

**CREATING COMPUTER GENERATED SCENE LIGHTING  
IN THE STYLE OF EDWARD HOPPER**

A Thesis

by

HEE YOEN JO

Submitted to the Office of Graduate Studies of  
Texas A&M University  
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2008

Major Subject: Visualization Sciences

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Approved by:

Chair of Committee,	Karen Hillier
Committee Members,	Carol Lafayette
	Michael Greenwald
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## ABSTRACT

Creating Computer Generated Scene Lighting  
in the Style of Edward Hopper. (May 2008)

Hee Yoen Jo, B.H.E., Ewha Womans University

Chair of Advisory Committee: Prof. Karen Hillier

The goal of this thesis is to study the lighting styles used in three selected Edward Hopper paintings: *Morning Sun*, *Summer Evening*, and *Night Windows* and to create an original, three-dimensional scene lit in a similar style. For a general understanding of the reference paintings, visual analyses were conducted before studying the lighting styles depicted in them. During the process of conducting this lighting study, the lighting styles in the three reference paintings were closely examined and digitally reproduced. The artistic inspiration gained from these three paintings and the lessons learned from the reproduction process are integrated into the creation of the original work which serves as the final project of this thesis. Consequently, the final project displays the lighting style represented in those of the reference paintings, refined by this researcher's own style.

This study defines an approach to develop the digital lighting that can dramatically enhance the moods in realistic scenes referenced by lighting in the three Hopper's paintings.

To Piljae, Joshua and family in my country

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## CHAPTER I

### INTRODUCTION

#### I.1 Introduction

In film, lighting plays an essential role to support the visual structure established for the story being told, by not only revealing what is happening but also emphasizing the action and creating atmosphere and mood to captivate the audience [1]. Lighting in computer graphics (CG) has the same objectives as in film. The methods to achieve them are different.

In the rapidly changing CG technology, a digital lighting designer is required to invest his or her time to learn new technology for effective digital lighting. However, a strong artistic sense is a necessary quality for a digital lighting designer. Studying traditional art, such as paintings or photography is a good way to polish one's artistic sense. Observing and reproducing oil paintings in a CG environment expands the understanding of light and shadow, color schemes, and composition demonstrated by each artist, as well as the technical skill for 3D implementation. One can also be inspired by identifying with a varying range of artists' styles: realistic imagery or otherwise.

This lighting study involves a 3D reproduction process of lighting from three of Edward Hopper's paintings. Edward Hopper, one of America's greatest modern painters, shows skillful manipulation of lights and darks in his paintings. The selected Hopper

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The journal model is *IEEE Transactions on Visualization and Computer Graphics*.

paintings are useful examples to learn how lighting produces a dramatic mood in a scene and how light becomes one of the primary design elements of a scene. As a final result, an original 3D digital image is generated inspired by three of Hopper's paintings.

## **I.2 Statement of Intent**

This thesis is an examination of the lighting style of three of Edward Hopper's paintings, *Morning Sun*, *Summer Evening*, and *Night Windows*. After examination of Hopper's work, an original 3D digital image inspired by the three paintings was created.

For the preliminary study, a visual analysis followed by 3D implementation was conducted for each painting. It led to the creation of an original 3D piece where lighting acts as an important visual element as in Hopper's paintings.

## CHAPTER II

### VISUAL ANALYSIS

#### II.1 Overview

Edward Hopper (Jul.22, 1882— May 15, 1967) is a twentieth century American painter, best known for his depiction of American realistic scenes conveying moods of loneliness and isolation [2]. These consistent moods of loneliness and isolation were achieved by his unique methods such as light manipulation, the subject matter, dramatic composition, which consists of simple geometric shapes, and the position of the viewer's eye.

In his paintings, light creates a dramatic effect, and furthermore light itself becomes the main subject of his work, far beyond its usual role to illuminate a chosen scene [2]. Particularly, interior and night scenes show powerful light play to create a certain mood. Hopper himself said, "light is an important expressive force for me, but not too consciously so I think it is a natural expression for me" [3]. He used the word "sun" or "sunlight" several times in the titles of his paintings, such as *Morning Sun*, *A Woman in the Sun*, *City Sunlight*, and *Second Story Sunlight*. Lloyd Goodrich, curator and director of the Whitney Museum of Art, said that "light plays an essential role in Hopper's painting. Whether outdoors or indoors, natural or artificial, its exact nature, its source, direction, and color are as fully realized as the objects on which it falls ... By creating definite patterns of light and shade, it acts as an integral element of design"[2].

The simple, geometric shape of lightfall in the room created by sunlight coming



Figure II.1. Sun in an Empty Room (Oil on canvas, Edward Hopper, 1963) [4].

through a window is a common motif in his paintings. Figure II.1, *Sun in an Empty Room*, is one such painting that shows how light and shade can be the primary subject in an artistic work.

Besides his use of light, Hopper's unique style of painting was achieved by several interwoven elements. In most of his paintings simple, dramatic compositions that consist of bold and distinct geometric shapes were used. Often, this technique extended the emptiness or the loneliness of the scene [5]. The human figures in his painting, mostly women, are almost always alone. Even if there is a couple present, it is difficult to find any connection between them. Usually they stare in different directions individually, or concentrate on their own thoughts. The position of the viewers is often placed such that the human figure in the painting cannot be aware of the viewers. These situations evoke senses of physical and emotional isolation and a sense of voyeurism. The remote position of the primary subjects is one of Hopper's techniques for creating a mood of isolation. He often isolates viewers from the picture space by pushing back the primary subjects in the picture space. As an example, the three-story white house, the primary subject of *House by the Railroad* (Figure II.2), is located behind the railroad. Because of the horizontal rail road, the house becomes the inaccessible place to the viewers. The use of this technique is shown in *Summer Evening* and *Night Windows*. For the same reason, Hopper often used a strong contrast of light in order to divide the foreground and the background. This technique is easily found in his night scenes including *Summer Evening* and *Night Windows*.



Figure II.2. Left: House by the Railroad (Oil on canvas, Edward Hopper, 1925)[7], Right: a Still cut of Psycho (Hitchcock, 1960) [6].

Hopper painted as an individual, outside the general art trend of the mid-twentieth century American art world, yet his unique style was a major influence on later art. Also, the very realistic but strangely solitary feelings evoked by some Hopper's paintings inspired film makers. *Psycho*, by Alfred Hitchcock, is one example which demonstrates Hopper's influence on film. In this movie, Victorian style shapes and details (pillars, roof-cresting, garret and oculus windows) of the *Psycho* house are reminiscent of Hopper's painting *House by the Railroad* (Figure II.2). The eerie, desolate mood of the landscape of the painting matched well with the main setting of this horror movie. Stephen Rebello, the author of *Hitchcock and the Making of Psycho* (1990), states that "one might almost expect to glimpse Mrs. Bates silhouetted in the window of the sloping dormer in Hopper's 1925 painting" [6].

Of his many paintings, *Morning Sun*, *Night Windows* and *Summer Evening* are utilized as original materials for 3D implementation in this study. The reason for this selection is that each work reflects a different time of day (morning, deep night, and



evening) and different lighting conditions (interior with natural light, interior with artificial light, exterior with artificial light), as well as suiting the researcher's personal preference.

The following sections are visual analyses of the paintings with particular attention paid to lighting. Lighting in CG often includes the task of describing the surface characteristics of objects and the compositing of special effects [1]. For these visual analyses, lighting will be discussed in terms defined in live-action, applied to the 3D CG environment.

These sections will mainly discuss the aesthetic contribution of lighting to each scene and the characteristics of the design elements showed in each painting based on both references and observations.

## **II.2 Morning Sun**

The following is Hopper's note from his work journal regarding *Morning Sun* (Figure II.3). "Pink night gown, brown hair, blond skin, white sheets with streaks of gray shadows. Back of head & figure in shadow. Cut window red brick upper stories. Blue sky. Vertical strip of masonry left side of window rim, white in full light. Room walls partly in shadow green, light areas light green. End of window shade dark green upper right" [7].

The title itself, *Morning Sun*, tells the time of day. The *Morning Sunlight* from the window is the only light source in the scene. This light creates the hard-edged,

window-shaped, highlighted area on the wall, and generates a blue-grey hard shadow on the bed.



Figure II.3. *Morning Sun* (Oil on canvas, Edward Hopper, 1952) [8].

According to the record book, the color of the masonry near the window frame is white and the building outside the window is red. However, those colors are tinted with yellow, possibly from color added by the sunlight.

