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Integrating a Lighting System With Objective Light Movement

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INTEGRATING A LIGHTING SYSTEM WITH OBJECTIVE LIGHT MOVEMENT

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Fine Arts
Digital Production Arts

by
Kiel Matthew Pease
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Accepted by:
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Abstract

When applying a light design within computer graphics software, there is no clear-cut way to achieve accurate and noticeable light movement without rigorous work animating the lighting tools by hand. This task can be arduous and involve constant test renders throughout a single frame range. This project strives to explain the production of a short animated feature, by incorporating a video-based lighting system, which is intended to assist with scenes that require objective light movement. The video-based lighting method will strive to minimize (not eliminate) the need to animate by hand light motion from environment lighting. Since lighting design is closely tied to artistic aesthetics, the proposed method must also be flexible enough to successfully light different scenarios with an intended artistic vision. While the video-based lighting system is the focus of this project, it will not be the only method used to light this animated feature. This paper will briefly cover the production of the short animation as a whole, since almost all aspects of the production pipeline provide motivation for the lighting.
Acknowledgments

To Mamaw, for making me so proud of my origins.
To Dad, for teaching me to think objectively, critically, logically, and reasonably.
To Mom, for your gentle nature, unconditional love, and support.
To Dr. Davis for your guidance in scholastic endeavors and in life.
Finally, to my beautiful wife Tamra for your patience and positive motivation.

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Chapter 1: Introduction

Computer animation is a process that melds computer science and animation into its own unique artistic and filmic medium. Juxtaposed, computer science and art are two very different fields of thought that require utilization of different halves of the brain. When used in harmony, the result can be an advancement of the art, film, computer graphics (CG) and animation genres. Technical achievement can hold artwork to a greater sense of realism while streamlining the production process as a whole. With regard to technical merit and pipeline efficiency, accomplishments today in comparison to score years ago can be considered astonishing. Yet, the aesthetics of the piece often make it timeless for the masses. When the viewer is drawn into the story and captivated by the subject matter, the animation is successful.

Regarding all of the production steps necessary to create a computer-animated work, such as modeling and surface texturing, lighting design is one of the most crucial elements to portray the artistic vision as well as enforce visual narrative. CG, like many other artistic media, uses lighting design to achieve aesthetic effect. Computer animation can utilize stage lighting techniques to accomplish tone, mood, flow, and realism. One of the key factors to achieving a more aesthetically pleasing image within a CG production pipeline is realized through effective lighting (see Figure 1.1).

Figure 1.1: Lighting within the pipeline for Pixar’s Monster’s Inc. [Pix11]

Figure 1.2 illustrates the way different lighting techniques can alter the mood of the scene while the subject matter (fruit bowl) and general layouts remain constant.
While the texturing and materials used to create the 3D images are somewhat different, each correlates to the object’s intrinsic characteristics, i.e. an apple texture for each apple, a banana texture for the banana, and orange texturing for an orange. Lighting is used to portray the scenes in dramatically different ways.

*Figure 1.2: Different lighting designs to create different moods; 1: Florian Wild, 2: Donal Khosrowi, 3: Andrzej Sykut, 4: Holger Schomann (www.3drender.com)*

*Image 1* of *Figure 1.2* portrays lighting that implies a surrounding environment of the scene. The viewer is able to perceive that a window to the left of the fruit possibly reveals a cloudy day. *Image 2’s* lighting centers the point of view on brilliantly placed rim lighting, providing just enough light to abundantly reveal the fruit without emphasizing the surroundings as in *Image 1*. *Image 3* depicts painterly lighting of a warm Dutch still life, while *Image 4* uses more of a typical professional studio lighting setup. The lighting design for each of these scenes varies tremendously, rendering each piece completely different aesthetically from the next. Scene lighting not only adds character to the 3D scene, but light that is in motion may act as a completely different character in the
animation. When a 3D scene’s lighting requires movement, a whole new level of analysis needs to be considered.

The four primary qualities of stage lighting are intensity, color, distribution, and movement. This paper focuses on lighting design with an emphasis on movement, which illustrates variations of each of the three qualities over time. Achieving movement in 3D can be somewhat arduous considering the multitude of possibilities that motivates light movement. When lighting is a suggestive device for actions within a scene, the accuracy of the movement becomes more important. For example, light from a television spilling on a character in a dark room, as in Figure 1.3, flickers in intensity, as well as shifts in color, thereby combining the character(s) of the room with the illumination emitted from the television’s contents. This emphasis is further highlighted when the audience recognizes the subject on the television and understands how this subject should illuminate the character.

One approach to handling moving light is an accurate and efficient work flow using image-based lighting (IBL). Image-based lighting is a technique that uses images (usually from real-world environments) to assist in lighting the scene. IBL offers detailed environment lighting and can produce realistically rendered appearances of objects
Debe01. *IBL* is a useful source of environment lighting, particularly when representing light originating from a great distance [Birn06]. When a video frame range is substituted for the image as the image-based light, the motion of the video can contribute to the movement of the light. This video footage is often live-action or real-world footage. When such footage is used as a light, its change in pattern, intensity, color, and distribution over time can offer a great representation for light variation. For the sake of this paper, we will call this method *video-based lighting*, or *VBL*. VBL, following in accordance with image-based lighting, has its limitations. As mentioned earlier VBL is a great source of environment light representing illumination from distant environment origins, but it is not completely effective when representing a nearby light source, e.g. an interior table lamp [Birn06]. Standard CG lights such as area, spot, and directional lights, must compensate for the lack of specific key light detail. These terms will be further elaborated later.

This thesis provides basic information on CG lighting, starting with lighting throughout art history, stage lighting concepts in CG environments, as well as detailed information on ways lighting was incorporated into the pipeline for a short animation project, *My Little Wooden Robot*. This animated production will provide graphical examples for various topics throughout the paper and will help illustrate the subjective purpose of each scene’s lighting design, in reference to desired mood, tone, and emotion. Further, it will present insight to lighting and shadowing methods and procedures for the video-based lighting technique.

