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1 Introduction

The process of digital lighting is a versatile task and when it comes to the techniques involved, the nature of the project as well as the resources available will depict how to approach it. Surely enough, an outdoor scene will have different requirements when compared to an indoor scene. Integrating computer elements with live action has its own requirements as well as do different stylistic approaches. Deadlines will have their say on how projects are being managed, which is especially true for animation where the multitude of shots will limit the amount of time available for the lighting of a shot. For animation one must also consider the time the viewer has to spend looking at a scene. Usually not much and that calls for clear and defined lighting solutions that don't distract but help carry the story as efficiently as possible. Lighting a scene is rarely a straight forward journey and many revisions will have to be made. One can constantly find himself returning to earlier stages to fix things and to try to get them to work the way they want.

With that in mind, rather than concentrating on just one specific scenario, this thesis will try to take a broader look at things. It is a collection of various thoughts, theories and techniques, but in every way fundamental to any lighting designer. To make the process more applicable to a real world scenario we will limit ourselves to certain constraints. We will have the not uncommon case of a future client who will be communicating his visions of a scene by referring to something he had previously seen, in this case a cinematic film. We take the role of the DP (director of photography) and try to convey the client's intent in establishing the drama and mood through successful lighting. When creating our scene we will be limiting ourselves to a particular visual style inspired by that of cinematography. The technical approach will be influenced by traditional media, film and digital photography.

Having set our base for this thesis, we will start off by defining and then analyzing our visual style. Next we will take a closer look into the mood and atmosphere that we want to create. We talk about the lighting style, its different elements and explain how it can contribute in achieving the look and feel we decided on in the beginning. Having our visual framework laid out, we will jump into the physical attributes of light and shadow. This will give us the fundamental understanding to be able to recreate something believable. Because our goal is to mimic something that was shot on film rather than to just imitate human perception we will need to talk about some of the differences between the two, especially when it comes to perceiving light. We also need to talk about how digital perception will differ from the two, not alone because we are going to work digitally. Furthermore, we will talk about composition in conjunction to our process description. In the end we will briefly cover some aspects on workflow, render layers, compositing and post processing effects.

The thesis is structured in a way to give the reader information to understand the analytical break down of a visual style, to help him understand the basics of light behavior in conjunction with a digital work environment, to help him think in ways of a lighting artist and give some valuable insights on an optimized workflow.

1.1 The lighting challenge

To best demonstrate the theories and the thought processes involved, the author takes part in the *CGTalk* lighting challenge. The *CGTalk* forum is part of the well known *CGSociety* online community. The *CGTalk* lighting challenge is one of the many challenges on *CGTalk* where artists can participate to improve their own skills in various fields of digital content creation through the help and feedback of the community including many industry professionals. The *CGTalk* lighting challenge has recently been hosted by Jeremy Birn, who is currently employed as a technical director at Pixar Studios and has been responsible for lighting shots in movies such as Up, Wall-E and Ratatouille. He is the author of one of the books we will be referring to in this work.

"The Carnival" is *CGTalk's* lighting challenge number 22. The given task is to light a carnival scene and the objective is to create an image from either one of the following themes; Bright Night, Child's Fantasy, Abandoned or Tale of Horror. The scene is modeled by Dan Koniecka. It consists of various elements; a merry-go-round, a Ferris wheel, a rollercoaster, a high striker, a tent, a bench, balloons, a trash can and the ground with some rocks and a couple of flowers. There are no lights in the scene. It is missing as well any kind of shaders and textures. Generally it's encouraged for everyone to reframe the objects to achieve the wanted composition. It is also recommended to assign shaders and textures for they will affect the way light will interact with those objects. Additional objects can be imported as long as they don't take away from the original goal of the challenge, which is to focus on the lighting part.

The themes that were given on *CGTalk* can be interpreted in many ways and many different results can therefore be achieved. Taking the role of the hypothetic client, the content will be framed story wise, which in turn helps to motivate all of the visual layout decisions. The idea that came to mind was to create a juxtaposition between the setting and the mood. A carnival in general is perceived as a joyful place packed with lots of happy people. In contrary to this a more melancholic feeling was to be provoked. The storyline would be based on the concept of a little girl who visits a carnival, gets lost from her parents and ultimately finds herself alone around closing time. The choice was made to have a fusion between the two themes *Abandoned* and *Bright Night* for it seemed the most suitable considering the story.

2 Look development

Cinematography techniques work with a film's mode of organization (narrative, documentary, or avant-garde), with its mise en scene and editing, and with its sound to produce meaning in an integrated way. The most powerful uses of cinematography do more than simply display technical expertise: they provoke emotional, intellectual, and aesthetic responses. Cinematographers "speak" to the audience in visual terms, using images as expressively as writers use words. (Pramaggiore & Wallis 2008, 128.)

The primary role of the cinematographer, who commonly is known as the DP (director of photography), is the creation of the visual mood and the feel of the film. His responsibilities include all matters pertaining to photography such as lighting, exposure, composition, cleanliness, etc. (Wheeler 2005, 31–32.)

To start off, one must stress the importance of reference material. In a real life work environment the client (who might be an advertising agency or considering the case of the DP would be the director of the film) will more than often been shown images and/or clips of movies, commercials and even animations previously done. This is to narrow down the endless possibilities and to quickly nail down the general look the client might be after. (Cirkus Productions 2010.)

In the case of this thesis the visual style was to be influenced by previous cinematography. Considering the theme *Bright Night* and the setting, one could quickly determine a row of recent movies that had scenes of carnivals at night. Some of these would include *Zombieland* (Columbia Pictures, 2009), *Cirque du Freak: The Vampire's Assistant* (Universal Pictures, 2009), *Big Fish* (Columbia Pictures Corporation, 2003), the opening scenes from *The Imaginarium of Doctor Parnassus* (Infinity Features

Entertainment, 2009) and as well the classic film *Strangers on a Train* (Warner Bros. Pictures, 1951). All of them being more or less successful in their own category none of them had exactly the kind of lighting and visual style we were looking for. Nevertheless, scenes from these movies proved to be helpful in terms of reference, such as giving valuable insights on attributes of carnival lighting at night.