Inside the room there can be seen only a window and a bed with a woman sitting on it. A figure, usually a woman, looking out a window is a frequent motif in Hopper's



Figure II.4. Study for *Morning Sun* (Conté, Edward Hopper, 1952) [8].

paintings. The setting of this scene is somewhat simple. However, by using light and shade on each object, such as the rectangular lightfall on the wall and the long shadow on the bed, the whole scene becomes a more interesting composition.

Figure II.4 is Hopper's preliminary sketch for *Morning Sun*. In comparing this sketch with the original work (Figure II.3), small differences can be seen in the shading of the woman's body. The shadow on her lap covers most of her thigh, as seen in Figure II.4. But in the original painting the shadow covers only half of her thigh, making a distinctly curved edge. Assuming that she is lit by sunlight from the window, the shading of the woman's body in the sketch looks more natural than the shading in the original work.

It also seems unnatural that the vertical line that splits the light and shade on the wall also exactly splits the light and shade on the woman. Thus, the shadowed side of the woman is contrasted with the highlighted side of the wall in order to separate the figure from the background of the scene. This unnaturalness can be attributed to artistic license. The sketch for *Morning Sun* (Figure II.4) shows that the artist studied the scene realistically, but expressed it differently in the actual painting.

The blue and purple toned shadow color is generally used in paintings as a shadow color of a warm colored light. However, in this painting, the bluish shadow color of the bed behind the figure magnifies the warmth of the figure. Consequently, the erotic aspects of the figure, wearing a short pink slip, become more noticeable.

The pinkish light bounced from the dress on her lap, and the white light on her calf that is reflected from the bed sheet both look exaggerated rather than real. The bounced lights' colors taken from the surfaces surrounding the skin were described in exaggerated terms. Therefore, the skin color consists of several tones—yellow, blue grey, pink, and so on.

### II.3 Summer Evening



Figure II.5. *Summer Evening* (Oil on canvas, Edward Hopper, 1947) [9].

According to the title, this painting (Figure II.5) depicts a summer evening. However, the view of the outdoors offered seems more like night. This could be due to an artistic intention to render a strong contrast between the lighted and unlighted areas. The borderline between the bright and dark areas constitute a distinct rectangular compositional line. The main source of light for this scene is obviously the electric light on the porch, and the color is a very bright yellow. The entire porch is so bright that it

looks like a stage in a theatre.

In contrast to the intense light on the porch, the outdoors is so dimly lit as to make the outline of the house and skyline barely recognizable. The darkness outside the porch effectively separates the foreground from the background, and exaggerates the distance between the subject and the artist's viewpoint, implying that nothing outside the porch is important. This could be a good example how the light isolates the subject upon



Figure II.6. Part of *Summer Evening* [9].

which the artist wishes to focus, and blocks the subject from communication with the viewers. Hopper said *Summer Evening* was in the back in of his head for twenty years, but he never thought of putting the figures in until he actually began the work. [10] According to his statement, the figures could be intended as a part of the whole scene, and not as the main subject. However, with the bodies positioned in front of the dark

background, the bright rim of reflected light on their bodies (Figure II.6) distinguishes them from the scene and draws the viewers' attention to them.

By using this device, the couple's relationship looks to be disconnected—the man seems to approach the woman, but she gazes at the porch and offers no favorable body gesture. This disconnection intensifies the solitary mood of the painting. The solitary figure shown in *Morning Sun* and the figures who cannot communicate with one another, as shown in *Summer Evening*, are illustrative of the Hopper method of creating a sense of isolation. There is a young couple on the porch, yet the whole scene looks lonely rather than romantic. The figures also reflect the disconnection between the scene and the viewer.

#### **II.4 Night Windows**

Hopper frequently painted city interiors as seen through windows from the artist's viewpoint. Goodrich states, "usually it is night, with the lighted room and its occupants framed by dark walls. This use of interior light and enframing darkness is the motif of paintings as different in their subjects as *Night Windows* (Figure II.7), *Drug Store*, *Room In New York*, and *Nighthawks*." [11] Among the paintings listed above, *Night Windows* shows the smallest portion of bright interior separated from an almost black exterior, and this successfully defines the position of the artist's viewpoint, a higher and more distant position from the bright interior. Due to the high contrast between the interior and exterior lighting, the relative positions of the artist and the half naked woman inside the



Figure II.7. *Night Windows* (Oil on canvas, Edward Hopper, 1928) [12].

window evoke a voyeuristic sense, as well as a feeling of isolation. Based on the building exterior shown in the bottom part of the painting, the room with the woman locates higher than the ground floor. This setup hints that the room is a private space, unable to be seen from the street. Her appearance—the seminude woman seems to do something with banding her waist—also implies that she does not know she could be viewed from outside. These circumstances play significant role to stimulate the voyeuristic instinct of the viewers.



The eroticism, one of the themes repeatedly used in Hopper's works, makes the voyeuristic sense stronger in this painting. The red (pink) color for her dress evokes romantic and sexual feelings, and nighttime is a most erotic moment of the day. Both represent intentional selections made by Hopper to create this erotic mood. The fluttering white curtain and the bent posture of the figure also help to enhance this eroticism.

This painting has the same title as an etching by John Sloan, who inspired Hopper in his choice of subject matter [13]. Hopper's common subjects—American landscapes, daily city life, and a solitary woman in an interior setting—are directly

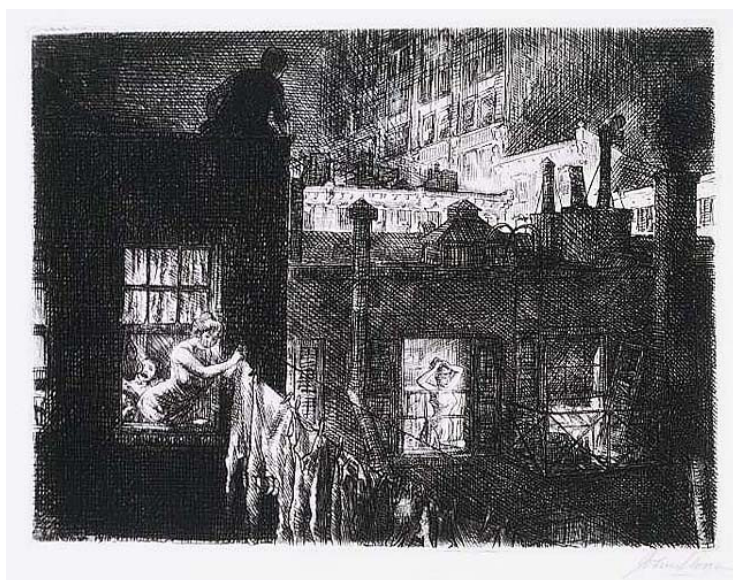


Figure II.8. *Night Windows* (Etching, John Sloan, 1910) [12].

influenced by Sloan. Hopper even used the same titles as some of Sloan's works, including *Night Windows* (Figure II.8) [13]. Gail Levin, Professor of Art at the City University of New York, states that "common themes include a woman in an interior by a window, city rooftops...But Hopper's composition is more subtle, more sensual, and his focus more intimate. Hopper also allowed the artificial interior illumination to be the sole, dramatic source of light." [12] The bright yellow incandescent light is the main source of light in the scene. Inside the right window, there is a shaded lamp that locally emits red light. Comparing the color of the two window shades, the incandescent light is positioned a bit left of the center of the room. Most of the shading in the room and the building's interior made by the incandescent light is clear. There seems to be no light source coming from the exterior of the building. The faded interior light vaguely reveals the outline of the building.

## CHAPTER III

### LIGHTING CASE STUDIES

#### III.1 Overview

Three lighting case studies are presented in this chapter. The purpose of these case studies is to observe the lighting styles from three reference images and to translate them into computer generated images. The three reference images were selected from the book *Edward Hopper: A Catalogue of Raisonné* [8], [9], [12]. This book is the fruition of almost twenty years of research by author, Gail Levin, well known as the foremost expert on Edward Hopper's works [14]. Therefore, the picture quality of the images in this book can be assumed to be close to the original color used in Hopper's works. The selected images were scanned in order to be used in the 3D reconstruction process. The process of scanning was performed carefully in order to minimize color differences between the print in the book and the scanned image displayed on the monitor. During the 3D lighting reconstruction process, the 3D lighting was created and fine-tuned to match the lighting in the scanned reference image. There could be color shift problems, depending upon the monitors' color calibration. However, if a set of images (a scanned reference image and its 3D image) is displayed on the same monitor, those problems can be removed. The detailed procedure is described below.

At first, lighting in each reference image was observed carefully, based upon the following check list, derived from the reference, *[Digital] Lighting and Rendering* [15].