Chapter 2 provides background information necessary to understand the scope of concepts, both artistically and technically, utilized to produce the *My Little Wooden Robot* animation with the video-based lighting method. Chapter 3 explains the production process for the short film, while providing detailed information regarding the lighting pipeline for the animation. Chapter 4 explains the results of the production and
provides images from the animation's scenes. The final chapter concludes and offers future directions.
Chapter 2: Background

This chapter begins with brief descriptions of lighting throughout art history, including an explanation of the Renaissance masters that contributed to the advancement of lighting in art, and provides a foundation of lighting concepts for the *My Little Wooden Robot* project. Fundamental stage lighting concepts, such as the “qualities of light” will then be described before advancing these ideas for incorporation with CG lighting techniques and methods required to produce the animated production.

![Figure 2.1: Two-point perspective on a flat plane representing a 3D cube.](image)

### 2.1 Origins of Visual Perspective and Lighting

To completely understand CG lighting as an art form, we must first explore the origins of light and shadow in art. Throughout art history, no better cultural movement exists which advanced art and artistic lighting more than the Renaissance. These advances were not just aesthetic, but technical in merit. Before the Renaissance, art was much more stylized and often lacked depth and realistic qualities; yet, technical advances soon helped solve some of these problems. Giotto di Bondone (1267–1337) is accredited for treating a paint canvas as a window into space (much like the concept of a pixmap or ‘screen’ is understood for a frustum when computing 3D ray traced images)
Filippo Brunelleschi (1377-1446), an architect and engineer, developed the technique of linear perspective to accurately represent three-dimensional figures on a flat two-dimensional surface (Figure 2.1). The development of linear perspective as an artistic technique paved the way for other notions of form with respect to light and shadow while adding a greater sense of realism [Sto04].

2.1.1 Leonardo da Vinci and Sfumato

The great polymath Leonard da Vinci (1452-1519) further progressed artistic realism with perspective, brilliant human anatomy studies, and the use of the canonical painting mode, *sfumato*. The Italian word, *sfumato*, means to “varnish” or to “shade.” The idea behind *sfumato* was to imagine a thin layer of smoke between the viewer and the painted subject. This smoke would obfuscate some of the brighter hues as well as lighten some of the darker hues of the image, much like photographic and CG concepts of “low contrast”. Da Vinci’s studio is famous for his elegant paintings demonstrating a tender use of soft, rich, smoky shadowing (*sfumato*), as seen from his works in Figure 2.2 [Vez97].

*Figure 2.2: Two of Da Vinci’s primary sfumato works: Left: Leonardo Da Vinci’s “Madonna Litta” (1490-1491), Right: “Mona Lisa” (1503-1519)*
Da Vinci was one of the first artists to create works that transcend the impression of a painting merely as a drawing which has been colored. While early Italian art may have suffered from this condition, Da Vinci used *sfumato* to solve the problem of color gradation between two different lights and between light and darkness. The technique’s mild and gentle effect also contributed in resolving form issues within objects containing color variation [Sas01]. Da Vinci’s use of *sfumato* has been said to be a direct predecessor to *chiaroscuro* (and *tenebrism*), another canonical Renaissance painting mode used by later Renaissance masters. John Moffit concludes in his work, *Caravaggio in Context*,

...we can now attribute an odd kind of symbolic significance to a specific artistic practice Leonardo had pioneered, namely his famous *sfumato* (‘smokey' shadow effects). *Sfumato* is, technically speaking, a direct precursor to *tenebrism* practiced a century later by Caravaggio and his contemporaries.

Da Vinci’s theories about nature, color, expression, and ideas behind lighting within a painting seem to be the embodiment of Caravaggio’s naturalism and *chiaroscuro*. Leonardo’s techniques involving *sfumato* and the interdependence of color and lighting to provide form and relief to human figures altered 16th century artistic practices and had a profound effect on later works. Caravaggio absorbed these ideas and methods established by Da Vinci while studying in Milan [Pug00].

### 2.1.2 Caravaggio and the “Lux Divina”

Michelangelo Merisi da Caravaggio (1571-1610) is considered to be the inventor of *tenebrism*, a pronounced form of *chiaroscuro*, where the painting or image contains strongly pronounced light and dark areas. Dark areas seem to possess a dominating presence in an image with qualities of *tenebrism*. In fact, Caravaggio is considered to be so closely linked to *tenebrism* and *chiaroscuro* that the term “Caravaggism” has been used in a synonymous fashion. The term *tenebrism* most likely derived from the Biblical
phrase, *in tenebris*, meaning “in the shadows,” found in the Gospel of John, verses 1:5, 12:35, and 12:46, to name a few. In fact, Caravaggio used light in his works in the traditional sense of *lux divina*, or “divine light,” which is a literal or physical manifestation of God’s grace and will [Moff04]. Caravaggio often used light (along with the character’s stylistic gestures and posturing) as the protagonist of this work [Sga07]. Further, Caravaggio used light in a literal sense, i.e. his works did not merely use light or contain light to show the subject matter, but rather the light was actually part of the subject matter, a presence within itself. The light’s presence in *Figure 2.3*, “The Calling of Saint Matthew,” is that of divine illumination. Here Caravaggio uses light to not only depict the Jesus character as “the light of the world,” but stepping out of the darkness to illuminate the room and reveal his calling [Pug 00].

*Figure 2.3: In “The Calling of Saint Matthew” (1599-1600); the light not only molds the characters into form and dimension, but draws the eye toward Matthew as if the light were an intentional character, or “lux divina.”*
2.1.3 Rembrandt and Tenebrism

Another definitive master of artistic lighting is Rembrandt Harmenszoon van Rijn (1606-1669). Not long into his career, his works began to show a strong influence of tenebrism, where he introduces exceedingly atmospheric paintings. The darks and shadowed areas throughout the atmosphere often lead to intimate compositions, as shown in Figure 2.4 [Add06]. Rembrandt also used the notion of the lux divina in his works. The lighting within them has been said to not pertain to the realm of the characters that are illuminated by the light, but rather the character’s occupation of the realm of the light, which is the realm of the soul [Sim05]. This lighting not only has its own being and essence, but creates its own ambiance. This classical concept offers a vast number of possibilities when applied to CG media.