There was a change in approach. Instead of concentrating on movies with carnival scenes, more focus was laid on visualizing the mood and atmosphere of the story. Based on the authors mental library, suitable choices were quickly determined, with the primary choice being the movie *Blade Runner* (The Ladd Company, 1982), directed by Ridley Scott. DP was Jordan Cronenweth who was awarded with the *BAFTA Film Award* and the *Los Angeles Film Critics Association Award* for best cinematography on *Blade Runner* (imdb 2010).

2.1 Visual style

The masterful use of lights in *Blade Runner* sets it apart, creating a powerful mood and supporting the story throughout the film. *Blade Runner* can be, somewhat easily, categorized in terms of its visual style. One may refer to a genre known as *future noir*, a hybrid genre, combining *science fiction* with *neo-noir*. Neo-noir is the modern equivalent to *film noir*, using the same kind of elements, but with updated themes, contents, style and visual elements that didn't exist in the early 1940s and 1950s.

Traditionally film noir was shot in black-and-white and in its early years it was used to some extend to disguise limitations of set design in money-stripped B films. Typical stylistic characteristics of film noir portray high contrast, imbalanced lighting and a marked lack of fill light introducing much blacker shadows. Film noir prefers night-for-night shooting, deep focus and wide-angle focus lengths. Dissymmetrical mise-en-scène such as extreme low and high and oddly angled shots are not uncommon. Main characters or objects are often blocked by foreground obstructions or obscured by shadows. Light sources become part of the narrative content of shots. Most of the noir films use *low-key lighting*, which results in a *chiaroscuro* effect. (Mayer & McDonnell 2007, 71–76.)

To explain *chiaroscuro* we would need to delve farther into history where we can find links between film noir and the *German Expressionism* era of the 1920s' (image 1) which lends much of its appearance to *chiaroscuro*. *Chiaroscuro*, an Italian expression that can roughly be translated into clear-obscure, or in other words light and dark, refers to the dramatic modeling of subjects by the skillful use of light and dark. It first originated during the *Renaissance* period as a traditional painting technique and was mastered by a set of historical famous artists including Caravaggio (image 2), Rembrandt (image 3) and Vermeer (1632–1675), among others. (Larnier 2006, 12/4.)

Image 1. The Cabinet of Dr. Caligari 1920. Directed by Robert Wiene.

Image 2. The Calling of St Matthew 1599-1600. Michelangelo Merisi da Caravaggio, oil on canvas.

Freeman (2007, 110) further describes typical characteristics of *chiaroscuro*, where as the painter would have shafts of light illuminating dark scenes to draw attention to the important parts of the image. It is referred to as modeling with light, adding more and more brighter values to a dark base until a three dimensional form appears. It is creating the illusion of people and objects coming out of darkness and into light.

Image 3. The Philosopher in Meditation 1632. Rembrandt van Rijn, oil on wood.

The effects of *chiaroscuro* can be met in the world of traditional art, cinematography as well as in photography. The digital content creation platform is a natural follower. The process of digitally lighting a scene is in its own sense similar to that of a *chiaroscuro* painter. We start from total darkness and add with great forethought light after light to best demonstrate the three dimensional form of objects, their material properties, the indented focal points, depth, mood, emotion, etc. Despite similarities in approach, differences in technical execution exist. Not alone because of the notable differences between the way traditional film, digital cameras and the human eye perceive and register light. Issues like that must be taken into account when the goal is to simulate either one of these mediums. As stated, *chiaroscuro* is dominantly evident especially in film noir and as such in the neo-noir genre of films. Take a look at image 4 for a demonstration on the implementation of *chiaroscuro* in the movie *Blade Runner*.

Additionally, one might find *chiaroscuro* in other genres where low-key lighting and the distinction of light and dark areas play an essential role, but they will not be further discussed here.

Image 4. Blade Runner 1982. Chiaroscuro, painting with light.

2.2 Mood, atmosphere and drama

The primary purpose of cinematic lighting is to tell a story whereas the director takes the role of the storyteller and the DP will attempt to reveal the directors vision with the help of his lighting design. It is his job as the lighting designer to captivate the audience by emphasizing the action and setting the mood. (Calahan 1996, 13.)

The movie *Blade Runner* shows, to no surprise, a lot of film noirs typical elements to build up mood, atmosphere and drama. In addition to its high contrast, low-key lighting, Mayer & McDonnell (2007, 71–76) mention in their description on film noir, shadowy mazes, vehicle headlights, fog and mist, zigzag lines that fracture screen space, all of which are abundantly present in *Blade Runner*. The typical setting of urban wasteland and connotations of decay, moral turpitude, and despair contribute to the tone and mood, which is often characterized as being bleakly and full of cynical pessimism.

The night-for-night shooting that predominated in *Blade Runner* called for wet surfaces such as wet pavement and walls sprayed with water making it look it had just rained (image 5). In accordance with Birn (2006, 95) this is a commonly used practice in order to capture extra glints of light and reflections in those otherwise completely dark scenes.

Night-for-night shooting, is what it says it is, the filming of the movie during night time. On the opposite there is day-for-night where the film is shot during day time and the footage is made to look like it had been shot at night with the help of filters, lighting and/or post production.

Image 5. Blade Runner 1982. The wet streets serve as a natural light reflector, illuminating the otherwise dark areas in the scene.

In addition to its contribution to the overall mood, fog and mist helps to create depth in the image and among others in the case of *Blade Runner* it helped with the integration of back ground plates (image 6 & 7) such as the beautifully done matte paintings by the renowned artist Syd Mead.

Image 6. Blade Runner 1982. Fog and mist help to create atmosphere and depth.

Image 7. Blade Runner 1982. All but the foreground elements are initially 2-dimensional paintings.

Next we will take a closer look at low-key lighting and other properties of light and see how they can help establish the mood.

2.3 Lighting style

There is an infinite number of combinations of lighting properties that can be created for visual and emotional effects. To make it more accessible they have been categorized to describe lighting in terms of style. Lighting style will cover anything from the range of tones, from the darkest to the brightest highlights and grey values in between, to motivation, purpose, placement, direction, range, color, quality, quantity and intensity. Even before the viewer understands the point of the story, the lighting style will already have done its job in setting the feeling for a scene. (Calahan 1996, 25.)