Because this book covers many important points of digital lighting and rendering from a 3D artist's point of view, the contents are appropriate for this study. These lighting observations were conducted from a practical view: the major points of observations are what kind of 3D lights would be needed and where they should be located in the 3D scene in order to recreate the lighting in each reference image.

- a. "An apparent (or assumed) light source motivating the key light: position, color, intensity, quality (hard or soft)" [15].
- b. "An apparent (or assumed) light source motivating the fill light: position, color, intensity, quality (hard or soft)" [15].
- c. "An apparent (or assumed) light source motivating the back light: position, color, intensity, quality (hard or soft)" [15].
- d. "Proportion of light: How does the level of contrast affect the scene? Does the key-to-fill ratio make sense in that scene's environment?" [15]
- e. Shadows: color, intensity, length, angle and quality.
- f. "Do the shadows serve any visual functions? Are the quantity, darkness, and softness of the shadow appropriate to the scene? Do detail and shading appear in the shadow area?"[15]

The lighting terms used in these observations are derived from still photography, film, and 3D computer generated imagery. The results of these observations were applied immediately to create 3D lightings of corresponding reference images.

Next, the three reference images were recreated digitally using the 3D software, Autodesk® MAYA®. Modeling, shading, and lighting processes were implemented.

Figure III.1 shows the front, side and top views of a female figure. A female figure is common content to the three paintings selected for examination. This model was created in advance and used in each of the three 3D scenes.

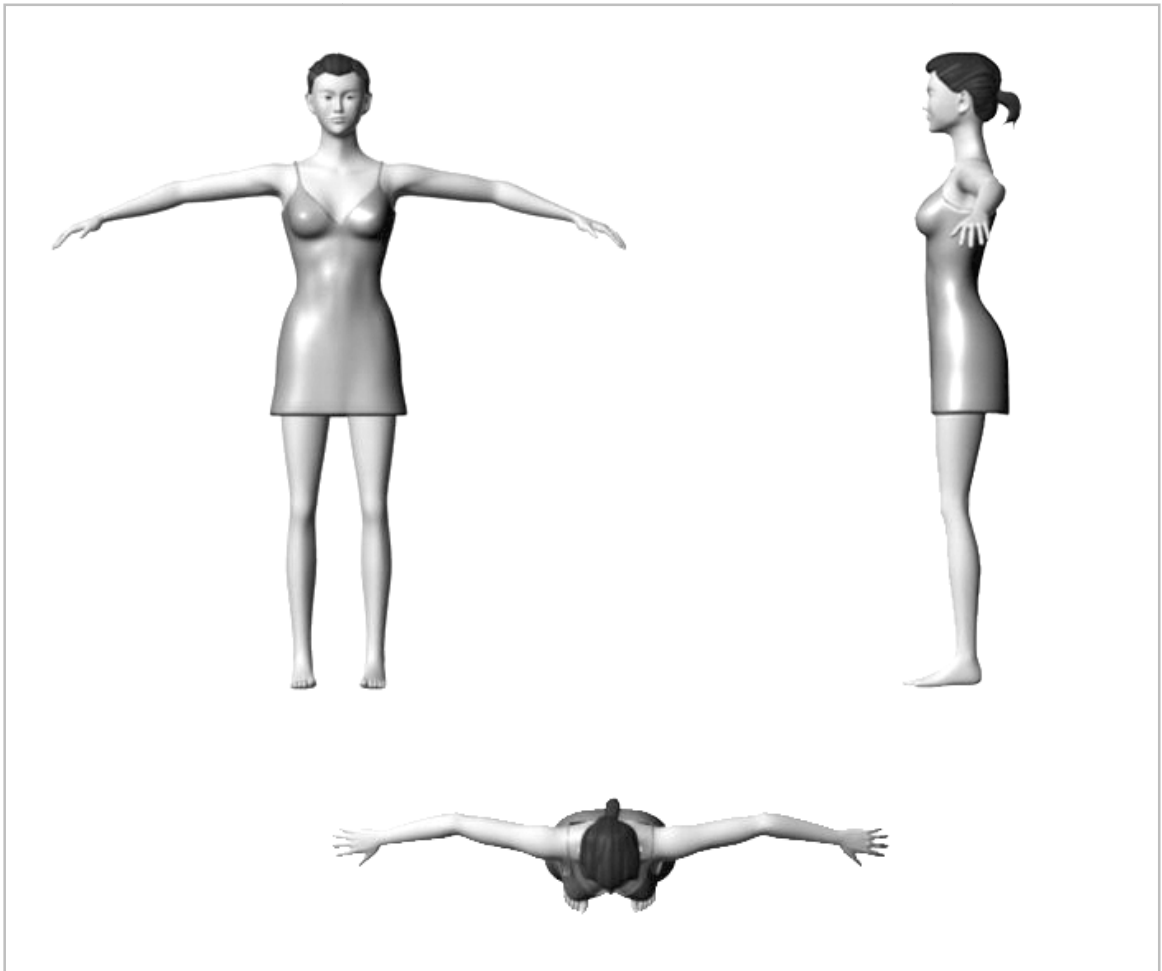
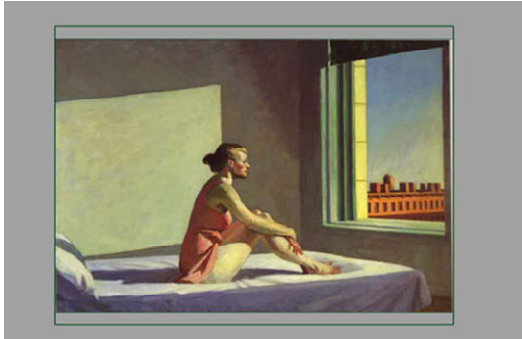


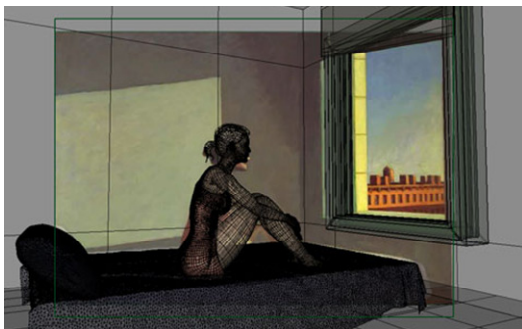
Figure III.1. Front, side and top views of a female model for 3D reconstruction.



(a) An electronic *Morning Sun* image file was connected to the image plane of the rendering camera.



(b) The environment was modeled. In this process, the properties of the rendering camera were adjusted to match the perspective of the reference image.



(c) The female figure model was imported into the 3D scene. The posture and position were matched as close as possible with the reference painting.

Figure III.2 Snapshots of the modeling process for *Morning Sun*.

During the modeling process, the reference image was connected to an image plane of a rendering camera as a modeling reference. Once the settings were modeled, the female figure was imported into the scene. Then, the posture and position of the female figure was modified according to the reference image. After the modeling process, proper shaders were assigned to the objects in the scene. Figure III.2 shows the snapshots and descriptions for each step of the modeling process for *Morning Sun*.

In order to make lighting a main variable for manipulation and comparison, modeling and shading processes were simplified on the condition that the 3D scene should generally have a look similar to that of the reference image. For example, the painterly brush touches making up the wall in *Morning Sun* are important, because the multiple colors on the wall made up of the painterly brush strokes consist of the color of the wall itself, the color of the light that illuminates the wall, and various colors of reflected lights from the objects in the scene. During the 3D implementation, these painterly brush strokes were simply replaced with procedural textures of object shaders. The procedural texture could not mirror the painterly brush strokes exactly, but it could efficiently simulate the multiple color mixture.

Finally, 3D lights were located based on the prior lighting observations with the check list, and the properties of the 3D lights were adjusted to match the color of the 3D image to the counterpart color of the reference image. First of all, a pair of images (i.e., a reference painting and its 3D reproduction image) was converted to grayscale, and their color values were compared as Hong did in her thesis study [16]. In this step, the intensity and the brightness of 3D lights and shadows were mainly adjusted. This process

prevented possible misjudgments regarding the brightness of the 3D light caused by differences of hue and saturation in its color. Then other properties, specifically the hue, the saturation, the softness, and the shadow, were manipulated. This fine-tuning process was repeated until the lighting of the reference image could be successively recreated in the 3D scene.

An ambient occlusion pass was rendered separately by *jrOcclusion*, the ambient occlusion plug-in for MAYA®, to add a more realistic sense. Soft shadows, contact shadows, and darkness found in close surfaces (corners, cracks and creases) could be achieved by ambient occlusion. This lighting technique mimics efficiently the effects of global illumination.