Figure 2.4: Tenebrism in composition and atmosphere: Left: “Jeremiah Lamenting the Destruction of Jerusalem” (1630), Right: “The Storm on the Sea of Galilee” (1633)

Rembrandt used his light studies as a primary objective in his paintings. When he painted self-portraits, he reportedly took more interest in the light striking his face in an
unexpected manner than in showing his own likeness. He often modified his work after a first impression, changing the lighting and shading effects, adding and removing strokes to achieve fresher *chiaroscuro* lighting schemes, much like test rendering within 3D scenes. When Rembrandt's work is studied under modern x-rays, a clear struggle to attain a desired *chiaroscuro* look emerges, revealing Rembrandt's methods and process when creating his masterpieces. Rembrandt's etchings, however, depict substantial changes between various states in his progressing works, as seen in Figure 2.5-right [Add06]. In some of these pieces, Rembrandt fabricated light to provide a warm sense of intimate atmosphere and ambiance that is difficult to achieve in reality [Gio06]. His lighting best portrays a sense of religious solemnity, where a divine origin is present when viewed through non-secular eyes. These theories of *sfumato*, *tenebrism*, and the *lux divina* will be used to explain the lighting of the *My Little Wooden Robot*.

![Figure 2.5: Left: “Self Portrait” (1659) is not merely just a self-portrait, but a lighting test, Right: “The Three Crosses” (1653) is an etching which reveals Rembrandt's dramatic use of light.](image)

### 2.2 Stage Lighting

We have briefly covered some of the origins of aesthetic lighting in art history with the master painters of the Renaissance and early baroque period, but these artists used a non-moving medium. They were able to cleverly and even brilliantly portray life
and motion in their works, but ultimately their art was stationary. Stage lighting theory connects ideas originating from aesthetic lighting in art history to lighting with motion. Though the stage is the medium, these general theories apply to scene lighting in an animated CG environment as well.

Stage lighting is any form of light that fills a dark stage; however, stage lighting accomplishes much more. Frasier writes, "Good stage lighting adds character to space, texture to object, emotion to event, impetus to action, and powerful dramatic emphasis to the stage picture" [Fra99]. Its explanation can be furthered to add atmosphere to space, composition to stage layout, and as with the lux divina, can add presence as a being itself. Stage lighting is therefore an art and not merely an exercise in illumination. Further, it is a creative art and like many other creative forces, two co-equal elements are critical to the process: the art and the craft. The art is the creative artistic vision, while the craft is the mastery of the tools, methods, processes, and techniques used to realize the artistic vision.

2.3 The Art of Light Design

To cover the artistic element presented above, a bit of psychology must come into play. As the concepts of good and evil are depicted in art with light and darkness, they are similarly conveyed in lighting design. When a scene is darkly lit with the possibility of murkiness, most viewers naturally react with a sense of foreboding. The mysterious quality of dark lighting design creates in the viewer an uncertainty of what lies in the shadows. The sense of the unknown in the darkness adds to this feeling. A scene that is brightly lit or well illuminated in the design presents the viewer with a warmer, more relaxed feeling since all entities are visible [Gill78].
2.4 The Qualities of Light

The craft element of light design starts with the formal qualities of light mentioned earlier: distribution, color, intensity, and movement. An understanding and mastery of these qualities allows the lighting artist to blend and manipulate the light(s) to create a cohesive lighting design. A description of each follows.

**Distribution** covers various aspects of light, since a light source can be distributed many different ways. Distribution is dependent upon a light's focus, pattern, position, and direction/angle. Focus describes the direction in which the light is pointing, but may also describe the edges of a spot light, as shown in *Figure 2.6*.

![Figure 2.6: A spot light’s focus quality: the sharp focus on the left has a hard edge as opposed to the softer focus with the image on the right.](image)

Pattern refers to lighting gobos, often called “cookies” in a CG light pattern. A cookie or gobo is used to partially obstruct the light to give it a particular shape. This obstruction limits the light to certain areas to present a desired mold or pattern which can achieve an environmental effect. A cookie can be useful for scenes where the light and its obstructing object originate off-screen. The obstructing object may be produced or created outside of the 3D package. For example in *Figure 2.7*, a cookie light pattern that represents light entering through a window does not require that a window be created in the environment.
A light’s position and direction/angle are important to establishing a mood in the lighting design. For clarity, a series of light positions and directions are illustrated using Maya in Figures 2.8a – 2.8d. The “three-point lighting” scheme, shown in Figure 2.8e, is a helpful starting point for a lighting setup, but is by no means an ultimate solution.
Figure 2.8c: The key light is the apparent and primary source of light for a scene. Usually it is positioned closer to the front of the subject, but not directly in front to avoid flattening the subject.

Figure 2.8d: A fill light is often used in conjunction with a key light. It adds clarity to some of the darker areas of the subject which are not illuminated by the key light. Note that a fill light is often lower in intensity than a key light.

Figure 2.8e: A standard 3 point lighting setup contains a frontal key as a primary light, a fill light to illuminate the darker side not lit by the key light, and a rim light to help separate the darker edge of the subject from the background.
Each light presented in a scene should be intentional and purposeful, enhancing the unique mood and emotion of the scene. As Jeremy Birn writes,

> It would be a mistake to adopt three-point lighting as a set of rules that you had to follow in every scene....The main idea to take away from three-point lighting is that every light in your scene has a specific visual function. [Birn06]

**Color**, or light color, is often used to drive the emotion of the scene. These lights are typically separated into warm colors (red, orange, and yellow) and cool colors (blue and green). While color has a psychological effect on the audience, not all viewers react to color in the same way. Color used by the lighting designer’s own artistic sense will increase the effectiveness of the lighting design. Since light mixing is an “additive color mixing” process, when the three primary beams of light of equal intensity (red, green, and blue) hit a neutral source, they produce white light. When two primary colors intersect at equal intensity, they produce a secondary color of yellow, magenta, or cyan. When two secondary colors intersect, they can produce any color of the visible spectrum (except for primary colors and those close to primary colors) depending on their intensities. [Gill78].