> *A Film-noir lighting generally has a clear, definite rendition of textured highlight, featured middle tones, and detailed shadows. The harsh highlights are always balanced with dark shadows that have short width terminators. In essence, the film-noir look is mostly hard lighting, low-key lighting, and accent lighting with emphasis on compositional juxtaposition. (Gallardo 2001, 296–297.)*

So what exactly does account for low-key lighting? According to Yot (2010) the majority of situations we encounter will have a balance between light and shade, producing an average medium grey as demonstrated in image 8. This is what we would generally perceive as being normal.

Image 8. A roundabout in Istanbul shows an even distribution of light and dark shades.

However, our environment will present us with situations where it will shift towards either extreme of light or dark. Image 9 shows an example of that. The abundant presence of snow and fog renders the whole image into a bright extreme. Even the shadows are light due to the amount of reflected light. Scenes like that are referred to as being *high-key*. (Yot 2010.)

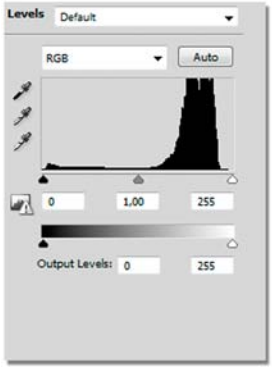

Image 9. Whistler mountain, bathing in a cloak of fog represents an example for a high-key image.

On the contrary, a scene shot at night would generally be dominated by a large amount of dark areas (image 10). It is this lack of light, especially the lack of fill light that makes a scene low-key. Similar situations might occur in interiors or even during storms. (Yot, 2010.) With the help of controlled lighting the artist can achieve either one of these scenarios for its own visual impact and to convey a specific feeling and mood. Yot (2010) continues that high-key lighting tends to look light and is in general soft and low in details. Gloman & LeTourneau (2005, 130) both state that high-key scenes are associated with happy, energetic situations. This might be the reason why it is often employed for advertising and catalog, as outlined by Larnier (2006) who adds the implementation of high-key lighting being further evident in many television sitcoms, in which it is necessary to keep a character well lit in any positions on the set.

Image 10. A night shot taken at the Bosphorus Strait. Even though the image is rather dark, a lot of details are present in the shaded areas.

Low-key lighting on the other hand creates a rather dark and somber mood (Gloman & LeTourneau 2005, 130). This is why it is often employed by the film noir genre to achieve its gritty, hard-edged cinematic effect where abstracted geometric shadows, intense lighted areas, and high-contrast drama are characteristic. Low-key-lighted objects have gradual tones on their *terminators*, a terminator being the fictive line where light and dark meets. Shadow areas can range from dark and featureless to open and detailed and are prone to have a rich, black tonality with pleasing, textured highlights. Low-key lighting can have a multitude of lights present in the scene, or as few as one light to convey its emotional impact. (Gallardo 2001, 323–324.)

To establish the mood of a scene the lighting designer will make use of exposure and lighting ratios. A lighting ratio is a figure determined by comparing the intensity of the *key light* to that of the fill. A low-key situation would call for a high key to fill inverse ratio, resulting in deeper shadows and a more textured look. (Gloman & LeTourneau 2005, 122–123). This might be confusing, but like Brooker (2008,71–73) points out the terms low-key and high-key, which are used in the physical world of lighting, mean the opposite of what one might expect. In other words, low-key scenes have a *high key-to-fill ratio*, e.g. 10:1, whereas a *low key-to-fill ratio* of e.g. 2:1 will be seen as being high-key. A high key-to-fill ratio will result in strong contrast due to the presence of dark shadows and brightly lit areas and is generally used for night scenes where the key light represents the moon or artificial light. According to Wheeler (2005, 107) the lighting ratio can be measured by metering the light of two or more surfaces in the

scene. Where there are several surfaces, each one stop brighter than the next, the amount of light reaching the film will double and therefore the lighting ratio will double as well. A stop refers to the opening of the aperture and thus will have an effect on the amount of light reaching the film.

The key light is the most dominant light in a scene, which means it will create the most defined and noticeable illumination and shadows, whose angle, density, softness and so on, will provide clues to the type and location of this source. Brooker (2008, 65) further highlights that in case of the key light representing the sun it will serve to determine the time of day. An early morning or late afternoon would see the key light placed low to form soft and long shadows. The *fill light* stands for a secondary light that is less intense than the key. This light fills in the dark areas of a subject and is often represented by bounced light. Kahrs (1996, 45) mentions in his article that without fill light on a live action set, the shadows would be too harsh and dark since the natural light in the scene is usually not enough to soften the shadows.

Brooker (2008, 71–73) emphasizes that the successful use of this ratio lies in the careful set up of lights, in order to illuminate the important visual details, using the full range of tones available by having well lit areas alongside darker ones. Dark areas should not be under lit to refrain from loosing important detail.

Lighting ratios deal specifically in terms of modeling with light involving the primary subject of the scene. However, as a general rule, low-key shots will be apparent in shots where the background is at a lower intensity compared to the background used for high-key ratios. (Gloman & LeTourneau 2005, 122–124.) Like previously mentioned, the lighting ratio alone is not the only contributing factor to determine the mood of a scene. Let us continue to have a look at additional factors.

For one there are the *qualities of light* that need to be considered including the *density* and *sharpness* of the cast shadows. Using harsh specular sources will cast dense shadows with sharp, well-defined edges and specular highlights. These situations tend to have a high contrast range. On the other hand we might have soft diffuse sources that cast transparent shadows with poorly defined edges, soft highlights and a lower contrast range. (Gloman & LeTourneau 2005, 23–25.) Other qualities of light that need to be considered include the *angle, throw* and *color* of the light (Calahan 1996, 26).

The angle of the light can give visual clues on where the light is coming from. It can tell you what time of day it is. A late afternoon sun will come from a lower angle than light in the middle of the day. (Birn 2006, 3.) Throw refers to the way in which a light's illumination is shaped or patterned. This breaking up of light can be caused by anything, from an ordinary lamp shape to clouds in the sky. In cinematography cookies are used to create shadow patterns on backdrops and/or subjects. They will be positioned in front of a light source to break up evenly flat lit areas and to create interesting pools of light and shadow. (Gloman & LeTourneau 2005, 263.) Usually, cookies are not more than simple rectangular panels of metal or wood with patterns cut out of them and placed in front of the light source. These help to give a scene a higher level of visual detail, give the viewer valuable clues about what lies outside of the scene, give clues to the location and help with setting the mood. An example would be light passing through the detailed shapes of leaves or venetian blinds (image 11) that add to the suspense and help to identify things as being three-dimensional. (Brooker 2008, 122.)