All the passes were composited using 2D software, Adobe® Photoshop®. As the occasion demanded, more than two passes were generated and composited for one final image.



### III.2 Case 1: Morning Sun

#### III.2.1 Lighting Observation and Application to the 3D Scene



Figure III.3. The scanned image of *Morning Sun* (Oil on canvas, Edward Hopper, 1952) [8].

In this section, the results of lighting observations of *Morning Sun* (Figure III.3) and how the results were applied to the 3D scene are stated. Figure III.4 is captured images of 3D software to show where and what kind of 3D lights were placed.

Taken altogether, light and shadow on the objects in the *Morning Sun* show clear differences in their brightness, with clear edges. This explains the lighting situation of

the scene as a room directly lit by sunlight coming from the opened window as only one light source. On the other hand, the differences in saturation between light and shadow on the objects are relatively lower than those in brightness because of a diffusion of sunlight. Overall, the contrast of this scene is moderate in spite of the clear edges of the highlight on the wall and the shadow on the bed. Therefore, a medium key-to-fill ratio should be used for the 3D reconstruction.

The light source motivating the key light in *Morning Sun* is sunlight from the window on a clear day. The key light is positioned where it can create the same shape of lightfall on the wall and the figure's shadow on the bed as those in the reference image. The objects inside are tinted with the color of the key light, yellow. Brighter yellow spots are shown in the highlights of the objects, such as the lightfall on the wall, the figure's arms, and the bed sheet around the figure's foot. Among them, the yellowness on the bed sheet is diminished gradually as the distance from the key light increases. In order to simulate this appearance, a fill light which can add to the brightness of the key light but falls off quicker than the key light, is needed. The intensity is strong enough to illuminate brightly the interior with this light source. The quality of the light is hard, which is determined by the crisp edges of lightfall on the wall and the shadow on the bed. In the 3D scene, multiple 3D lights (lights (1) ~ (4) in Figure III.4) were used to simulate this sun light of *Morning Sun*. Light (1), the key light of 3D scene, illuminates the whole scene with yellow colored light and makes a substantial lightfall on the wall. Lights (2) and (4) are fill lights that supplement the shortage of brightness of the key light of 3D scene. The linear attenuation option was turned on for the light (2) in order to simulate

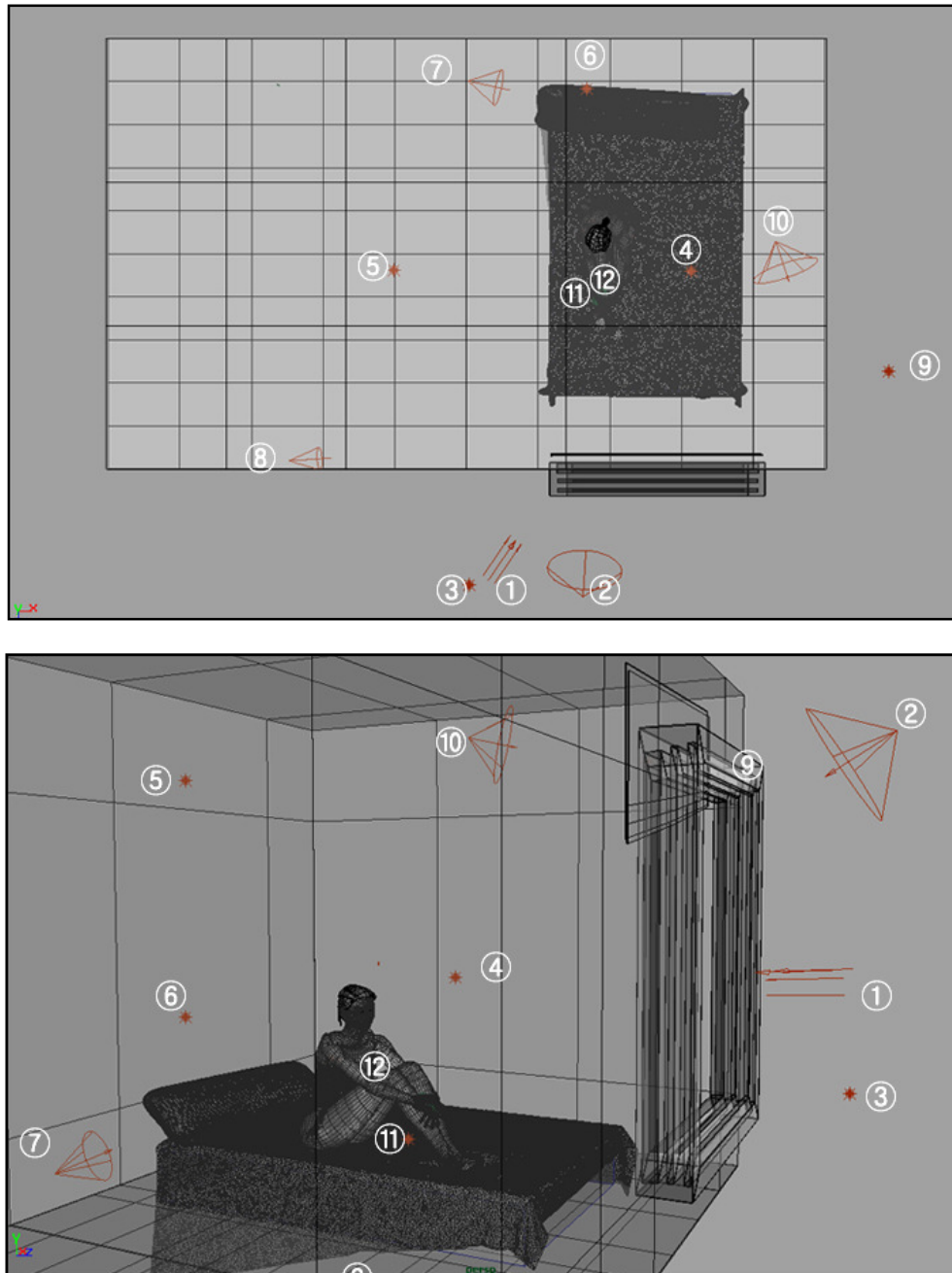


Figure III.4. Placement of 3D lights for *Morning Sun* in top and perspective views.

above-mentioned diminishing sunlight and (4) are fill lights that supplement the shortage

of brightness of the key light of 3D scene. The linear attenuation option was turned on for the light (2) in order to simulate above-mentioned diminishing sunlight. According to the lighting observation, besides the fill lights which are needed to assist the role of the key light, several fill lights are required to illuminate dark areas in the room and to simulate reflected lights. Lights (5) ~ (8) were placed in the 3D scene for this purposes. These lights have various tints in order to represent reflected lights from the contents of the scene. The strong scene contrast created by lights (1) ~ (4) was effectively decreased by controlling the intensity of these lights.

Two apparent areas that require a reflected light are observed from the reference image. One is the bottom parts of the figure's back of calves with a white light reflected off the bed sheet, and the other is the figure's thighs-tops with a pink light reflected off the figure's pink dress. Lights (11) and (12) were placed to simulate those reflected lights on the figure.

Back light for the figure was not used in this painting. However, the contrast between the light and shade of the figure and those of the wall (the highlighted front side of the figure is against the shadow of the wall, and the shadowed back side of the figure is against the highlight of the wall) made the figure stand out.

In *Morning Sun*, the noticeable shadows are generated by the sunlight. The particularly long shadow of the figure on the bed and the rectangular lightfall created by the shadow of the window are important visual elements for breaking the monotonous space and enhancing the composition of the scene. They have clear edges and are intense.

The characteristic of the figure's shadow on the bed indicates that the time of the

day is early morning. The long shape of the shadow suggests that the sun is positioned lower in the sky, like sun in the early morning or late afternoon. The bluish shadow color of the white bed sheet evokes the mood of early morning rather than afternoon, because the shadow's color becomes the complement of the light color, in this case the color of early *Morning Sun*, yellow. [17]

During the 3D process, light (1), which functioned as sunlight, successively generated all the shadows in the scene except the shadow on the figure's body. For this reason, a figure pass and a background pass were separately rendered. For the figure pass, light (3) was replaced with light (1), which resulted in the accurate shape of the shadow on the figure's body. The bluish shadow color shown in the bed was generated by controlling the properties of the shader for the bed.

The shadow on the top corner of the wall in the reference image was expected to be generated by the key light in the 3D scene. However, it couldn't be created with the key light, light (1) or even with the other 3D lights mentioned so far. Thus, negative lights, lights (9) and (10) were placed in the 3D scene. Particularly, light (10) has a rectangular shape using barn door option in MAYA® to mimic the shadow's shape in the original painting.

