we can divide two major components of reflected light, we can also further separate materials into two main categories: metals and nonmetals.

First, let's talk about nonmetals. These kinds of materials are called dielectrics. They include Formica tables, enameled automobile body parts, bic pens, telephones, pool balls, polished wood, dull paper, enamels, glass, magazine covers, polished fingernails, granite, marble, any other plastics. The list goes on.

Dielectrics have two important characteristics. One is that the highlights are always white (well, actually the color of the light), and the second is that they usually have a specular component of only about 4% or less.

What this means is that most nonmetals usually reflect no more than 4% of the light as specular energy, and this energy is the color of the light source, not the diffuse color of the object. The rest of the reflected light is of the diffuse component. This may not seem right, but when you take a closer look at the world around you, it makes sense.

Reflections in a car's bodywork, for example, are actually rather dim compared to the reflections in the chrome. In addition, these reflections aren't colored, they're neutral. If the reflections on a red car look red, it's because the reflected light from the paint is showing through from underneath, not because the reflection itself has a tint to it. Tinted reflections are the province of metals, which are discussed in the next section.

When people discover, with delight, that they can reproduce reflections in computer-generated images, they enthusiastically make the mistake of pumping up the specularity so the reflections are more pronounced. This is often seen in student animations, including my own.

Shinier on the Edges



When you look in store windows, it's easy to see increased specularity as the surface turns away from us. Here's a material that effectively has the diffuse component eliminated from it, and the dimness of the reflection in the window is just a fraction (about 4%, coincidentally) of the intensity of the street behind you. It isn't reflecting like a mirror at all.



As the window surface turns away from us, the reflections become much more pronounced, to the point where the glass becomes opaque, and it does behave more like a mirror.

Now a word about white highlights. It's OK to bend the white highlight rule from time to time, especially with subtle materials such as skin, but using white highlights is a solid starting point for nonmetals. Most of the highlight variation in these kinds of materials are in it's size and intensity, not the color.

Metals



The highlight colors of metals are the same as the diffuse color, and metals tend to have a much higher specularity than dielectrics.

Since the reflections are such a prominent component of the way metals look, lighting metallic subjects has more to do with controlling the reflected environment than adjusting the light on the subjects themselves.

If there were no surrounding environment to reflect in these spheres, all we'd see is the specular highlight on a black field.



Another interesting thing about specularity is that it increases as the surface turns away from the viewer. A good demonstration of this phenomena is to take a piece of paper (something that seems to have very little shine, if any) and hold it out in front of you so it's almost parallel to your line of sight. You might be a bit surprised to see shiny highlights and even some dull reflections in the surface.

You can see this effect clearly at night while driving: in the pavement are reflections of the headlights of oncoming cars. Pavement and paper aren't materials you normally associate with having reflections, but there you go. Look out across calm water, and you can only see reflections. Look down into the water, and the reflection is much fainter.

Where this effect gets really interesting is in conjunction with rimlighting, or kicker lights, or backlighting, or whatever you want to call it. Because these kinds of lights hit only the edges of the subject, and they come from behind the subject, these circumstances combine with the above mentioned phenomena of increased specularity to create brilliant, dramatic highlights that separate the subject from the background.

Unfortunately, understanding this detail about edgelighting isn't enough. You might be stuck with a renderer that is simply missing this capability, and many of them are missing it. This is one example of something that seems small, but when it's not there, your eye tells you there's something wrong.

Metals

As materials go, metals are a different animal, compared to dielectrics. The highlight color of metals is the same as the diffuse color, as opposed to neutral, and the specularity is much higher than that of nonmetals. A mirror is essentially a highly polished metal with neutral coloring, and would be considered an extremely specular object. All metals could be

considered totally specular, and the amount that the user specifies really has to do with how much oxidation, surface abrasion or dirt there is on the surface. A subway car is almost mirrorlike, but the dirt and coatings drop the specularity down considerably.

Beyond these characteristics, making metals look great is the same as making transparent materials look great: it's not about the light that hits them, it's what they reflect and refract that matters. It's about the environment around the object, not the object itself. This is why anyone who knows about photographing jewelry spends most of their time up front building these house-of-cards environments around the piece, and spending most of the time lighting that controlled environment.