Image 11. Blade Runner 1982. Cookies - Venetian blinds.

The creative *placement* and direction of the light source can help create interesting visuals and are powerful tools for enhancing the mood. Image 12 illustrates this well. Lights directed at the subject from the back are commonly known as *backlights* or *kickers*, which are often employed as *hair lights* and also help to separate the subject from the background. Take note that placement of the light source will have an effect on light intensity, highlight intensity and highlight position as well as on shadow casting.

Image 12. Blade Runner 1982. The direction of the key light creates tension in the scene.

Lights don't always need to be on screen, but are more than often placed *off-screen* (image 13). Photographers know this just too well and make common use of this while positioning their studio lights and reflectors. To put it simple, off-screen space refers to the area that isn't visible in the shot, such as the space above the camera. When designing the set up of lights it is important to be able to imagine what might exist in the off-screen space that would be motivated by real-life light sources. (Birn 2006, 2.)

Image 13. Blade Runner 1982. The key light placed off screen.

Before adding any lights to the scene one should know their *motivation*. In other words, one finds out the cause or the original source for each of the lights in the scene. (Birn 2006, 2). Lights will be categorized as either *logical lights*, also called *practical lights*, or as *pictorial lights*. A logical light can represent any actual light source, like that of a lamp or the outside illumination outside a window (Brooker 2008, 42). If lights are motivated purely by aesthetic reasons, where the only goal is to produce a pleasing effect, they will be described as pictorial lights (Calahan 1996, 26). In general the *quantity* of logical lights should be kept small even though many lights might be used to achieve the effect of one light. There should always be a motivation behind any light source and the temptation to use one light to serve two purposes should be avoided. (Calahan 1995, 26.) Nevertheless if there is a good purpose for using a higher quantity of lights it can work rather well. Like image 14 demonstrates, the large amount of small lights on the spaceship and building helps in establishing scale and form.

Image 14. Blade Runner 1982. The quantity and size of the small lights help emphasize size .

The color of lights will help determine the color style. The color style is formed by choosing a small section of colors while keeping in mind on how they will correspond to each other. Here we often talk about color relationship. Lighting can help to accentuate or minimize individual color areas and furthermore set the color for the overall scene. (Calahan 1996, 30.) According to Brooker (2008, 24) the similarities and differences of colors in lights help determine the mood, for example neutral colors will give a more somber tone, as well reinforce the type of light source that is being represented.

Warm colors will draw the eye, especially if used subtly within a cooler palette and make them feel to be closer to the viewer, whereas cooler lighting tends to recede and as such works good for distance lighting. Warm and cool used together will complement each other, creating a vibrant and interesting scene. (Ablan 2002, 64.) Two complementary colors, when juxtaposed, will accentuate each other and will appear more intense than they would if we would place them close to an analogous color (image 15). Colors will also evoke physiological, psychological and emotional responses. (Calahan 1996, 21.)

Image 15. Blade Runner 1982. Complimentary color scheme.

There have been quite a few studies concerning our response to certain kind of colors. For example, the colors blue and green are considered to be soothing and relaxing. A scene bathed in blue light can also take on a sad feeling. A blue tinted light can further create the impression of winter or night air, and make a location or a person look colder. Many colors will have their own associations, e.g. red relating to love and passion, being an energetic and attention grabbing color. This kind of color association or *color symbolism* is not always straightforward. There are clearly differences in our emotional response to a certain color, not alone by comparing different cultures. It is also fair to note that there has been criticism towards conventional color symbolism. Angela Wright, the author of the book *Beginners Guide to Color Psychology* (Colour Affects Ltd, 1998), is one of these critics. In her words *"to say red has this effect or blue has that effect is a totally meaningless statement"* and *"there are at least a million blues, a million reds, a million yellows ... it's all a matter of which particular one you use. And, even more crucially, what you put with it. Color evokes mood, but the play between light and shade is often what helps the impact of a shot".* (3D World, June 2006.)

The color palette used in *Blade Runner* will differ between local setting and mood. Nevertheless, many of the things previously discussed are very much apparent. Outdoor scenes will have their backgrounds lit with cool shades of blue while foreground elements tend to be much warmer of tone. Some scenes will have burning barrels laid up in the foreground and some scenes make use of red lights contrasted with the blue background, leading the eye of the viewer towards the focal point in the scene (image 13). Some scenes will be bathed purely in monochromatic light like portrayed in image 16. All in all it is quite interesting to note the strongly saturated color palette apparent in many of the scenes, which works rather well considering the genre.

Image 16. Blade Runner 1982. Monochromatic color style.

3 Physical properties of light and camera

Before we go any further, we should stop for a minute and have a look at the underlying principles to really understand what is going on in the physical world. The best way to learn to light is to observe the world around us. But we need to understand what it is that we see and to be able to break it up into its components. Only then will we be able to reproduce accurate renderings of our surroundings or be able to manipulate light in a meaningful way. We should also acknowledge the differences in light perception between the human eye, film and digital.

3.1 Light behavior

Light can be seen as rays of energy that travel in multiple directions or in case of our sun they travel as linear rays (image 17). This is not quite physically accurate, but for the sun residing such a great distance away we perceive it as such. (Vickery 2007.)

As light travels further away from its source, it covers a larger area, which makes it lose its intensity to the reciprocal of the square of the distance. For example, at two meters away from the source, light will have lost a quarter of its intensity compared with its intensity at one meter from the source. This is because the area it has to cover is four times bigger. It is known as the *inverse square* law. (Brooker 2008, 17–18.)

DPs are well aware of this and in order to have their subjects evenly lit and to avoid falloff problems they position their lights at the greatest distance possible. The decreasing level of intensity can be countered by using stronger lights. (Gloman & LeTourneau 2005, 27–30.)