**Intensity** is an effective light quality for establishing composition, emphasizing characters and setting, and contributing to the mood of the scene. It can be used to engender warmth and clarity of the subject, or to create a dim mysterious aura of the subject. Multiple lights in a design require fine-tuning of their intensities, especially when the lights are of varying hues (additive color mixing), to achieve the desired emotion.

**Movement** in light can be defined as a variation over time of any of the previous qualities of light mentioned. It is most often interpreted as a change in the direction/angle or position of a light, but light movement can be a temporal change in color or intensity as well.
A change in pattern qualifies as a movement quality of light and thus sparks the notion of the video-based lighting technique. Traditional stage lighting shows pattern movement with a rotation of a gobo to represent phenomena such as stars sweeping across the night sky, moving clouds, tree branches shifting in the wind in a storm, or possibly even a warped psychological emotion. In CG animation, pattern movement of light allows the possibility of simulating environmental lighting with a changing pattern. This idea will be explained more fully in Chapter 3.

2.5 Basic CG Lighting Tools

Several different tools are used to light scenes in *Maya*, each with certain advantages in particular situations. The various types of lights include:

**Ambient Light** in a CG environment is light that exists everywhere. It does not contribute shading to the objects or reveal dimension of the objects. An ambient light brightens all objects in the scene equally regardless of position or direction (although in *Maya* an ambient light may also produce diffuse light contribution if it's *Ambient Shade* control is set greater than 0, which helps add dimension to objects much like that of a point light). Ambient lights are generally used to contribute to the overall brightness of the scene.

**Point Lights** emit light in all directions from a single point, which represents the light's location. A point light’s direction and rotation is irrelevant since it emits in all directions. The *Decay Rate option* in *Maya* controls the level that the intensity of the light decreases as the distance from the light increases.

**Area Lights** emit light from one side of a scalable two-dimensional plane. The larger the plane is scaled, the larger the area to project light, and hence, the greater the light projected from the area. Three different factors for controlling intensity with an area light include: intensity setting, area size, and decay rate.
**Directional Lights** produce rays that shine evenly in one direction. They are often used to represent a distant light source where the rays seem to be almost parallel, like the sun.

**Spot Lights** produce light from a single point to shine within the confines of a circle that resides near the light's look-at point, giving the light the shape of a cone. *Maya* includes a few unique controls for this light, such as *Cone Angle*, which modifies the size of the circle (or base of the cone) to which light projects. The *Penumbra Angle* defines the area around the cone (or past the exterior of the circle) where shadows begin, allowing a soft edge of light past the cone boundaries. *Dropoff* controls the intensity decrease from the center of the cone base to the edges. Spot lights are useful because of their controllable qualities.

**Volume Lights** are similar to point lights, except that they are delimited by three-dimensional primitive shapes. This light has a linear decay rate from the light's center point to the shape's boundary. Numerous controls in *Maya* determine primitive shape type, the color range of the light's decay, etc.

### 2.6 Shadow Types in Maya

In a real-world environment, we are accustomed to seeing shadows produced when an object obstructs a light. When a light is created in *Maya*, shadows are automatically deactivated. If an object is illuminated by this light, it will produce self-shadows. Yet, this object will not cast shadows onto other objects until shadows are activated for the new light. In *Maya*, the lighting artist is given certain controls over shadows to create varying results and to streamline render times. The two types of shadows used in *Maya* are depth-map shadows and ray-traced shadows.

**Depth-Map Shadows** are produced based on calculations from values in the *depth shadow map* file, which stores the distance from the light to objects in the scene for each
pixel. This depth information is calculated by the render engine to determine which areas on the object, and ultimately the scene, are illuminated. *Depth-Map Shadows* are typically soft while allowing for fairly quick render times, which is an advantage over ray-tracing. The main drawback to depth-map shadows is their inability to calculate refractions from transparent materials. They are also prone to aliasing or jagged edges along shadow edges if using low-quality settings.

**Ray-traced Shadows** provide more physically accurate shadows, but at the cost of increased render times. Ray-traced shadows also compute refractions for transparent objects such as glass, as stated previously. In *Maya*, ray tracing must be enabled in the *Render Global Settings* for ray-traced shadows to appear.

### 2.7 Image-Based Lighting

Image-based lighting (IBL), as mentioned in the *Introduction*, is the process of illuminating CG objects using an image as the light source. These images are often real-world photographs mapped to a sphere encapsulating the environment and providing illumination from all angles to mimic real-world light. A mapped sphere is not necessarily needed to produce this effect; a flat plane can suffice, as shown in *Figure 2.9*. In either case, the ambience of the image texture is raised to simulate direct and bounce lighting from the image’s environment. IBL is especially useful for environmental reflections on shiny CG models. These reflections simulate the surrounding environment and thus, increase realism [Debe01]. Chapter 3 will further explore the IBL method with the use of video.
Figure 2.9: Left: An example of IBL from a spherical world dome. The lighting influences all sides of the subject. Right: IBL projected from a simple plane where the lighting influences only one side.

2.8 Ambient Occlusion

For this animation we rendered an ambient occlusion pass to add depth and form and to help define certain shadowed areas to the CG characters and environment. Ambient occlusion is a method used to darken or shade parts of an object’s geometry that are close to other geometry; therefore, areas such as corners, cracks, folds, and crevices are darkened. For each geometric point hit in an ambient occlusion pass, rays are sampled in all directions. The more these rays hit other objects in the scene and the closer these other objects are to the current object, the darker the shading [Birn06]. The ambient occlusion pass is composited with other render passes to create the final rendered image.

2.9 Rendering

Maya has two primary rendering techniques: ‘scanline’ and ‘raytrace’ rendering. Scanline renderers vary by means of execution across different render packages. Some operate as tile-based scanning and others scan on a row-by-row basis. The scanline
render in *Maya* examines the objects in a scene and divides the image to be rendered into tiles to optimize memory usage. Objects within the tiles are sorted from front to back and shading samples are produced for each pixel in a tile [Lan06]. For small or static scenes, scenes with final gather, or scenes without much depth complexity, scanline rendering is faster and more efficient than ray tracing.