It also doesn't hurt to sometimes recreate the blurry reflections in the surface, if it's right for your purposes. This can be accomplished most easily by blurring the reflection map, or writing the diffuse reflections calculations into the rendering software itself. The latter is a more accurate technique, but the former is a nice cheat that renders quickly.

Limits of classic computer lighting models

Before we jump into practicing what we've preached, let's cover a little more ground on a specific element of material characteristics.

Because of the way computer lighting models evolved, we have to use a somewhat limited way of creating realistic material qualities. Every renderer or raytracer uses some variation on a solution for creating specular highlights in materials. They assume that the light source is a point source, such as a 100 watt light bulb on the other side of a room. If that's your lighting situation, you've got it made. But what if you're trying to create, say, little characters that live 2 centimeters beneath that light bulb? Suddenly it's not a point source any more, it's an immense, broad field of light that encompasses the subject. How do we recreate this situation with "traditional" computer lighting models?

The answer isn't so easy. The problem is that as the size of the light source increases, the one-stop shopping solution for specular highlights starts to break down and become inappropriate. The classic highlight is only a quick approximation of what's happening. A highlight is a reflection of the light, sometimes soft and broad, sometimes tiny and tight, but still a real reflection. Unless the light source is on the small side, the distinction between the lights and the reflections of objects becomes more vague.

Also keep in mind that the diffuse lighting may not "wrap around" the object properly if the software is always treating the light as a point source. The quality of light from large light sources such as overcast skies are difficult, if not impossible, to reproduce with a renderer that considers all lights to be point light sources.

These limitations are found in almost every renderer software that uses traditional lighting models for CG imagery. There's been some very interesting research done recently to address these shortcomings, but they often involve very compute-intensive solutions. (Let's face it, these are complex phenomena that are difficult to recreate). But when someone has no R&D department, or little time, other solutions must be found.

At some point, you have to make a call as to how you'll solve this problem: the reflection of the light source doesn't fit with what's happening.

If the object is reflective, and you can raytrace or create an environment map, then you're in luck. Get rid of the specular highlight and reflect an object or a map of the kind of light source you'd see in such a situation. If the surface is rougher, you might try blurring the reflection map, which is a classic trick that works for most situations.

Other, more diffuse materials have no visible reflections but still have some highlights, like skin, or clothing. In these very soft, large light source situations, usually you can simply

spread out the highlight. Consider eliminating highlights altogether and concentrating on getting a softer quality of diffuse light with multiple soft shadow-casting sources.

We've discussed some major points with lights and materials, and we've isolated different components in all materials. Some people might be scratching their heads when they go to apply these ideas to whatever software they use: Specularity doesn't do what is described in the notes. Perhaps "diffuse" is not available as a control. Maybe it's called "shininess", and what's that?

Nobody has to conform to anyone's idea of how to name, control or relate material characteristics. For instance, in the Blue Sky renderer, a field called "Roughness" controls the size of the specular highlight, and "Specular" controls the intensity of the highlight. In the Softimage original renderer, the slider that says "Specular

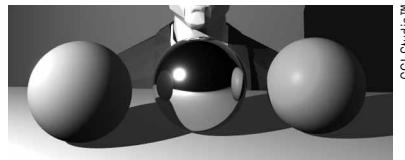
"decay" controls the highlight size, and a triple RGB slider controls both the color and the brightness of the highlight.

Sometimes a control called "roughness" or "shininess" is the control for the specularity of objects. However it ends up, it's up to the user to isolate and find out what knob really controls what. In the end, even cheap software can end up being pretty impressive if it's reined in with what you know.

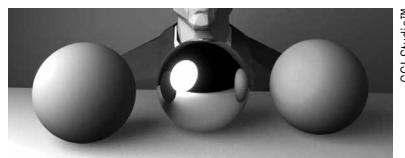
Lighting with a plan

The previous sections should give us a better understanding of what computers do to recreate light and materials. This section continues to emphasize finding the needs of the lighting situation, and making appropriate decisions in response.