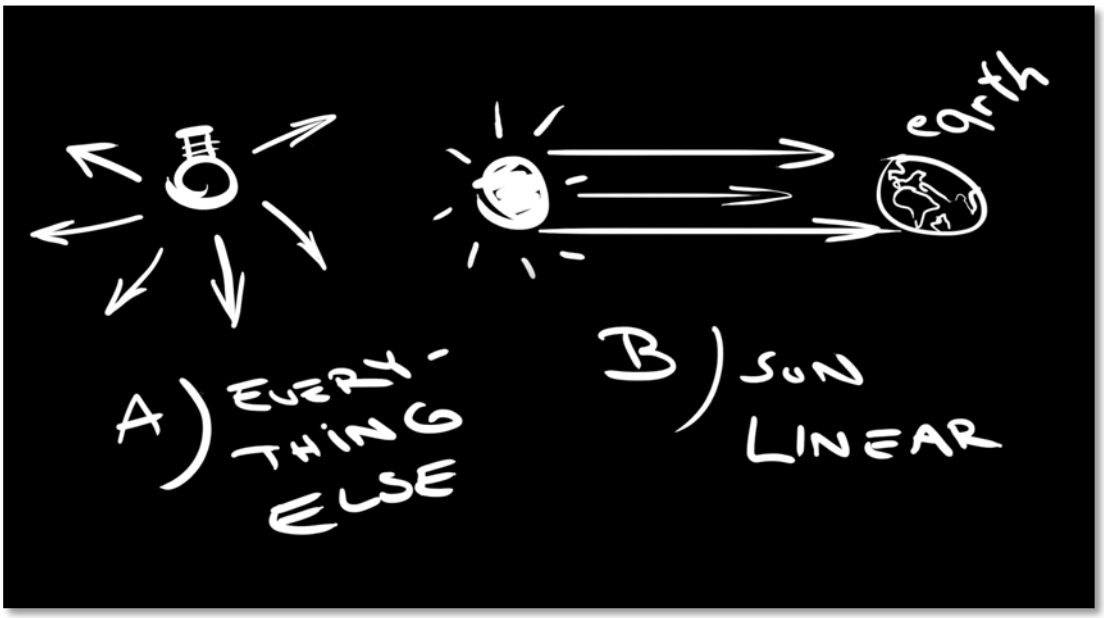

Image 17. Light rays explained.

Different substances will emit different wavelengths. On the visible spectrum (image 18) this will result in different colors of light. Light sources with longer wavelengths will be nearer to the red while shorter wavelengths to the violet end of the spectrum. Longer wavelengths are perceived as being warm and the shorter wavelengths, are perceived as being cool in color. (Gloman & Tom LeTourneau 2005, 3–5.) We will return to this when we start to talk about color temperature.

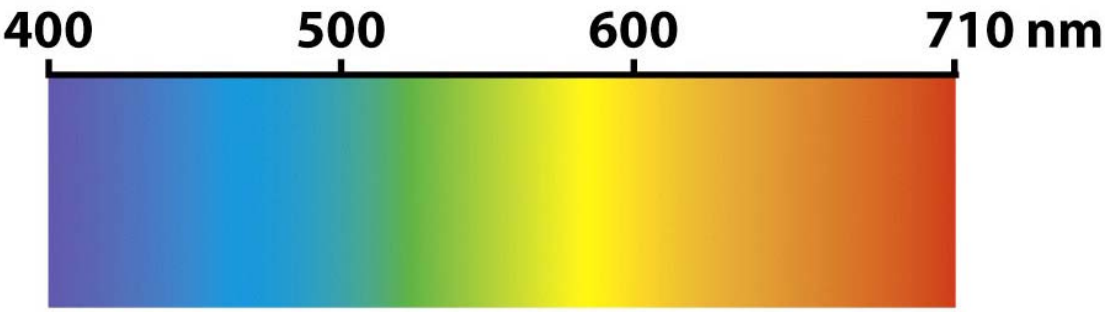

Image 18. The visible spectrum.

Light in our world does one or more of three things when hitting a surface; it reflects, refracts or is absorbed (Vickery 2007). According to Yot (2010) a white object will reflect all wavelengths equally, whereas a black object will absorb them all. *Reflection* refers to the light bouncing off a surface whereas *absorption* on the other hand will turn light into another form of energy, like e.g. heat. If white light is to hit a red surface it would reflect the red wavelength and absorb the rest. When this reflected

light hits the next surface in its path it will illuminate it with its own color and then bounce off again to the next surface in its path and so forth until it is all absorbed (image 19). This phenomenon is called *radiance* and it is a subtle but noticeable real world effect. Would it be not for this bounce light the world we live in would be a dark place.

Image 19. Radiance.

There are two kinds of reflections, *specular* and *diffuse reflections*. A specular reflection happens when all light rays reflect at an equal angle to source rays incident angel. This occurs in smooth, shiny surfaces like the perfect example being a flat mirror. Eyeglasses, polished metal, calm water, high gloss paint, moist faces, windows, and vinyl are just some of the things that can produce a specular reflection. (Gloman & LeTourneau 2005, 66–67.)

A diffuse reflection occurs in surfaces that are rough, where light rays are scattered in many different directions (image 20). It is the even reflection of light, regardless of the direction from which it came. (Gallardo 2001, 99.)

Image 20. Diffused reflection.

In most cases it will be a mix of the two like demonstrated in image 21. There are not many mirror like objects in the real world and even shiny objects are uneven to some extent, even if it is just on a microscopic level. (Vickery 2007.)

Image 21. Mix between specular and diffuse reflection.

If the source is specular, its specular reflected light will cast hard and well-defined shadows. Should the camera be on the axis of a specular reflection, a glare or hot spot will result. In film, to avoid bright hotspots, diffuse light sources and sometimes even tenting, where the subject will be completely surrounded with a translucent diffusion

material, are employed. (Gloman & LeTourneau 2005, 66–67.) In addition digital photography often uses polarizing filters to handle unwanted reflections. (Hunter, Biver & Fuqua 2007, 46). With computer graphics we might want to include these types of effects to give the scene more realism. Adding to this, overly bright highlights and overly deep shadows are results of the limits within a camera's *dynamic range*. This will be further addressed in just a moment.

Some if not most materials reflect light differently depending on the angle to our eye. Reflections tend to be stronger at a greater angle as we would see in the case of a window, where the reflecting sky will appear to have a stronger reflection at a grazing angle than when looking at it straight on (image 22). This effect is known as *Fresnel,* named after French physicist Augustin-Jean Fresnel.

Soft and fuzzy objects like clothes also appear to have an angle dependent light effect. Because of their microscopic surface shape, light is picked up in complex ways. (Vickery 2007.)

Image 22. Fresnel effect.