Ray-traced rendering simulates the interaction of light rays with objects using principles of geometric optics. The underlying model of ray tracing used for light ray/object interaction is simplified from those of nature, but are close enough to provide realistic results [Lind92]. The ray tracing process fires a virtual ‘ray’ from a camera point through each pixel on a screen representing the camera’s view plane. The first surface the ray intersects determines the hit point. At this point, a variety of factors are considered for shading the hit point: lights, textures, object surface normals, reflectivity, shadows, and Final Gather (explained below), among others. Ray tracing is thus a very powerful rendering process, but requires much more time and memory to produce results.

Final Gather is a *mental ray* ray tracing function that incorporates bounce light, color bleed, and indirect illumination in a render. Secondary rays shot from an object's intersection point with the primary ray (emanating from the camera point) are directed at random angles within a hemisphere. As the rays hit new surfaces, the light energy contribution between the secondary hit and the primary ray hit is calculated and stored in a Final Gather map, which ultimately contributes to the shading of the hit point [Lan06].

In the next chapter, all of these lighting and rendering techniques will be implemented to produce final frames according to the artistic guidelines previously discussed.
Chapter 3: Implementation

This chapter focuses on the lighting aspects of production for the animated short film, *My Little Wooden Robot*. Lighting interacts with other areas of the animation pipeline such as modeling, shading/texturing, and animation. These areas are briefly covered as they pertain to lighting, yet the primary topic of this chapter is the lighting implementation for the short film.

3.1 Initial Considerations for Lighting

For most of the animated short, *My Little Wooden Robot*, the intended mood is somewhat melancholy and slightly somber. The lighting must reflect this tone in a fluid manner and correspond to the visual narrative. Once these issues are addressed and the lighter begins working the environment, additional consideration arises concerning rendering and effective ways to work with frames. A compositing package, such as Shake, can be used to alter elements of the images; however, the scope of elements or rendered layers created must be anticipated. To capture the ethereal disposition of the animation, a number of compositing techniques can be used in conjunction with rendered layers. All of these ideas must be researched, tested, and developed into a successful and fluid functioning methodology.

Lighting for animation, in many ways, can be defined by the story and the setting. Although this guideline appears to limit artistic liberties, source lighting that helps to explain a narrative also provides motivation and inspiration for the story. For example, a window on the back wall of a work shed interior during the daytime can provide ample positioning for the key light, yet other technical and artistic factors must be considered, as the nature and quality of the light entering through the window will have a great influence on the scene. The light could blast through the window as if an atomic bomb
were exploding outside, or conversely, only a slight hint of blue light may be entering for a night scene. *My Little Wooden Robot* begins in a woodworking shop with cloudy overcast light seen through the window. How will this light affect the workshop’s interior objects? How will the shadows appear? At what intensity is this light emitting and with what color? *Figure 3.1* illustrates possible answers to these questions after a storyboard panel and environment are developed.

*Figure 3.1*: Visual development within the short film pipeline. Note the consideration for the background window within the storyboard.

### 3.2 Brainstorming, Concept Art, and Story

The genesis of this animation was a poem about a robot. The concept for the poem provided a rhythmic narrative on which to base a short film. The idea behind the story involves the narrator (reading the poem) as something of a variation to the Geppetto character from Disney’s *Pinocchio*. He made a robot with hopes that it would fill the void of his longing to have his own son. The robot learns about life and eventually ventures into the real world on his own, while his maker guides him and can only watch him leave, just as parents experience with their children. The robot eventually returns home and relays his experiences. The style of the poem matches a child’s poem used to illustrate a lesson as if the narrator who built the robot is telling a grandchild about his past experience via poetic parable. The content of the poem is as follows:
My Little Wooden Robot

I made a little robot,
I made him out of wood,
I made him for the purpose,
to love and perform good.

He tries to understand the world,
but it often makes him sad,
to see this world spread hate,
and treat each other bad.

I love my little robot,
I want him to understand,
that in life it’s sometimes hard,
to give and lend a hand.

We often get distracted,
from the things that matter most,
like faith and friends and family,
and the love that keeps us close.

My little robot traveled,
across this world and wondrous land,
to seek such things as beauty,
and a truth that makes us grand.

After years of wandering travel,
and sites that daze the eyes,
my little wooden robot,
concludes what makes him wise.

He learns of a world of chaos,
harmful and corrupt.
And a world of tranquil splendor,
calm and yet abrupt.

He now comprehends a life that’s pure,
and the simple counts the most,
where the humble and humility,
replaces a need to boast.

In the end what he learned,
is what I told him all along.
It’s the love we have between us,
and a faith that keeps us strong.

-Kiel Pease

The poem offered a theme to a storyline, which helps produce imagery to match the story. Storyboards as well as concept art are based on this theme, as shown in Figure 3.2. Storyboards also informed lighting considerations for scenes based on layout and shot transitions. This initial phase of calculating light positions, intensity, and shadow blur according to the makeup and mood of the storyboards, sets the artistic narrative and establishes goals for technical development.
3.3 Short Animation Pipeline

The general pipeline for this animation is based on Maya’s ‘.ma file’ scene referencing. Models are referenced, not imported, in compilation files; thus, they are independently editable from the prop’s base level, allowing changes higher in the pipeline. Models are created as individual CG props and packaged with texture images within their own folders. This approach to texturing eliminates long and confusing file paths where the chance of a broken file path is minimized. These modeled props are then referenced into a CG compilation, or a ‘set’. Every such model is a stagnant item inside of the set, rather than an animated character or prop used in the animation process. Environment lights can be added to the set for areas that will not be affected by the animated character or light movement, but in general animated characters, lights, and cameras are preserved for referencing into the ‘scene’ file.
Figure 3.3 shows the reference hierarchy chain involved for the development of a scene. The elements that are frequently edited inside the scenes for this film are often animated characters/objects, cameras, and lights. Basically the scene is used to capture all of the elements in their correct positions for rendering. Cameras are positioned for layout, characters and objects are animated to add life to the story, and lights are positioned to add volume to the stage and set the mood. Once the camera and lights are positioned and the character animation is completed within the scene, the shots are rendered in appropriate layers for compositing within Shake (further explained later). Shake generates the animated sequences for each scene, which are then edited within Final Cut, to produce the final movie.