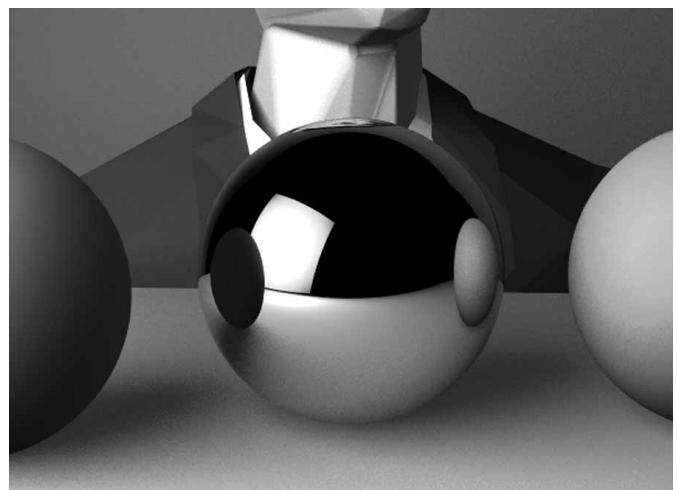
A limited solution for highlights



With the standard computer graphics lighting model, lights are considered point sources. If this matches your situation, then highlights look believable.



As the size of the light increases, the size of the highlight can be increased to match, but at some point, this specular lighting model becomes unable to approximate what would happen, especially for highly reflective materials.



One solution is to eliminate the point source highlight and replace it with a reflection of something more logical. In this case, the sphere raytraces a box with a bright, vignetted map on it that mimics a very soft, square studio light.

Working with computers to create pictures provides advantages that visual artists from the past never had: perfect perspective rendering, scientific models of the way light behaves in a scene, complex texturing capabilities. It's neat stuff, but it's only a tool: it can't truly refine the image. That's the job for you, the user.

Ollie Johnston, a great Disney animator, created an indispensable list of animation notes. One of my favorites says, "Spend half your time planning your scene and the other half animating." It's good advice, and it's no different for lighting. There's a lot to be said for having a clear idea of what you want to do before you even begin to rough out the lights in a scene. Sometimes, if you're working for a director, they have this clear idea about what a scene should look like. That's usually a good thing, but you still have to bring your artistry to fleshing out the details. There are other times, though, when no one is providing the vision except yourself. So where does this vision come from?

Some ideas about where to start have already been utilized in the examples for these notes. In every situation, there is an effort to isolate each scene on its own terms, to find just what exactly is happening with the light. Not to shoe-horn the scene into some formula of how lighting should be, but really think about how the light and materials need to fit together to make the image work for you.

Using Reference

One image integrates perfectly, another falls far short. One scene really looks like what you want, another just isn't right for some reason. There are a lot of reasons why some images succeed and why others don't. One of the keys to success is to use reference, to recognize what it is about the lighting situation that makes it what it is, and to put this knowledge into practical use.

One place to start is to figure out what you've got to start with, and look at reference for similar lighting situations. Not to copy from, but to give answers about why certain things are occurring.

What kind of lighting situation is this? Exterior, interior? It sounds obvious, but sometimes the answer surprises you. What time of day is it? Is exterior light coming in the window? What color is the light? What is the possible range of colors for that light? Are these colors what you think are right for the light, or have you looked at the real thing? What is the size of the light source? Is a soft or hard light, and what can be done to get this quality in the CG lighting? Is the environment bright or dark? If so, how does this affect the overall ambient light in the scene?

To go even further, what is the mood and emotion of the scene? What kind of lighting is acceptable in this situation? Is it open and light, or dark and mysterious? How well does your scene get this visual idea across? What can be done to reinforce this idea visually? Is there a style or genre you're working in that has loads of reference material to offer? If so, get a hold of some and find out what it is that makes this genre what it is.

Lighting in the CG realm is in many ways like drawing. When you draw from life, the drawing is often successful when you constantly compare your work with the reality of what you see before you. Without the reference from life, you rely on your visual memory to signal whether something feels right or wrong. The strength and clarity of your visual memory dictates how resonant the image is that you pull out of thin air. If your visual memory is faint or vague, just look around you at life again, and there— you have solid reference again.

Having reference is crucial. Without it, you're guessing. With it, your dead ends seem to disappear. Just imagine how far you could get lighting an airport at dusk with no reference material. Sure, it might end up looking quite nice, but why miss out on the subtleties we don't even know about in our mind's eye? With plentiful images of the real thing, the options explode, often leading in exciting directions that you hadn't even conceived before.

One place where reference is indispensable is in terms of ambient light. How much? What color? What qualities? It's all there in the pictures. At Blue Sky, radiosity is in the production software, and it can provide a very interesting reference for ambient light. When ambient lights are turned off and radiosity is turned on, all the ambient light occurs naturally and correctly, so it's like taking a photograph of the scene. From there, "imitation" ambient lights can be tuned so they're more accurate.