For the final image, three layers were composited: a figure layer, a background layer, and an occlusion pass layer. The cityscape view outside the window is the original painting itself attached to an image plane of a rendering camera. The redness of the figure's body (cheek, fingers and toes) in the original painting (Figure III.3), that looks exaggerated by artistic license, brings more life and a vivid feeling to the scene. In the

3D reproduction image, this appearance was achieved simply by retouching in Adobe® Photoshop® during the compositing process, rather than creating a texture file for the human figure's shader for efficiency's sake.

In order to decrease the sharpness of the digital image, the depth of field function was used for the rendering camera. As a result, the background over the figure was blurrier than the figure.

### III.2.2 Resulting Image



Figure III.5. The grayscale image of *Morning Sun* (left) and its reproduction (right).

The reference painting and the final image are displayed in grayscale in Figure III.5 for the purpose of comparing the values of both images. Figure III.6 shows a final image of the *Morning Sun* 3D reconstruction in color.



Figure III.6. A final image of the *Morning Sun* 3D reproduction.

### III.3 Case 2: Summer Evening

#### III.3.1 Lighting Observation and Application to the 3D Scene



Figure III.7. The scanned image of *Summer Evening* (Oil on canvas, Edward Hopper, 1947) [9].

*Summer Evening* (Figure III.7) shows a strong contrast between the lighted (the porch) and unlighted areas (the outside of the porch) of the scene. For this reason, a high key-to-fill ratio should be used for the 3D reconstruction. This strong contrast psychologically intensifies the remote feeling of the scene. In the following sections,



details of the lighting observation and application to the 3D scene will be discussed.

An obvious key light source in *Summer Evening* is the incandescent lamp on the ceiling; its intensity is strong enough to illuminate brightly the whole porch. The light (1) in Figure III.8 is the simulated incandescent light on the ceiling illustrated in the painting. However, during the 3D reconstruction, one key light (Light (1)) was not enough to diffuse its light throughout the whole porch without causing an excessive glare around the light source. On this account, several lights were used to fill up the brightness of the key light. Lights (2) ~ (9) are fill lights used for adding brightness where the key light is not sufficient for illumination.

There are two more light sources in this scene. One is an outdoor light, assumed to be moon light. It plays as fill light, illuminating objects in the shadows created by the key light. It is so dim and soft that it barely reveals the outline of the house and the ground. In the 3D scene, light (12) softly illuminates the exterior of the house with a brown tint. The sky was textured by an *envSky*, an environmental texture map which is provided by Autodesk® MAYA® for creating images of a planetary sky. A negative spot light was placed in order to darken the hill seen behind the house because the hill was brighter than it is in the final image without the use of this negative light. The 3D light is not shown in Figure III.8. Its position is too far from the other 3D lights to put them together in one snapshot.

Another light source is the yellowish, soft light inside the window and under the curtain. Like a candle or a desk lamp light, the light quickly fades with distance and illuminates the limited small space. In order to simulate this light, a volume light (Light

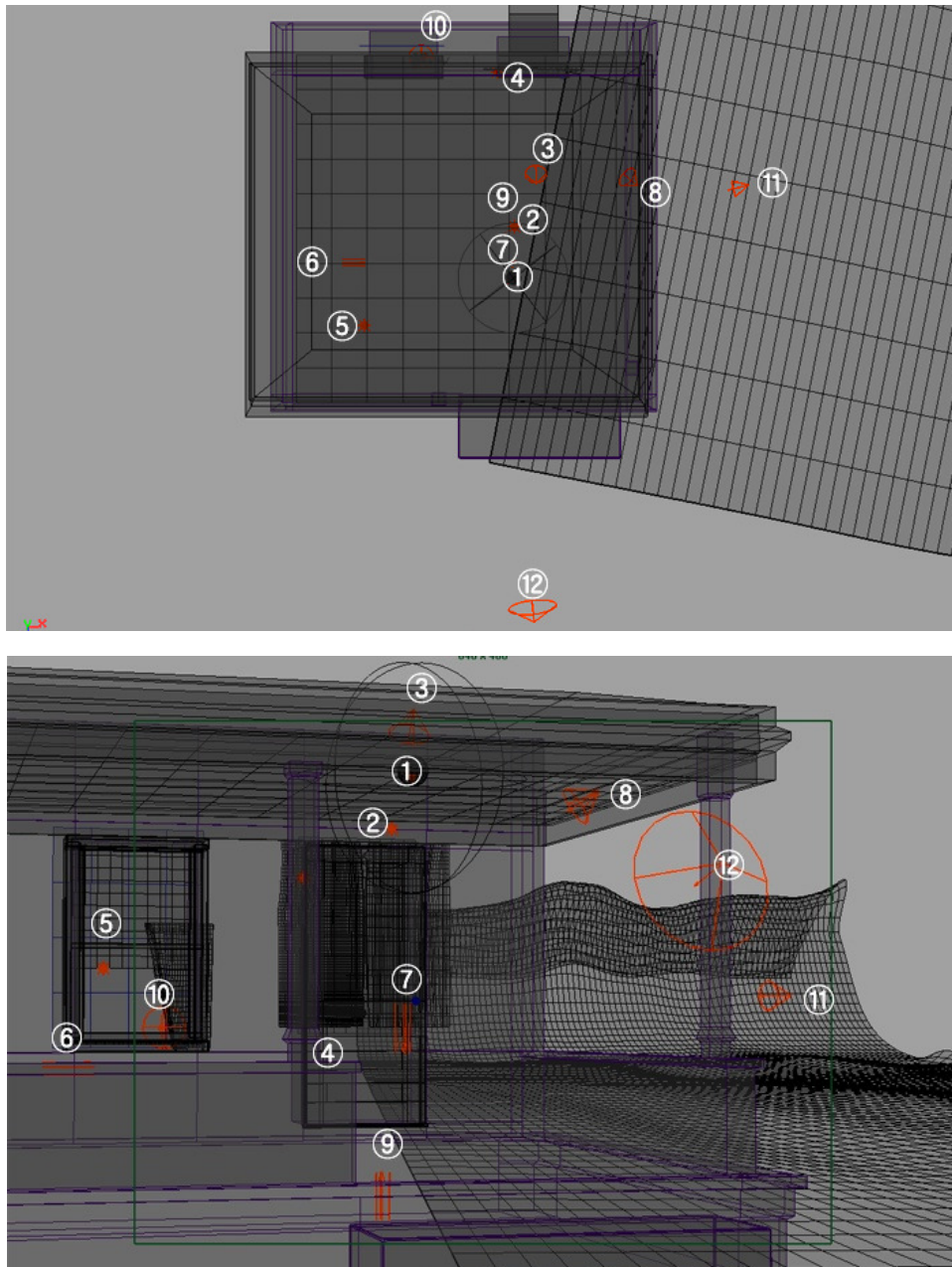


Figure III.8. Placement of 3D lights for *Summer Evening* from top and perspective views.

manipulate the outer boundary of the illumination. The leakage of the porch light on the (10) was implanted into the 3D scene, because with a volume light it is easier to right side of the ground was simulated by an additional spot light because the amount of light leakage was not sufficient to match that of the 3D lights placed on the porch.

During the lighting observations, the rim light for the figures seemed not to be necessary for 3D reconstruction. However, because the shadow parts of the figures (the back sides of them) look brighter than their surroundings, a light that acts like a rim light was applied to the 3D scene. Light (11) is the spot light used to illuminate softly the back sides of the figures.

The noticeable shadows in this painting are the figures' shadows. They are created by the key light and have crisp edges in a medium grey tone. The shadows on the porch (except for the shadows of the inside of the door) are brighter than those on the outside of the porch. By reducing the differences in the brightness between the light and shadowed areas of the porch, the brightness of the foreground (the porch) contrasts with the brightness of the background (the outside of the porch), and that contrast strongly engages the viewer's attention. In reality, under the same lighting situation with this painting, the brightness of the shadows would be darker, even if the reflected lights from the surface of the porch are considered. These shadows could be intentionally brightened in order to create a strong contrast between the foreground and the background, similar to how the darkness of the outside is exaggerated.

During the 3D reconstruction, the one male figure in *Summer Evening* was omitted in order to save time during the modeling. The exterior siding and speckles of

the wall were textured with an image created with Adobe® Photoshop®.

For the final composition, the shadows of the building itself were rendered separately to match the darkness of the shadow with the reference image. Because there are several lights on the porch, the shadows of the building were brightened when they were rendered on the first pass. An occlusion pass was rendered separately and composited to produce the final image.