The most important mesh model for this animation is the robot, which is the main focus of the animation in almost every shot. The robot’s appearance must be visually appealing, while its rig functions must be able to perform all of the required animated tasks throughout the story. Each shot requires the robot to take unique and specific actions to complete the story’s narrative; thus, the robot’s positioning and physical
activity must be carefully planned for every shot. The final robot model is shown in

*Figure 3.4.*

![Figure 3.4: The robot model and rig in the standard T-pose position.](image)

The robot uses forward kinematic controls for animation throughout its body, except for its eyes and a version of its legs. Blend-shapes are used for eye gesture animation, in which numerous blending controls for the eye geometry allow for a wide range of expressions and ultimately pathos for the character (*Figure 3.5.*)

![Figure 3.5: The robot’s eyes manipulated by set controls from Maya’s blend-shape GUI. The various eye positions are often controlled in conjunction to create the desired expressions.](image)
The robot character is comprised of two separate rigs: one with inverse kinematic (IK) leg controls for shots in which the robot stands and walks, and one with forward kinematic (FK) leg controls for shots where the robot is sitting. A root control for the translation, rotation, and scale of the robot’s mesh and rig is important for initial positioning and layout in each scene.

### 3.4 Light Types and Light Linking

Each scene in *My Little Wooden Robot* uses point lights, area lights, and image-based lighting to project environment illumination. This scheme follows the narrative of the shots and provides the overall mood of the scenes through direct and indirect light. Spotlights are used extensively in this scheme since they are versatile and easily controllable for lighting broad areas as well as specific areas and objects. This feature is not only useful for accuracy of illumination, but can also reduce rendering time.

Light Linking is used within Maya’s ‘Relationship Editor’ to specify which lights illuminate individual objects in the scene. This feature is especially useful when the scene contains a large number of different lights for specific objects and elements [Dera06]. As this short film production increased in size, scene elements also grew, including more objects with increasingly complex geometry, advanced shaders, and lights. Ultimately, this growth caused the rendering engine to perform more calculations, resulting in longer render times. Light linking (Figure 3.6) is an important tool to streamline the efficiency of rendered lighting calculations. Additionally the ability to specify certain lights to illuminate choice objects within the scene, rather than all objects in the scene, allows the lighter more control over the simulated environment.
3.5 The Shadow Light

One of the controllable advantages of CG lighting is the shadow light, which contributes no light intensity to the scene or objects, only shadow. This type of light is useful when lights are positioned in the scene, but does not offer an aesthetically pleasing shadow. A shadow light can be added and positioned within the scene to provide an adjusted shadow only. The most common way to set up such a light in Maya is to add a regular spotlight to the scene, position it to cast the desired shadow from the object, set the light’s ‘Color’ to black, and the light’s ‘Shadow Color’ value to -1. Such a spotlight will contribute only a shadow to the scene, offering more control to the light design.
3.6 Light Distribution per Scene

Light placement is one of the most important aspects of lighting. It is specifically important in professional CG lighting, because a change in light position often requires a complete re-render of the scene. Obtaining the correct light distribution of lights within a certain deadline can be crucial to an animation studio; therefore, the light positions in each scene of this production are carefully placed, checked and tweaked to ensure an artful aesthetic composition. Figure 3.7 shows the opening woodshop scene with six lights: two area lights and four shotlights. The primary purpose of the area lights is to represent the general base lighting from the window, with one light outside the window and one positioned at an angle inside the shop to act as a key light. Three of the four spotlights add rim lighting to the main character and objects in the bench area. The last spotlight (shown on far left of the image) provides fill light to the scene.

Figure 3.7: The woodshop scene with objects and light rig.

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Using much of the same lighting setup as the opening shot, the fourth shot of the animation is also set in the woodshop, as shown in Figure 3.8. The character is attempting to stand on its own, but falls in the process. Since the character is now on the ground, the environment objects are lit with the lights positioned from the opening shot, but eight spotlights are added to light the main character and the trash can. Five of these spotlights are used to add rim light to different parts of the character as it falls on its back. This number of spotlights might seem excessive, but since the character is moving quickly over space, more accuracy is needed to obtain adequate rim light. Further, take note that each rim light utilizes light linking for specified parts of the character to reduce render time.

![Figure 3.8: Left: camera view of rim spotlights, Right: overhead perspective](image)

The dining room scene provided a dynamic environment for lighting. Two background windows in the set are perpendicular to each other, which provides an opportunity for one window to be the motivation for a key light, with the other a source for rim light. Figure 3.9 illustrates the area lights set up outdoors to not only show light emitting from the windows, but to add volume to the window panes.
Four spotlights were placed in the shot to add detail and control to the window lighting. A spotlight behind the character presents a slight rim, while two strong spotlights to the side act as key lights: one for the main character and one for the flower vase. An additional point light (bottom left of Figure 3.9) acts as a fill light. This scene is rather simple, but the lighting provides nice soft volume to the objects.

The hallway setting contained more lights than any other scene in the film. Figure 3.10 shows an overhead view of the hallway with all 15 lights. This shot also depends heavily on light linking, as most of the spotlights were individually positioned to provide key lights for various objects within the scene. Additionally, some spotlights (shown at the bottom of Figure 3.10) acted as low-intensity fill lights. Almost all of the spotlights in the scene did not cast shadows, which not only saved render time, but avoided multiple shadow crossings that may otherwise misrepresent the bright daylight from outside the front door.
The living room set was different from the all the previous settings, because it did not use area lights, as shown in Figure 3.11. Since no source of external outdoor lighting was indicated for this set, artificial lighting, which permitted a different approach to the light rig, was used instead with seven spotlights and one point light. Since the table lamp is the primary source of artificial light, spotlights were placed to establish the influence of the lamp as a key light. Since spotlights provide a large amount of control over the distribution of the illumination, they are used within this scene to act as a representation of bounce lights from the walls. Light ray bounces can greatly increase render time, therefore, ray bounces are minimized in the render engine (around 2 to 3 in mental ray) and substituted with representational spotlights for bounce illumination. Since this
bounce lighting is reflected from the matte/diffuse textured walls, a few low-intensity wide-cone-angle spotlights offer a soft source of fill light to the scene.