Using reference is a way of truly understanding the dynamics of a scene. Don't hack the scene together. Think about it what's happening there first. Again, let the renderer do the work for you, and don't cheat until you have to. (Or at least do it right first, then find out what you can get away with.) Use the live action model: create custom effects and specialized lights to refine the scene only after the basic lights have been roughed out. If the lighting setup gets too complex and numerous to keep track of, break down the components and find out what each light contributes.

Efficiency and simplicity

The majority of lighting situations can be re-created and look great with variations of only a few lights. Lighting is very much about quality, not quantity. We have infinite control over quantity of light. That's the easy part. Adding more and more lights into a scene is not neces-

sarily going to make it better. Too many lights can often make a scene look flatter, run slower and creates a rig that's too complex to keep track of. A clean, simple lighting rig can usually provide a unified, balanced look, no matter what the subject.

Perhaps the idea in CG lighting shouldn't be, "With the computer, I can add as many lights as I want, and independently control each one!" The software is based on a physical model of reality, and much work has been done by the people who wrote it to insure that what happens, happens for a reason, so let it happen. Let the renderer do the work for you. Don't fill in every shadow with a separate light, let the shadows fall, and adjust the lights in general, or move the lights. Your first instinct should be to refine the existing lights, not to add another one.

When the rig does get complex, it's important to know which light does what, and an easy way to do this is to temporarily turn off all the lights except the one you're interested in. Unless you know what each light contributes in a complicated rig, you often find yourself flailing and getting nowhere.

With a simplified lighting rig, it's easier to understand and change the degree to which each light contributes. Not only is it easier for you, but also for whoever else works on the scene. And it'll render faster with fewer lights.

There's a time for deciding if there's a way to get lighting effects *without* lights. Flying over a city at night, for instance, is the kind of scene that could use a light for each street light on every street, but you'd be a lot better off figuring out some alternative with mapping effects.

Image impact

Adding more and more lights to refine an image brings up another issue: overall image impact. It is lights and darks and large shapes that create depth and impact in an image. It's much of what the eye responds to. If every shadow across the image plane was filled and groomed and perfectly balanced, it ends up looking pretty boring.

You many find yourself grooming the lights in a scene for a long time, thinking it's going to be great when you're done with all the tweak work. The next day you look at it with a fresh eye, and it looks as bland as oatmeal. When you work too closely on the details of an image, and ignore its needs as a whole, the details can sometimes have a homogenizing effect. There's a reason that painters stand back from their work. They're looking at the forest, not the trees.

It helps to think of separating the image into a series of planes, where one plane reads against the next by virtue of its general value. Complex textures such as hair and trees can become jumbled and unclear when layered over one another, so consider separating with an overall value shift, or avoid an overlap. Higher contrast elements tend to come forward, whereas lower contrast sections recede, which is something to think about when you're trying to direct push and pull elements compositionally.

Introductory photography classes teach students to utilize the entire dynamic range of the medium: to have a perfect black and a perfect white in the printed image, which helps give the picture more impact. This should never be thought of as a rule, though. Don't think that every image should be pushed this way: to have more bold lights and darks. Some lighting situations call for a subtle, low contrast look, which can have just as much powerful impact and readability as a high contrast image. Low contrast can have a kind of impact all its own.

Integration

If CG lighting in general can be helped by using reference, then lighting for integration into a live-action plate *depends* on it. Anytime anybody is trying to trick the audience into thinking that something artificial is really there, it's important to know what it would look like if it really was there. The key is whether or not it matches our own eye's reference, in terms of lighting, texture, motion or any thing else. The audience will be able to tell easily whether or not the digital element fits or not, even though they may not be able to pinpoint exactly why.

Getting the info

When lighting for integration, the place to start is there on the live action set. Most of the info you need to succeed in integration is there. The location, color, size, and quantity of lights should be carefully noted. The environments that may reflect or refract in your objects should be photographed. Most importantly, you must get whoever's in charge to let you shoot reference footage of something that closely matches the digital object you're going to integrate. If it's a person, shoot a reference person. If it's a magical object that flies, hold a real-life, non-magical version in front of the lens and roll some film. The point is, when you get real footage of your digital object, you have the ultimate calibration tool. It's probably not a good idea to rely heavily on exact light meter readings because it can be too confining to try to match the info. If it looks right, it is right, whether the numbers match perfectly or not.