Refraction stands for the light that is neither absorbed nor reflected. This occurs among others in *transparent* and *translucent* objects, like for example glass, leaves and even skin. Gloman & LeTourneau (2005, 24) describe that whenever light travels from one medium to another, both of a different density, it will bend (image 23). The amount that it bends can be measured, resulting in the *index of refraction (IOR).*

Image 23. Light bending -refraction.

Like with reflection, there are different kinds of refraction. The most obvious being specular refraction as we have in the case of glass. Interesting is the effect of *caustics*. When light gets bent and continues to travel on to the next surface, the light rays will cumulate in certain areas, forming hotter spots as pictured in image 24. (Vickery 2007.)

Image 24. Caustics.

If the object is thin and its surface qualities are somewhere between transparent and opaque, like a piece of paper, a leaf or feathers of a bird, it is known as translucent. If light passes through translucent surfaces some of it is reflected and some of it will go

through and will be scattered in multiple directions (image 25). This is called *diffuse refraction*. Furthermore, diffuse refraction can occur with certain kind of thick objects, like skin, wax, clouds, fruits, and so on. These objects have a reflective layer, but are translucent enough to let some of the light pass. Often this light will bounce multiple times beneath the reflective layer, illuminating it from the inside (image 26). This is known as *sub surface scattering*. (Vickery 2007.)

Image 25. Translucency.

Image 26. Sub surface scatter.

There are as well other light phenomena in our nature, like e.g. *opalescence* that is an attribute common to opal stones and *iridescence* that we encounter in soap bubbles and certain insects for example. These are less common and will not be discussed any deeper than that.

There is another prominent effect in nature referred to as *volumetric lighting* and has to do with light particles getting scattered by air, atmosphere, fog dust, water particles among others. Here are a couple of examples. Light particles we perceive as blue color are made out of shorter wavelengths and get more easily scattered, which in terms accounts for why our atmosphere is blue and objects receding farther away will have a bluish tint to them (image 27). This is important to acknowledge in order to create the illusion of depth. Notice as well that the farther we recede the less the contrast will be. (Vickery 2007.)

Image 27. Atmospheric depth.

The fact that blue light particles scatter more easily will also result in the predominately red light during sunsets and sunrise. Light has to travel through a thicker layer of air, thus the blue light gets scattered and only the longer wavelengths will reach us. (Yot 2010.) The effect of volumetric light is even more evident in under water scenes, like pictured in image 28, giving a sense of distance and depth.

Image 28. Underwater depth.

3.2 Shadows

Shadows are just as equally important than light out of many reasons. They can often reveal things that otherwise would not be seen. (Birn, 2006 44.) They help to determine spatial relationships between objects and give visual cues to both depth and position of objects in their surroundings. They can add richness to the tones and shading of the image, tie elements together, shape the space and define the elements within it. They also improve composition in leading the eye of the viewer, obscuring the areas surrounding a focal point and framing part of an image. They help to judge where a light source is located and are able to cover large areas that would otherwise be bare. (Brooker 2008, 45–47.)

If we put it simple, shadows are the absence of light. They can appear crisp with specular light and soft with diffused light. A good example of this difference is a shadow from the sun on a clear day versus the shadow on a cloudy day. On a clear day the shadows will be relatively sharp. In contrast, the diffused light of the sky on a cloudy day will give off very soft and diffused shadows. The same principle applies to the size of the light source; the smaller the harder the shadows and vice versa and the more light sources in the scene the softer the shadows will be. In general most lights will give soft-edged shadows. On a clear day some shadows will appear comparably softer the greater the distance between shadow and the shadow casting object (image 29). (Vickery 2007.)

Image 29. Soft and hard shadows.

The closer the shadow moves to the objects the more they are being occluded and the darker the shadows will be. The same effect is noticeable in corners, cracks and crevices (image 30) where less and less diffused light will be able to leak into the shadow areas. (Vickery 2007.) When simulating this with computer graphics the term *Ambient Occlusion* evidently comes to mind. This ambient occlusion can be achieved in different ways, but usually will be rendered out as its own render pass for maximum control.

Image 30. Ambient Occlusion.

3.3 Color temperature

Differences in color temperature are measured in degrees Kelvin (°K) and are recorded on the *Kelvin Scale* (image 31) (Wheeler 2005, 120). Because different substances emit different wavelengths of light when heated to identical temperatures, a specific substance called the *blackbody* was needed to determine a standard for different color temperatures. This blackbody material is somewhat a mythical substance that neither emits nor reflects light whatsoever and if heated to certain temperatures will emit certain combinations of wavelengths resulting in different colors of the visible spectrum. For example, if the blackbody was to be heated at a temperature of 3200°K the wavelengths would lie at the yellow end of the spectrum and if heated even further will it emit additional wavelengths nearer the blue to violet spectrum. (Gloman & Tom LeTourneau 2005, 3–5.)

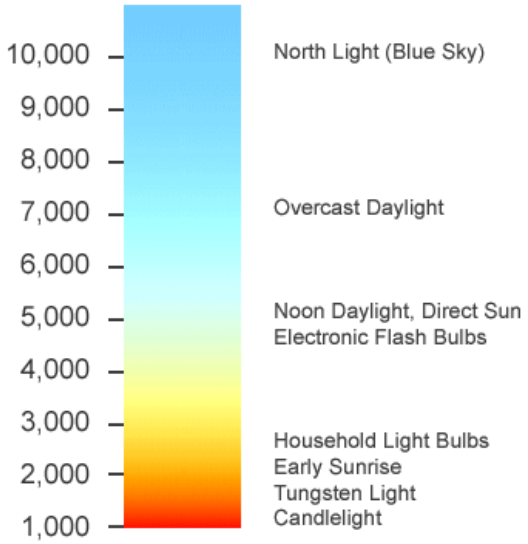

Image 31. Color Temperatures in Kelvin Scale.

The majority of different light sources that we encounter in our everyday life will have a color cast. For example, a 2k tungsten lamp that has a color temperature of 3275°K will emit light at the yellow end of the spectrum. Sun light and shadows will change their color temperature depending on the location of the sun making this a powerful tool in communicating the time of day. (Wheeler 2005, 125.) Notice that colors will be perceived by our brain in a relative rather than absolute manner. In other words, as

long as there is a vague mixture of the three primaries in the light our brain will interpret it as white. The same principle of relativity is true for light intensity which we will cover in the next part. If we moved to the far sides of the spectrum, our brain would find it more and more difficult to compensate for the shift in color temperature. In the case of candle light for example, which is located at around 1850°K, the light will appear to us reddish in tone. (Yot 2010.)