### III.3.2 Resulting Image



Figure III.9. The grayscale images of *Summer Evening* (left) and its reproduction (right).

Figure III.9 shows the reference painting and its 3D reproduction in grayscale. The final image in color is presented in Figure III.10.



Figure III.10. A final image of the *Summer Evening* 3D reproduction.

### III.4 Case 3: Night Windows

#### III.4.1 Lighting Observation and Application to the 3D Scene



Figure III.11. The scanned image of *Night Windows*  
(Oil on canvas, Edward Hopper, 1928) [12].

In *Night Windows* (Figure III.11), the bright interior combined with the small space effectively leads the viewers' eyes inside the windows, contrasting the interior scene with the dark outside. The outside seems to have no light source at all. This substantial difference between the interior and the exterior in terms of their brightness enhances the mood of night. In order to implant this lighting into a 3D scene, a high key-to-fill ratio should be used.

Figure III.12 shows the snapshots of the 3D scene in both top and perspective views. An apparent key light for this scene is a yellowish, incandescent lamp located slightly to the left side of the center of the ceiling (Figure III.11). It brightly illuminates the whole interior space. Also, its faded light leaks from the windows. According to the lighting observation, it creates all the light and shade both inside and outside, and around each window on the outside.

In the 3D scene, light (1) simulates the key light, the yellowish incandescent light. However, with only light (1), it was hard to create all the lights and gradations of value shown in the reference painting (Figure III.11). This could be due to the differences in the shapes represented by the building and the arrangement of the objects in the room between the real subject of the painting and those in the 3D scene. For this reason, several 3D lights (from light (2) to (14) in Figure III.12) were added into the 3D scene. The function of light (1) is to illuminate the room with the brightest intensity and generate the shadows of the bed and the radiator. Light (2) is for additional illumination, only for the top of the radiator. Lights (3) ~ (6) fill up the short illumination of the key light. Lights (7) ~ (12) create the light and shade on the outside of the building, around

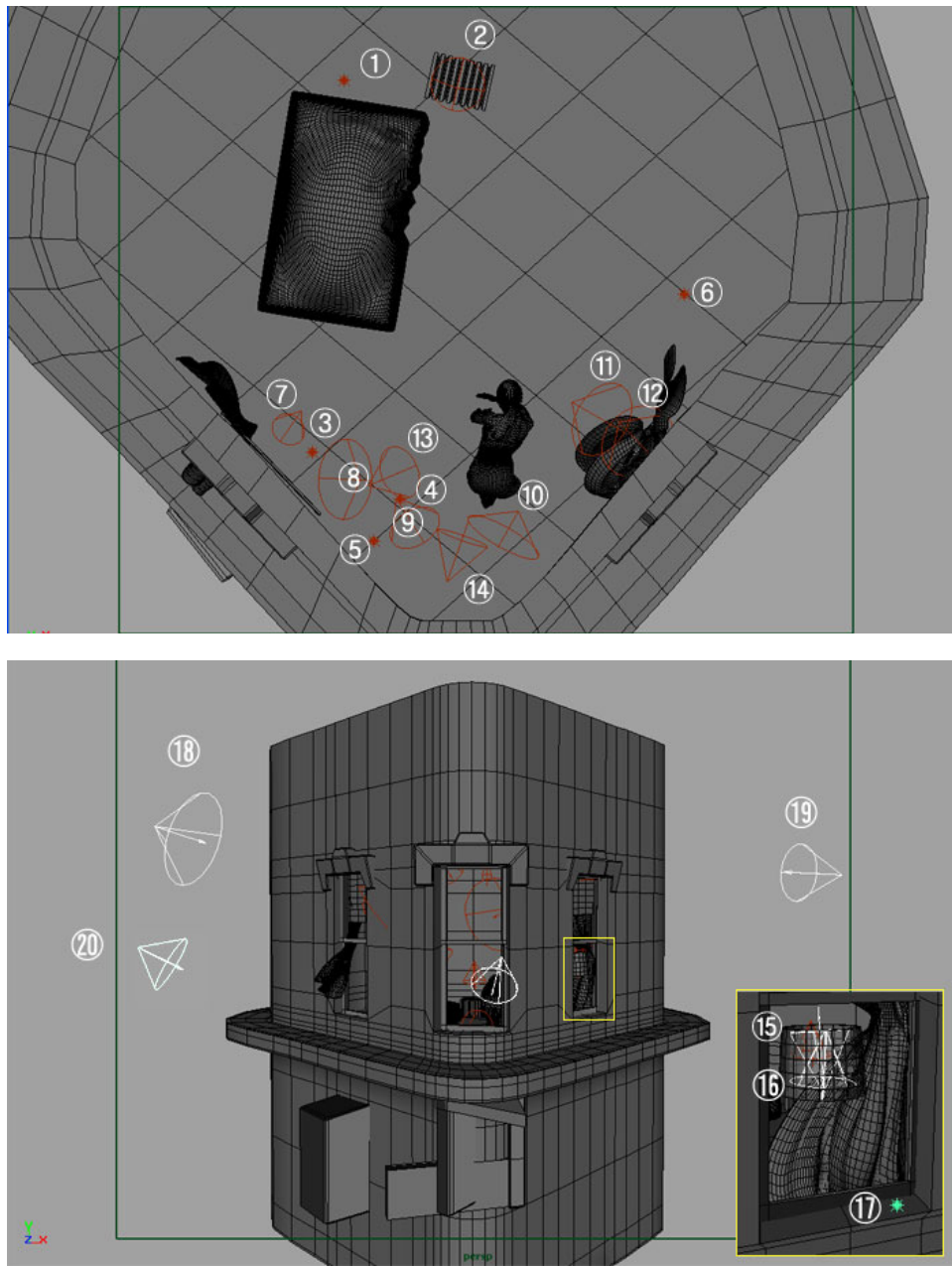


Figure III.12. Placement of 3D lights for *Night Windows* in top and perspective views.



the window frames. In order to simulate the lightfall and the faded, permeated light for each of the outside windows, two spot lights per each window were used. Lights (13) and (14) add more illumination to the figure and generate the figure's shadow.

Through the window on the right in Figure III.11, a cylinder-like object with a red curtain is shown. Near there, a very diffusive orange light can be observed.

There is no evidence to verify what the cylinder-like object is or where the orange color comes from. However, during the 3D reconstruction the cylinder object was translated into a red, color-shaded lamp, and the orange color was interpreted to be a mixed color resulting from a combination of the yellowish lamp light and the reddish reflected light from the red curtain. Lights (15), (16) and (17) are the 3D lights used to simulate this. Lights (15) and (16) are the yellowish spot lights used for the lamp light. Light (15) illuminates upward and light (16) illuminates downward from the lamp shade inside. Light (17) is a point light that simulates the reddish reflected light from the red curtain.

Besides around the windows, the exterior of the building is very dark - close to black. The interior light which spreads out from the windows obscurely reveals the appearance of the building's exterior around those windows. To simulate this, lights (18) ~ (21) illuminate the outside of the building with a very low intensity and create shadows.

With regard to the interior shadows shown in this scene, they are dark and have crisp edges except for those shadows on the red curtain. Because they are generated from the key light (which is the only light source with a strong intensity) the darkness and the

edge of the shadows are reasonable. The building exterior in the shadow, created by blocking the interior light and dark night atmosphere without any other light source, makes the bright interior more distinguishable and elevates the voyeuristic mood of this scene.

The vertical wooden color pattern on the wall was created with Adobe® Photoshop®. The texture of the window shade and the texture for the building exterior were both generated by using the procedural texture built in Autodesk® MAYA®.

For the final image, an image rendered by Autodesk® MAYA® was composited with its occlusion pass.

#### III.4.2 Resulting Image



Figure III.13. The grayscale images of *Night Windows* (left) and its reproduction (right).

Figure III.13 displays the reference painting and its 3D reproduction image in grayscale. The resulting image in color is shown in Figure III.14.



Figure III.14. A final image of the Night Windows 3D reproduction.

## CHAPTER IV

### IMPLEMENTATION AND RESULT

#### IV.1 Setting Up the Environment

A room housing a female figure lit by the late afternoon sun provides the setting of the final image. The lighting for this scene was originally inspired by the three Edward Hopper paintings selected for the previous lighting case studies: *Morning Sun*, *Summer Evening* and *Night Windows*. The influences Hopper had on the final image are not confined to the lighting. During the modeling and shading processes, composition, subject matter including setting, and color from these three Hopper paintings were applied to the final image in order to maximize the effect of the lighting implemented in the style of Hopper.