If you decide that you want to improve upon the reality of the reference, by all means, that's all part of the fun of the CG business, but at least with some reference footage, there's a place to start and return to if things get out of hand.

Image impact



The task of lighting often involves making images clear to the viewer: how well does it read? First-year art student drawings often get lost in the details and lack overall impact. The student gets in close to the piece, painstakingly shading every detail, step-by-step, in the drawing. But from a distance, it becomes a complicated jumble of lights and darks with little or no impact.



When the image is “corrected” to separate the major elements into clearer planes of light and dark, the image has more impact.



If we degrade the image by blurring it, the adjusted image still reads as a person in the foreground, exterior, with buildings and trees in the distance: it still has depth and space.



The original image becomes illegible more quickly, and doesn't hold up under less than perfect conditions.



“If it reads as postage stamp, it'll read as a billboard.”

Texture: blur and grain

Blur and grain are more than simple tricks. They can make or break an integration job, and they can add an organic beauty and authority to totally CG scenes. These characteristics fall into the realm of the photographic image, so when you add them to smooth and sharp synthetic pictures, you get an instant shot in the arm of "photorealistic" credibility.

For all the high resolution of 35mm film, it has an inherent softness, as does the film to tape transfer process.

You have two seconds . . .



In terms of image impact, this scene from a television commercial represented an especially difficult problem. A feeling of tremendous complexity had to be portrayed, and three characters had to be revealed and understood in the space of only two seconds. With the help of local spotlights, each character was emphasized by falling in a pool of brightness. The other elements were subdued, but not enough to diminish the feeling of complex machinery. Behind the camera is a box, mapped with a bright, blurry image of the same kind of environment. All the outward facing metal surfaces reflect the mapped box, helping to define the outlines of the complicated paper path clearly.

To give a feeling of richness of light in the space, a few non-shadowing lights project images of warm shadows of varying sharpness down through the mechanical parts, something that helps the scene look photorealistic. This kind of solution was arrived at only by looking at a reference mock-up of real printer and copier parts in a box.

Tricks and tips

These notes try to provide a lighting foundation that applies to all aspects of CG image making, but there's also the matter of just having the right specialized trick at the right time. Here are some tips that may come in handy.

Television

When it comes to TV, watch out.

Depending on who you talk to, you'll find different ideas about what's allowed for television images. Some people never use total white or total black, just like my painting instructor told me. It's usually ok to use the full dynamic range and just keep an eye on the scopes to see if you've gone over. When certain images are very contrasty, such as white titles on black, the once-acceptable ranges can get illegal for broadcast because the analog signal starts to get dicey, but you should find out about it personally from someone who's more qualified to explain it.

Temporal Aliasing

This issue concerns overly sharp images on NTSC, that video standard of choice for televisions across America. Diagonal elements in an image can look smooth as silk in a still frame, but as soon as it moves, it can look like a buzz saw is running along it. This is called temporal aliasing, and it's a separate issue from ordinary aliasing effects.

Because of the way video scans and interlaces the visual information, you have to be very careful with the sharpness of moving edges, especially diagonals, in NTSC video. Softening the image helps diminish the buzzing, but motion blur is what really does the trick. Sometimes it's impossible to get rid of without destroying the image, and it's all you can see, you have to just live with it. One solution is to render the image on fields, but field rendering tends to have an electronic, extra-smooth look to it.

RGB good. NTSC bad.

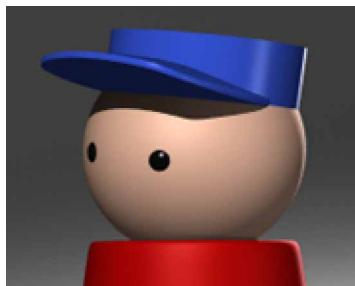
Don't light for television on an RGB monitor either. The color and contrast fidelity of RGB is miles ahead of TV, so you're just kidding yourself unless you refine the image on a properly calibrated NTSC monitor. That's where it's going to end up inevitably, so bite the bullet and correct for it on a television, not your computer monitor. Also, if it looks great on a old black and white 12-inch Zenith, then it'll probably look great anywhere. (It a bit like hearing a

great song on a transistor radio at the beach. The tune is so solid, it even sounds good on a 2-inch speaker.)