While the human eye is capable of adapting to a wide range of color temperatures, pickup chips of the camera cannot (Gloman & LeTourneau 2005, 6). On a technical standpoint, from that of a cinematographer, it is therefore vital that any light source that should appear to be neutral in the final rendition will have the same *color balance* as what the film has been designed for. Cinematograph film comes balanced in one of two color temperatures: indoor film balanced at 3200°K and outdoor film of 5600°K. In comparison, digital cameras will let you choose the *white point* much more freely. In order to change a color temperature of a given light source cinematographers often result in using filters, e.g. gels, in front of the light source, which subtract unwanted colors from the spectrum of light. One should bear in mind that this kind of subtraction will have an effect on light intensity. Film filters are used to correct the color of the light required by the film in use or to enhance the storytelling element. Film filters are catalogued by a combination of numbers and letters, e.g. 85 and 85B. (Wheeler 2005, 120–128.) Note that in addition of placing filters in front of light sources they are often used in front of the camera lens for a wide variety of reasons, like e.g. diffusion filters.

Image 32. Tungsten light becoming more yellowish in tone with daylight balanced film.

To be able to understand these technicalities becomes of even greater importance when the goal is to produce renders that should look like they would have been shot on film. We need to understand how color balance dictates which color of light will appear white when filmed, and how other light sources will be tinted correspondingly (Brooker 2008, 14).

Artistically, it is also of importance to understand the psychological and emotional effects of the color of light within a scene like we have previously discussed in chapter 2.3. An interesting fact is that the actual temperature required to achieve a given color temperature is the reverse of how we emotionally react to the color of the light emitted. (Wheeler 2005, 120.)

There is another effect apparent when it comes to color temperature. If you would go and sample image 33 with a color picker in your image editing software, you will notice the color gradually shifting according to the Kelvin Scale while leaving the hotspot of the light source. Notice how the color will get more and more saturated the more we move into the shaded areas. The greater the difference between color balance and color temperature the stronger and more saturated the tint should be. (Vickery 2009.)

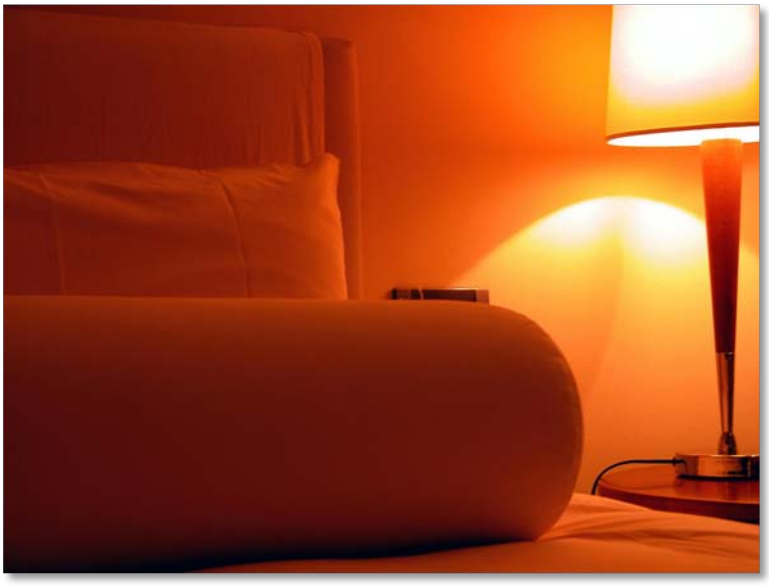

Image 33. Shifts in color temperature.

3.4 Exposure, dynamic range and gamma

When we talk about light and its intensity it is valuable to know about the concepts of *exposure* and *dynamic range*. Any respectful cinematographer and photographer, working in either traditional or digital form, will have a thorough understanding concerning these subjects. As previously mentioned, the way our eyes pick up light and color compared to a camera lens will be different. To further complicate matters, the way a digital camera registers light compared to a conventional one will have its differences as well. Why we should care will be obvious soon.

As a side note, because our brain is such a complex organ there are in fact quite a few differences in the way we perceive light compared to a camera. Gallardo (2001, 30) describes seven eye movements which we are not fully conscious of, such as *tremor*, *drift* and *flick* among others. Without going into each one of these let us pick just one example. In a dark room with a lighted cigarette as the only light source, the light will appear to be hovering and attempts to make it stationary will fail. If we fixate on it, it will appear to vibrate. Gallardo (2001, 30) names this phenomenon tremor and highlights that the perception of movement is only illusionary.

Exposure is the amount of light allowed to fall on the camera sensor/film. It will be regulated through adjustments in *shutter speed* and *aperture size*. Shutter speed is the amount of time the film will be exposed to light. The aperture size refers to the opening of the camera lens, with a larger opening allowing more light to reach the sensor. The size of the opening will be indicated by f-stop in still photography and t-stop in motion photography. (Gallardo 2001, 66–67.) Opening the aperture by 1 stop will double the amount of light reaching the sensor.

According to Freeman (2009, 58–58) the key subject of interest will usually, though not always determine the exposure. To determine the correct exposure one would first identify the key tones of a scene and from there continue to think about other important areas and if they need to be of a certain brightness. This will be of even a greater importance in scenes with high dynamic range. Freeman (2009) makes use of *tonal grids*, which are no more than a *desaturated* and *pixelated* version of your image (image 34) to analyze key tones and distribution of values in retrospect.