The models are designed to evoke the common feeling expressed in many of Hopper's paintings: loneliness. The empty room with a window, the solitary female figure looking out the window, and the curtain fluttering in the wind are all frequent conceits in Hopper's paintings and are adapted creatively for the 3D scene (Figure IV.1). The wall on the front left side is the device used to convey that there is a physical distance between the human figure and the artist's viewpoint. Additionally, the woman's posture—lost in thought with eyes averted away from the viewer—hints that the woman isn't aware of the existence of the viewer, and the woman and the viewer are disconnected. These two devices intensify the feeling of loneliness and reveal the

phenomenon of voyeurism.

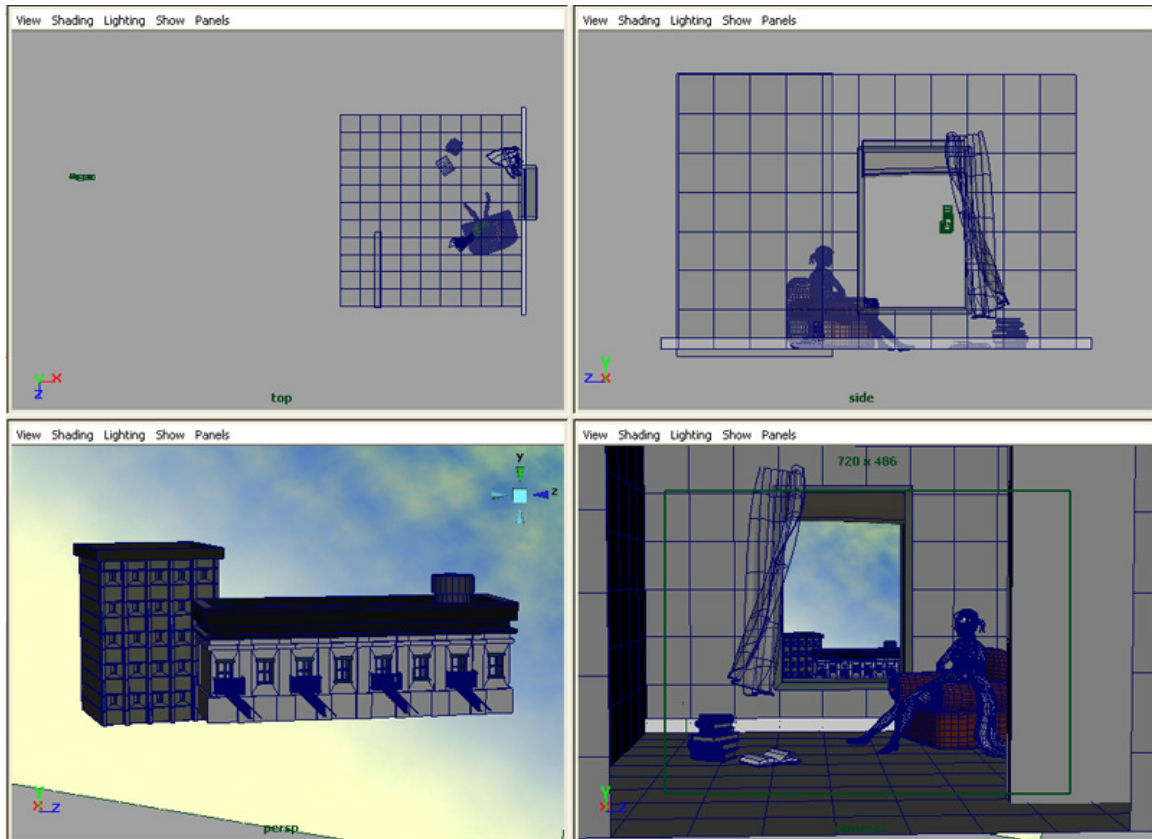


Figure IV.1. The screen shot of the modeling process of the final image.

The window in *Morning Sun* acts as an example of Hopper's technique. The singular window in the room serves as the only available passage for the sun's rays to penetrate into the room, and create a lightfall on the floor.

The voyeuristic sense that can be gleaned from *Summer Evening*, *Night Windows*

and Hopper's other works pervades the final image. The open book on the floor seems to be laid there by the female figure just before the image is captured. The woman sits on the couch in a relaxed pose, wearing only a pink slip. These situations are purposely created in order to represent the idea that the woman spends a private moment alone. In addition to these situations, the wall on the front left side acts like a barrier between the woman and the viewer, and this makes the viewer peep at her private life, around the wall, without being noticed. This voyeuristic sense is heightened by the sense of erotic mood often present in Hopper's paintings. The pink slip and the sheer curtain fluttering in the breeze are both motifs adapted from *Night Windows* to add an erotic mood to the 3D scene. The symbolic meaning of pink: the slip color, the half—naked woman figure, and the sheerness of curtain fabric give a tangible expression of eroticism to the final image. Moreover, the billowing curtain—"a traditional indicator of carnal sensuality [4]"—and the fluttering leaf of the book, stimulate the imagination to the viewer suggesting that the breeze wandering over the room, which comes from the window, would wrap the female figure's bare skin softly and awake her sensuality.

The shading process for the final image begins with an application to the final image of the selected shaders, from among those used in the 3D *Morning Sun* image. However, the colors are different when adapted to the final image. For example, the shader for the wall in the final image is derived from the shader used for the wall in 3D *Morning Sun*, but they are not the same as one another. The differences are caused by the different lighting settings between the final scene and 3D *Morning Sun*, and the different adjustments performed on the shader properties implemented during the development

and refinement of the final scene. The shaders for the couch, the throw, the cup, the curtain, the books and the buildings outside are newly created for this image. The texture of the sky was created in Adobe® Photoshop®.

The rendering camera was pulled back from the initial position in order to make the figure relatively small in proportion to the scene. This is an effective method for making the scene seem isolated from the viewer. The high angle of the camera provides enough space on the floor to show the lightfall. The compositional lines are managed to be both vertical and horizontal in order to make the oblique shape of the lightfall stand out. For the psychological effect, the vanishing-point of the view outside was matched with the point at which the female figure stares.

## **IV.2        Lighting Process**

Lighting follows the modeling and shading process. The lighting styles which are shown in the three Hopper painting are borrowed and adapted for use in the final scene.

Basically, the goal of the lighting was to be realistic. Under this condition, several techniques were used to successively visualize the original concept of the final image. The strong contrast between the primary subject and the surroundings, shown in both *Summer Evening* and *Night Windows*, was applied to the final scene. As a result, the darkness of the unlit area was exaggerated by artistic license and the darkest area (the wall on the left side) became almost black, like the outside in *Summer Evening* and *Night Windows*. At the same time, the brightness of the reflected sunlight on the floor

was slightly exaggerated for the same reason. This is an effective technique to direct the viewer's attention to the primary subject. The rectangular lightfall created by the sunlight coming through the window became a compositional form itself, and emphasized the human figure through contrast with the surroundings, similar to the technique used in *Morning Sun*. This lightfall increased the feeling of isolation by framing the human figure inside.

With regards to shadows in the scene, only those shadows created by sunlight have clear shapes and are intense. For the reality of the scene, contact shadows created by *jrOcclusion*, the ambient occlusion plug in of MAYA® were added. Detailed explanations of each figure according to their separate lighting steps are presented as following.

Figure IV.2 shows the effect of the key light in the final image. The key light is the sunlight from the window, the only light source which creates the main shadows on the floor. A spotlight was used for the key light and its linear attenuation option was turned on to simulate diminishing sunlight as sunlight penetrates further into the room. The goal that the shadows of the female figure and the couch remain inside of the lightfall to keep the shape of the lightfall dictated the position of the key light.

Figure IV.3 shows the effect of the fog light. The fog was added in order to visualize sun rays entering the window and the air's dust being lit by sunlight. However, the light and fog intensity of the fog light are very low because excessive fog would evoke a surreal mood. The fog light was generated by duplicating the key light because both lights have the same purpose, simulation of the sunlight. Since the fog light has the





Figure IV.2. The screen shot of the final scene lit by one key light.