One last thing about NTSC. Very saturated blue-green colors are outside the color space of television. It simply can't display certain colors. Teal is one of these difficult colors that is used in commercial products so often these days, but is just about impossible to get on a television. Teal is difficult to get on RGB, in print, and even on some film stocks, so watch out for that.

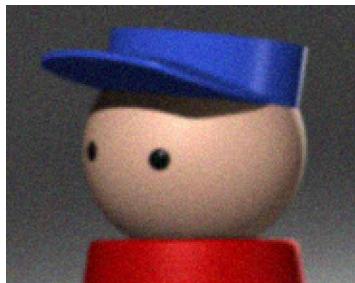
Blur and Grain

CGI Studio™



In any detail of a clean, unadulterated computer image, it will tend to be too sharp, and too clean to integrate well into a live-action plate.

CGI Studio™



Slight softening and a little added grain are a few simple tweaks that make any CG image look more photographic.

Overexposure

When the light from extremely bright objects goes into a camera, overexposure occurs. This happens in your eyes, as well as in a camera, so when you see it in printed or projected image, it's a strong visual cue to your brain that says, "Golly gosh, that's bright!"

One thing that happens is diffraction, where the light passes through a very small aperture and produces a fringe of light, sometimes appearing as bands of light and dark. Another consequence of overexposure is called halation, where the light is so bright that it enters the layers in the film emulsion and scatters around in between the sandwich of the film back and the halide crystals. This light spreads outward from the local area, resulting in another kind of flaring, blooming effect. A similar effect also occurs in your retina, and on the CCD chips of video cameras.

Unless CG artists add this effect, objects that are supposed to look bright appear merely as flat, white shapes with hard edges.

Fortunately, there's been interest in these phenomena, notably by Alias and more recently Mental Ray, who can dynamically process or post process the image to distribute superbright pixels values into the surrounding areas. Stock lens flare effects in Adobe Photoshop, 3D Studio, Lightwave, and Alias to

name few, have their place as well, when used appropriately. If your software doesn't have these capabilities, you might want to explore the compositing method described next.

Diffusion filtering

This is an effect that's only appropriate in limited doses. It's like candy, somehow. It's no big secret, only a recreation of putting a diffusion filter, or a stocking, or a little nose grease over the lens to soften the image, and it's been around for ages. Take the original image and blur it significantly, then add a percentage of the blurred image back into the original image.

Sometimes it pays to pull a high contrast version of the original image, then blur it, as this limits the "flaring" effect to the (logically so) brightest areas of the image. It also might be a good idea to dim down the original image before the add operation so you don't blow out the result. Though it's not a perfect replacement for more accurate replications of overexposed pixel distribution, sometimes it's a good cheat that works fine.

Color in shadows and light

This is one thing that adds an incredible richness to CG imagery. Color changes in complex ways as surfaces turn away from light into shadow. Depending on the kind of environment, it can become more saturated. For instance, if your key light is warm, sometimes the fill light looks good if it's really warm. Skin tones benefit from this quality. There is a subtlety added to the image whenever different lights have colors in them. There's so much going on in the real world with inter-reflection and color temperature that computers only seem to scratch the surface right now. Even if the color difference is very slight, adding it makes it more interesting.

Conclusion

What seems most characteristic of computer generated sets is that a computer simulation of light and materials is only a rough approximation of the rich phenomena that occurs all around us in real life. And getting the approximation to look good has a lot to do with having an understanding of how light and shadows and surfaces behave in reality, and using this knowledge base to create our worlds in the machines.

The computer models only get us halfway there. The artistry and craft of this new cinematography is recognizing places where the computer models fall short, and again, using what we know about the real world and reference material to guide us as we fill these spaces. Unless we understand what we're doing, and why we're doing it, the software can and will lead us into a kind of computery-looking mediocrity. We can groom, tweak and tailor our dioramas of computer sets until they have a fineness, a sharpness, a resonance: something that feels right. Eventually, it comes down to each individual's aesthetic about the image. There is no correct or incorrect lighting, but there are intelligent ways of finding the images we search for when we start lighting on the computer.

Someday, the tools for computer lighting may be so interactive, that we can easily use light itself as the imaging tool, as in the Sorcerer's Apprentice portion of Walt Disney's "Fantasia". In that sequence, the shadows on the walls aren't just the light and shadow of an image, they *are* the subject. No matter how sophisticated the tools get, making the images succeed will still depend on us, and knowing how to best use those tools to get what we want.