![Figure 3.11: Living room set](image)

### 3.7 Video-Based Lighting

Video-based lighting (VBL) in a general 3D computer graphics package provides the opportunity for an enhanced contribution of environmental lighting within a given time range, provided that motion is occurring in the environment that affects lighting. A few select scenes in this animation benefited from VBL: the World War II television footage scene, the aurora-borealis scene, and the fireworks scene. Each sequence required animation of light by position, intensity, and color. VBL contributed to the scene not only as a source of illumination, but as a subject within the story, loosely modeling itself after Caravaggism. The light is a noticeable factor in the scene and its movement in context to the story suggests a divine presence to drive the ethos of the narrative. This notion is not as deliberate as tenebrism or Caravaggism in general, but can add a subtle suggestion for the inspiration behind the story that might not be noticed otherwise.
3.7.1 Video-Based Lighting Texture Referencing

The concept for this process was to use video footage as a texture on an object. That object would then emit ambient light onto the character object(s) within the scene, permitting the texture to act as a light source. The video texture would change over time, causing the light distribution to simulate movement, much like a video projector. Initial video footage was used as a direct reference for the object’s surface texture color, but Maya 2008 was not able to determine a specific frame within a referenced video file; however, a series of images could be used as the texture rather than the movie file itself. Each image frame corresponded with the scene’s frame to simulate light movement over time.

The appropriate application of video footage used light movement qualities of color change and intensity shift to project an accurate and noticeable contribution to the characters within the camera’s field of view. Once the appropriate footage was found, the video’s frames were separated into targa images through Shake. These images were then stored in a separate directory with a corresponding sequence name per frame, e.g., auroraHD.0005.tga. The targa format was preferred for this project because of its minimal lossiness, yet efficient compression.

The type of texture specified in Maya’s Hypershade did not matter as long as it could project an ambient color. Much of the other texture characteristics of the video-based light were irrelevant, since the surface and the texture itself were not seen; however, deactivating reflection, as well as other extraneous settings for the texture, might reduce render time. Figure 3.12 shows the texture settings used for the aurora-borealis scene. Specular shading settings, such as Eccentricity and Specular Roll Off for this Blinn texture were deactivated while Specular Color was set to black. Two other important settings in Fig 3.12 are Ambient Color and Color.
The Ambient Color setting was raised to its maximum amount, or completely white (1.0), to act as the light’s intensity. This setting could have been applied at a lower value if only a slight influence of ambient light were needed for the particular scene. The Color setting was set to reference a file with a render node from Maya’s Hypershade. Figure 3.13 (left, #1) reveals the ‘Create Render Node’ window used to select the file option. Figure 3.13 (right) displays the ‘File Attributes’ to reference the image path (#2) to the targa image files from the chosen video footage mentioned earlier. At this point, Maya had yet to recognize that it was reading an image sequence rather than a single image. For Maya to reference a subsequent image from the scene’s frame number, the ‘Use Image Sequence’ option was activated. The ‘Image Number’ correlated to, and changed with, the scene’s current frame number. If a later or earlier file number from the image sequence was needed to correlate with the scene’s frame number, the ‘Frame
Offset’ option could act as a convenient summation or difference. Figure 3.13 (right, #3) shows these options in the File Attributes along with the Image Number reference, which set the file expression for the frame extension. In this case the standard option to set the image file’s frame extension to the Maya scene frame number was as follows:

\[ \text{Arora}_01: \text{file1.frameExtension}=\text{frame}. \]

**Figure 3.13: Left: ‘Create Render Node’ and Right: ‘File Attributes’ for the Hypershade**

### 3.7.2 Video-Based Lighting per Scene

Once texture referencing for the image projection was defined, the scenes were arranged to benefit from this particular lighting asset. Although video lighting was the primary source of light, other lights were added to the scene. The environment light was perhaps more dynamic with movement, but the characters may have appeared flat and lifeless without help from key, fill, and rim lights. One of the main limitations with a video-based lighting technique is that it does not offer the intensity and control that point, spot, and area lights do. The aurora-borealis scene had four spotlights and an area light to
add volume and shape to the robot, while the aurora video contributed to animated color shifts, as depicted in *Figure 3.14*. One of the spotlights was a shadow light used to define a soft shadow on the snow behind the robot. The other spotlights were included as fill lights for the robot's body. The area light was intended to provide a boost in intensity for the environment lighting, and its intensity was animated through a line graph to coincide with the aurora environment video behind it.

*Figure 3.14: Aurora-borealis Scene with Light Rig*

The fireworks scene setup followed many of the same principles as the aurora scene, shown in *Figure 3.15*. Along with a directional light to represent a setting sun perpendicular to the fireworks, two area lights offered intensity support for the environment video lighting behind them. Each area light contributed different colors and animated intensities to support multi-colored fireworks exploding in the distance. Area light intensity was controlled over time with *Maya*’s ‘Graph Editor,’ shown in *Figure 3.16*. 
The World War II footage shown on the television was handled differently from the other scenes previously mentioned. The aurora and fireworks were projected from a large card to mimic the enormity of the events happening in the sky. The WWII scene projected video-based light from a television screen which was a much smaller surface. The texture was applied to the television object’s geometry much like an actual television’s picture would project light (see Figure 3.17, left). The video texture was
viewed from the camera for certain shots in this sequence, which displayed the video footage in motion and correlated with the rendered frames. Ultimately, this scheme saved a small amount of time and work since compositing the video footage over the television was not required.