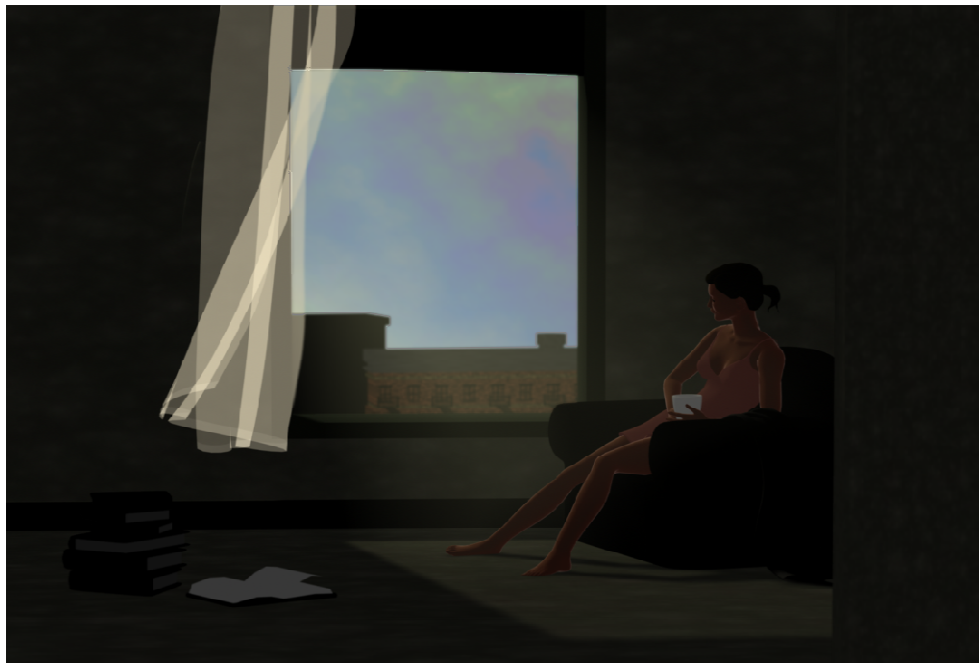


Figure IV.3. The screen shot of the final scene lit by one fog light.



Figure IV.4. The screen shot of the final scene lit by fill lights to illuminate dark areas.

same properties in common with the key light except the light and fog intensity, it created the same shadow shapes as the key light.

Figure IV.4 shows the effect of fill lights that illuminate the dark areas of the interior and interior objects. Because the window is the only passage for the light source, a large part of the interior was shadowed by the wall adjacent to the outside. Compared to the image rendered without these fill lights (Figure IV.4), the subjects in became more visible after the fill light application.

Figure IV.5 displays the effect of the two fill lights which darken the top corners of the wall without illumination. In reality, they are supposed to be brighter than they are

in this image. The width of the wall with the window is big enough not to make shadowed corners. In other words, the top corners of the window side wall exist far off the scene. The occlusion pass of this image, Figure IV.8 , proves that the top corners of the wall have no contact shadow. However, as a device for framing the primary subjects by darkness, these two fill lights were placed on both of the top corners of the wall.



Figure IV.5. The screen shot of the final scene: Two fill lights are added to darken the top corners of the wall on Figure IV.4

Consequently, the primary subjects became more distinguished and the volume of the image was accentuated, as compared with the image rendered before adding these

two lights (Figure IV.4).

In real life, the sunlight is supposed to illuminate the interior indirectly reflected off the surface of the objects in the room, in the same situation as this scene. To simulate this phenomenon, two fill lights were added.



Figure IV.6. The screen shot of the final scene: Two fill lights are added to simulate reflected lights on Figure IV.5

The left image in Figure IV.6 shows the illumination of the reflected lights from the sky on the floor. The simulating light, a spot light, was tinted with light blue to reflect the sky color, and has a rectangular shape using its barn door option reflecting the shape of the window. Additionally, when the reflected lights from the sky hit the floor, the lights also reflected off the surface of the floor onto the objects in the room. The right image in Figure IV.6 shows the reflected light from the floor on the nearer object, the wall under the window. Since the light was reflected from the floor, a yellow-green light, reflecting the floor color, was used for simulating the light. Both lights attenuate with

distance to prevent excessive illumination of the scene.

The next figure (Figure IV.7) is a resulting image from the application of several fill lights as the complements to the illumination of the sunlight to the final image. Two point lights illuminated the buildings outside the window, and one point light illuminated the human figure and the couch. The lights outside were placed on the assumption that the sun is located on left side of the image. The light inside filled in the insufficient illumination of the key light for the human figure and the couch. The following figure



Figure IV.7. The screen shot of the final scene: Several fill lights are added to support the illumination of the sunlight on Figure IV.6

(Figure IV.8) is an ambient occlusion pass using *jrOcclusion*. This pass provided reality to the image efficiently and covered the unnaturalness from the image that was rendered by only local illumination. Particularly in the final image, the shading of curtain and the contact shadows of the books on the floor were much improved by this pass.



Figure IV.8. The screen shot of the occlusion pass.

### IV.3 Final Composited Image

The final image (Figure IV.9) was made up of the two images: one is the image rendering all the effects of the digital lights of the scene, and the other is the image rendering the effect of occlusion shader (Figure IV.8). They were composited in Adobe® Photoshop®.



Figure IV.9. The final composited image.

## CHAPTER V

### CONCLUSION AND FUTURE WORK

This thesis is a lighting study which utilizes three of Edward Hopper's paintings as examples of subjects for digital lighting. Edward Hopper's paintings are an excellent source to use for studying the artistic presentation of lighting. Particularly, lighting in the selected paintings entitled *Morning Sun*, *Summer Evening*, and *Night Windows* offer excellent examples of how lighting enhances a dramatic mood in a realistic scene. Thus, studying these lighting styles is useful for developing digital lighting that is refined and offers artistic inspiration with a realistic look.

First, visual analyses and 3D reproduction processes of the three selected Edward Hopper paintings were conducted. The visual analyses were intended to help this researcher as well as a viewer understand each painting as a whole, and were not specifically focused on the lighting style in each. Through these visual analyses, an exploration of the artistic aspects shown in the paintings (such as the artist's characteristic style and his interpretation of color and lighting) was conducted. This exploration was guided by these observations and also by research in prominent reference books.

The 3D reproduction process made it possible to translate the paintings into 3D digital images. The close lighting observation of each painting was the first step in the 3D reproduction process. It helped this researcher gain insight into interpreting what kind of 3D lights would be needed and where they should be placed in order to produce



the same lighting style in the 3D environment as appeared in the reference painting. The creation of 3D set props intended to be as similar as possible to those in the reference paintings was an effective strategy for helping this researcher focus on the detailed lighting differences between the various paintings. The 3D lighting processes offered a good chance to practice simulating indirect illuminations by adding fill lights for reflected lights without global illumination. This result stemmed from the fact that the reference paintings were illustrated based on the theory of realism, as was mentioned above. The colors brought about by indirect illuminations that are commonly seen in real life are presented in these paintings, and sometimes are presented in an exaggerated fashion, depending on the artistic inspiration. The skill to use adequate lighting contrasts to create the necessary dramatic mood and the techniques to manipulate that lighting to enhance the composition of the scene were invaluable benefits of this research gained via the 3D reconstruction processes.

The final project was the creation of an original 3D image inspired by three of Hopper's paintings. The lessons learned from the previous step were incorporated into the final project. In the final project, several remarkable characteristics of the reference paintings, such as the mood of loneliness, a voyeuristic view point, a strong contrast between the illuminated and un-illuminated areas, and the subject matter: a female in a pink slip, a window with a white curtain, and empty room, were all utilized and refined by the researcher's own style.

The process of the entire lighting study was successful for understanding the lighting style rendered by different media and applying it to an original 3D scene.

Additionally, the artistic perception can be further refined through the investigative process. It is a benefit of this study that any kind of image can be utilized as a reference. If a reference image is worthy of study, following the same steps performed in this lighting study will lead to successful results.

For future study, paintings of non-realistic artists such as Picasso and Monet could be examined. The artistic license necessary to bend or break with the artistic convention to depict realistic content can provide the necessary inspiration to produce non-realistic 3D images.

A Director of Photography's (or DP's) work also would offer significant subject matter for a digital lighting study. Great DPs have a thorough knowledge of the overall lighting in live action, such as effective lighting techniques for storytelling and its influence on the viewer. Generally, DPs have their own styles of working with light. Lighting studies performed on the works of great DP's could suggest effective approaches to digital lighting styles reflecting different artists' styles.

Another future consideration could be a study on the time of day presented in paintings. Conveying the time of day or the season is one of the primary objectives of lighting used for setting a mood [18]. There is 3D software which can scientifically render lighting and shadow according to the input data of time, date and location. However, digital lightning in film doesn't need to be physically correct—just visually interesting. Sometimes, images which reflect nature exactly aren't attractive enough to captivate a viewer's eye. A study of paintings that dramatically convey a specific time of day would be helpful for enhancing the quality of digital lighting.

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