Bibliography

Painting With Light, by John Alton, University of California Press, 1995 (first published 1949).

The Illusion of Life: Disney Animation, by Frank Thomas and Ollie Johnston, Hyperion, 1981.

Principles of Traditional Animation Applied to 3D Computer Animation, by John Lasseter, Pixar; SIGGRAPH course notes 1987.

Tricks to Animating Characters with a Computer, by John Lasseter, Pixar, SIGGRAPH course notes 1994.

Toward High Level of Control of Computer Generated Animation, by Chris Wedge, Ohio State University SIGGRAPH course notes 1987.

Animation Tricks, by Chris Wedge, Blue Sky Productions, SIGGRAPH course notes 1994.

Envisioning Information, by Edward R. Tufte, Graphics Press, 1990.

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LIGHTING FOR COMPOSING AND INTEGRATION

By Dave Carson

Introduction

Most of us probably remember the first time we rendered an image using 3D computer graphics. Our initial reaction was probably something like 'Wow! This looks really neat!' followed immediately by a second reaction; "I wonder how I can make this look more real?" Though reality is only one of the goals available to the computer artist, it frequently is the one assigned to (or chosen by) us.

Attaining a realistic looking image is difficult under any circumstances, but the most demanding environment of all is combining a computer-generated image with a photographic background. Here, by comparison , an object that seemed realistic against a computer-generated background now may look artificial and somehow out of place when combined with the real-world image.

Since the very beginning at Industrial Light & Magic, we have been in the business of putting together photographic backgrounds and individual elements which have been created elsewhere. Originally, these elements were usually miniatures or artwork, though sometimes they might be actors or real objects filmed outside their ultimate environment. In later years however, these elements have increasingly become computer-generated imagery.

Whether a natural or computer graphic object, many of the tricks for lighting and combining these element in a photograph are the same. Below are listed the steps that we typically go through at ILM in the process of putting together a photographed background plate and computer generated imagery into one final shot.

Obviously, lighting plays a large part in this process, but in order to judge the success or failure of the lighting scheme under way in the computer, you have to combine the images at hand and to evaluate your progress. Therefore, I think it is also valuable to cover some of the other aspects of image generation and compositing, in order to give an overview of how they all play a part in lighting and compositing realistic computer-generated images.

Notice that I am presenting ten steps in this journey from planning the image to the final painted touches. But rather than being seen as adding to the complexity of creating a realistic image, each of these steps can actually be viewed as a way to simplify the process of creating a photorealistic image since each can offer an opportunity to compensate for some of the shortcomings present in our current rendering systems.

Also, note that at ILM we typically deal in moving images, so most of the references here will assume the CG images are being put into a moving filmed background. Of course, most of the principles here would equally apply when the end product is a static photograph.

I. Designing the shot:

When a shot is to be combined from elements created at different times, it is especially important that some form of 'blue print' be created defining the intended final image. Production design and storyboards are most often used to accomplish this. The production design concept art is important in establishing the look and mood of the shot (or of an overall sequence), while storyboards should define camera action, shot duration, and be fairly faithful to perspective and image content. Both are used to determine what will be needed to generate the final shot, and in planning what elements should be recorded during original photography and which elements are best added in the post-production process.

II. Filming the background image (the plate).

Special considerations involved in shooting the background image include choosing the film format, learning to compose for the missing elements, and deciding which environmental elements should be left out for addition later. Each of these aspects vary on a shot-by-shot basis.

During background photography, all necessary data required for recreating the environment in the computer should be gathered. This data includes recording the physical attributes of the set (or location) as well as gathering information that might help in recreating the lighting present. This would include noting the location and nature of the various light sources, as well as shooting some reference images which provide visual information as to the nature of the lighting being used.

III. Generating a computer graphics model of the background environment and camera.

Using the data gathered on the set, and the background film itself, a computer model of the real environment can be created. This virtual set should include scale models of all objects which might interact with the intended computer model, any objects which might have cast shadows on them from the computer-generated objects, and any light sources which were present during photography.

Also, a camera has to be created which matches the position, focal length, and if pertinent, the motion of the taking camera. This re-creation of the camera motion during photography can usually be done using a combination of the data gathered during background photography and a digitized version of the filmed background itself.

IV Building the computer model to look real.