![Figure 3.17: Left: TV with video texture applied, Right: WWII footage scene with light rig](image)

The WWII footage scene was rather dark (Fig 3.17, right), with the television acting as the primary source of light. Seven spotlights, two point lights, and two area lights were added to this scene. The point lights acted as fill lights from behind the robot, while two spotlights acted as backlights for the robot. One area light served as an intensity amplifier for the video footage texture, which was applied to the whole scene, except the robot's eye lenses, to which the second area light was light-linked. The intensity animation curve followed the same pattern as the first area light, but at a much lower level to avoid blowing out the lenses. Since the eye lens shader was much more reflective and sensitive to light, it needed to be treated more delicately with regard to light intensity. The other spotlights were light-linked to specific set objects and strategically placed to provide adequate fill and key lighting. All of the lights that were not originating from the television's direction were set to produce no shadows to avoid conflicting shadow lines with the primary television lights.
3.8 Render Method

The lighting process often involves a struggle between the quality of render output and render time/resources. This project, like most others, had a limited number of render farm machines and a limited amount of time for completion. The mental ray renderer was the primary render package used to generate these scenes, since it offers more control as well as a wider range of capabilities than Maya’s standard Software renderer.

The basic setup for rendering each scene was to use ‘Production’ quality presets for ray tracing with ‘Final Gather’ activated. This approach set optimum reflection and refraction rays for rendering. Ray tracing in Maya is activated by the surface of the object that occupies the pixel; therefore, Maya will fire a ray for reflection/refraction detected at a pixel. Otherwise, it will default to scanline rendering for that pixel [Lan06], which speeds up the rendering process for simple scenes. A few Final Gather options were tweaked for our scenes. The ‘Accuracy’ (‘Final Gather Rays’) setting was set to a slightly higher number, 150, for most of the scenes, since it increased the accuracy of the hit point by sampling more secondary rays. Another setting to include in our Final Gather render is ‘Filter,’ which applies to scenes with complex reflection and refraction materials using Final Gather that often produce random speckles throughout rendered frames. Doubling the Filter option from 1 to 2 helps eliminate and/or reduce the amount of speckles and hot spot artifacts left by skewed Final Gather ray samples.

3.8.1 Render Layers and Compositing

Three types of render passes were used to produce this animation. The first layer, or ‘master layer,’ included: diffuse and specular contributions, reflections, and cast shadows rendered together. The majority of the render computation was performed in this layer, but this project was fairly small with relatively few changes after lighting and
render tests; therefore, the master layer sufficiently handled this task. The second layer rendered was the occlusion pass, representing the ambient occlusion of the scene (see Figure 3.18).

Figure 3.18: Occlusion pass

The master layer and the occlusion layer were composited in Shake to create the final ‘Beauty’ pass with a ‘multiply’ node, which multiplied the base color with the blend color. Darker and/or black areas of the occlusion pass multiplied with the base (master) layer were therefore made darker, while white areas of the occlusion pass multiplied with the base layer left the base color unchanged. In an attempt to bestow a nostalgic feeling to each scene, a copy of the master layer was blurred slightly and combined with the original through a screen node using a ‘screen’ function. This node takes each image’s color information and multiplies the inverse of the blend with the base colors. The result is a lighter color that acts as a counterbalance to the previous ‘multiply’ image. The end result is a soft, but vibrant, image.
In this chapter, we covered the inspiration, brainstorming, and concept for the animation. We also discussed the pipeline and work flow for development of this project. Further, we described the steps of the pipeline from modeling, rigging, and animation, to lighting and rendering. In the next chapter, we will provide the results of these endeavors.
Chapter 4: Results

This chapter shows the resulting frames of selected scenes that represent the *My Little Wooden Robot* short animation. We start with scenes not employing the video-based lighting method. These scenes use the CG and stage lighting concepts described in the previous chapters instead. The second section (4.2) reveals the results of the VBL method incorporated into the remainder of the short animation’s scenes.

4.1 Beauty Passes per Scene

Once the rendered frames were composited together and color corrected to create the beauty pass, each scene was converted into an animated clip with *Shake*. The compositing techniques mentioned in *Section 3.8.1* were used to soften the images in an almost smoky way, similar to that in Da Vinci’s *sfumato* method. The intention was to create a gentle mood, as well as add relief to the characters and objects in the scene. *Figures 4.1 through 4.5* are the resulting images of this short animation pipeline.
Figure 4.2: The Woodshop ground view

Figure 4.3: The Dining Room scene
Figure 4.4: The Hallway scene

Figure 4.5: The Living Room book scene
4.2 Resulting Beauty Passes with Video-Based Lighting

One of the goals in lighting these scenes was to draw from the Renaissance masters' techniques discussed in Chapter 2. Most of the shots in the animation were lit to provide a sense of the lux divina as the robot interacts with its surroundings; thus, the robot occupied the environment of the light. This idea is further emphasized in shots utilizing light movement and the VBL technique (Figures 4.6 through 4.9). The quality of light movement within this narrative could be considered to offer a notion of lux divina since the very motion of light may furnish its objective status.

Figure 4.6: The Living Room with WWII Footage

Figure 4.7: Aurora-borealis scene
Figure 4.8: Fireworks top view

Figure 4.9: Fireworks side view
Chapter 5: Conclusion

This paper explains the production of a short animation, *My Little Wooden Robot*, while providing an efficient way of rendering objective light motion throughout different scenes. The video-based lighting system allowed the lighting designer to light CG scenes without the need to hand-animate every aspect of light motion. It also acted as a guide for changing the lighting and provided information pertaining to light quality that had been altered throughout the frame range. The process of hand-animated key lights was minimized and limited to intensity.

Intensity is the most critical issue in VBL. Since the ambient texture provides only a limited amount of illumination, it often needs assistance from additional light(s) to act as key lighting. Another limitation to this animation in particular involved using a plane from which to project the texture. Scenes in this animation were set up with the light source only illuminating one side of the object. Further study on projecting light textures onto spheres or more complex geometric shapes could prove beneficial for more encapsulating light rigs. Traditional image-based lighting often utilizes a hemisphere or complete sphere to provide environment light contribution.

The resulting animated short film attempts to captivate its audience with story, visual appeal, and emotional connection. Visually the short animation is consistent across shots and provides aesthetically enticing imagery. The lighting and compositing methods proved to imitate some of the previously specified techniques of the Renaissance masters, including *sfumato* for a lucid smoky effect and the *lux divina*, which gives the light a separate presence in the scene, almost as an additional character. These techniques add distinction to the animation, focus the project and technically drive an efficient process for *My Little Wooden Robot*. 
References