How much detail does it take to create a realistic computer model? In most cases, when compared to a photorealistic environment, it takes more detail than is practical using today's systems. Therefore, much of the modeling process has to involve creating surfaces which will later have texture and bump maps applied to them.

Of the portions of the details which will rely on modeling, aspects of the real world which should be taken into account are asymmetry, rounded edges and other common worldly imperfections. Special attention needs to be paid to these aspects of the modeling in particular because these are the types of things that do not come naturally in the computer environment, but are seen everywhere in nature.

V. Posing and animating the model in the cg world.

Once the 'real' world has been faithfully recreated, and the new computer models are built, they can be posed and animated per the requirements of the shot. Once this phase is completed, the task of creating photorealistic lighting and rendering can really begin.

VI. Lighting the model.

Matching the placement, nature, and intensity of the key lights that were present during original photography is an obvious first step in the lighting of the computer model. In addition to this however, many other aspects of the light on the set or location have to be matched in the computer. These include bounce cards, bounce lighting in general, duplicating the effects of cukes and flags, and recreating general atmospheric conditions. Obviously the accuracy and amount of data gathered at the time of initial photography can make a big difference in the time required to set up these parameters in the computer.

Some of these aspects of the on-set lighting however are still not handled very well with current 3D rendering systems, and therefore are best added by eye during later stages.

VII Rendering the computer graphic image.

The rendering phase takes all the information assigned to the computer model and the virtual world it exists in and creates a pixel representation of what that object would look like. Usually, this is done through some variation of ray tracing. The primary limitation of ray tracing as it currently exists is the exclusion of bounce light and ambient randomness which is so prevalent in real world lighting. Though a flat ambient level can be set, this is usually an unsuccessful substitute for the nature of ambient light in the real world.

By Contrast, some of the newer approaches to rendering which do take the effects of bounce light, or radiosity, into account, currently lack such vital elements as reflectivity, glossiness, and motion blur. Overall atmospheric perspective may also be lacking.

Whichever of these two approaches is used (or whichever combination of the two is utilized), some allowance must be made for their individual or combined limitations.

It is also at this stage that the alpha channel or compositing matte is created for the computer element. This is a key factor in how successfully the element can later be combined into the background image, and again its quality is dependent on how well it is handled by the rendering system being used.

Finally, for moving images or moving objects, motion blur should be calculated and rendered at this stage. Currently, the accuracy of motion blur generated by different systems varies in its quality and accuracy.

VIII Compositing the image.

More than just a combining of two elements, the compositing stage offers an opportunity to affect the incoming element in many subtle ways which can lend it additional believability. In particular, any adjustment to black levels, color aspects and edge characteristics which might initially fall into some of the other categories mentioned here can sometimes better be addressed by manipulation during the compositing stage. Also, the appearance of shadows is usually determined by the way in which they are composited into the background image.

Finally, the image and its motion blur are combined based on the alpha channel generated during the rendering stage. This involves some percentage of opacity and the quality of the blurred edges of a moving object are heavily affected by the way they are handled during the compositing phase.

IX Adding overall effects to the shot

Many times some atmospheric effect will cover the entire shot, overlapping both the background plate and the computer element to be added. In these cases, a tradeoff has to be made as to whether to face the challenge of recreating the effect over the CG element only, and risk creating a visible blend line, or whether it's better to add the overall effect in the post production process, and give up the nuances of reality which would be present if the atmospheric condition was generated on the set. The types of 'effects' referred to here include elements such as rain, smoke, fog, etc.

In addition, issues of creating matching film grain, image filtration, and post-process camera moves also fall into this same category.

X Paint as the final step:

Attempting to create a flawless scene which combines computer graphics and photography is an iterative process with the goal (hopefully) coming closer with each iteration. At some point, it can become more feasible to simply paint out the remaining imperfections (or add the missing enhancements) using digital painting techniques. In a moving scene, these additions have to be very carefully applied or they can call more attention to themselves than the problem they set out to address. However, when used successfully, they can solve problems which might have taken significantly more time to eliminate in the 3D world.

Summary

As you can imagine, each of the steps touched upon here could in themselves be the basis for an hour-long discussion. Hopefully however this overview will give some insights as to how ILM approaches the challenge of creating realistic computer graphic images and combining them with photographic backgrounds, and has given you some ideas on additional factors to consider in approaching such work in your own projects.