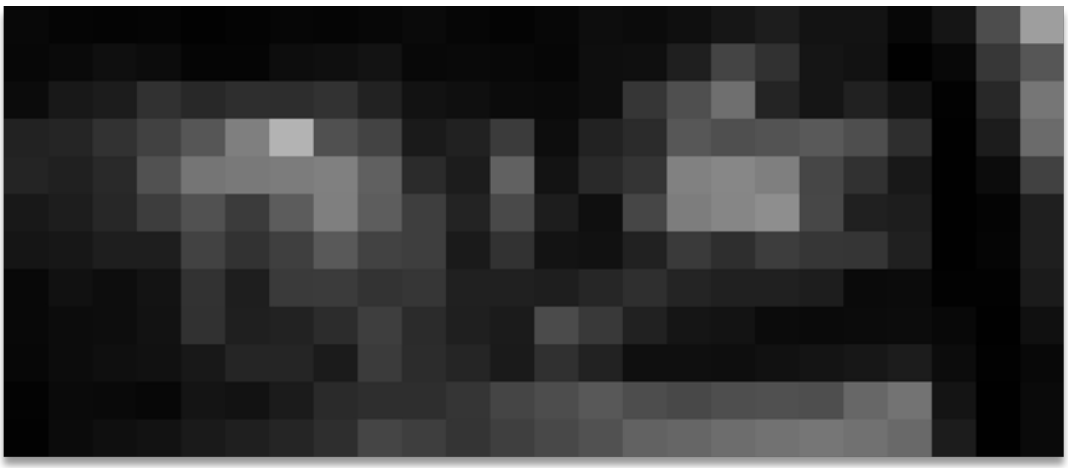

Image 34. The Carnival. Tonal grid.

Note that exposure will also have an effect on how the color is going to be picked up. Overexposure will weaken the hue, in other words make it look paler, while slight underexposure will strengthen it. How much will depend on the color. Each color will have its own ideal exposure, making it more pure and more saturated. Strong underexposure will darken the colors towards black. With the use of filters it is possible to bring colors back which were lost through exposure. (Freeman 2009, 60.)

Dynamic range refers to the amount of light information perceivable at one given time without the visual loss of detail, like e.g. highlight clipping and shadow areas that render black. There are two factors that contribute to the dynamic range. There is the light falling on and the light that is being reflected off surfaces in a scene with the first mentioned having a greater effect. A camera can perceive at one given time the amount of light information that its dynamic range allows. This is usually something between 10–11 stops. Note that visually losing detail in the highlights is far worse than in the shadows, still it happens much more frequently. The dynamic range in a scene will change according to the scale of light intensity present. For example a scene with dominantly diffused lighting like e.g. in the case of fog or an heavily overcast sky the dynamic range would be quite low. On the other extreme if we have e.g. a clear, sunny day with areas of deep shadows and brightly lit spaces, the dynamic range might be quite high. This would be even more evident, if you decided to shoot against the sun. One way to capture a high dynamic range is to use several different exposures and combine them into one single image. This is known as *HDR* or *High Dynamic Range photography*. (Freeman 2009, 32–38.) According to Wheeler (2005, 107–110) even the finest cinema screen can only reflect a limited amount of light and

in a very good cinema the difference between the darkest perceivable black and the whitest white will measure no more than 7 stops in exposure. Cinematographers will have to account for this. These limits in dynamic range became also evident when analyzing the levels of white and black pixels in a screen capture of *Blade Runner,* as pictured in image 35.

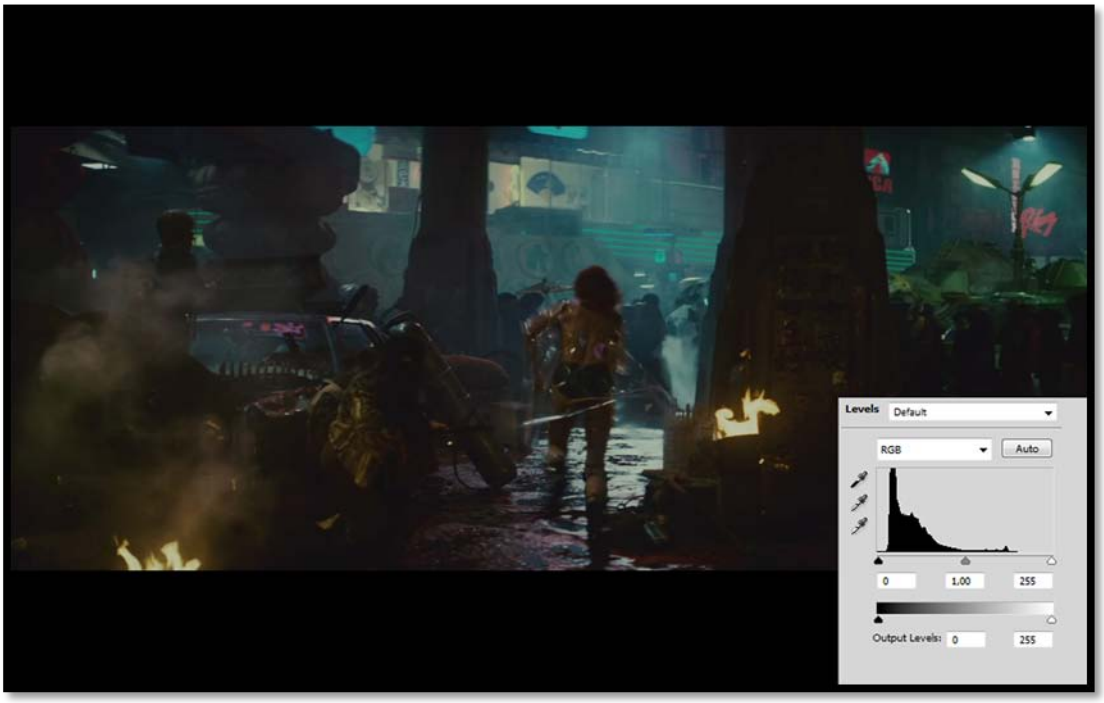

Image 35. Blade Runner 1982. Dynamic range.

According to Breidt (2009, 2), the human eye, when adapted to the current light situation, perceives a dynamic range of 100:1 at once and recognizes brightness differences of 1%. This means that we would clearly be able to see the difference between a 10W and 11W light bulb, but we would not see the same difference between a 150W and 151W light bulb. To follow up on this, Fracer (2004) explains that we perceive light intensity in a nonlinear fashion, which means we perceive relative and not absolute changes in light intensity, adapting to the overall lighting conditions around us. Most of our senses work in this nonlinear way so we are able to function in various situations without our sensory mechanism overloading.

Conventional film mimics this non-linear eye response, sampling the values of a scene *logarithmically* (image 36). With logarithmic sampling, there are more steps in the area

of the shadowed part of the scene than in the highlights, which results in the recorded values being more evenly spaced across the tonal range (Wheeler 2005, 95.)

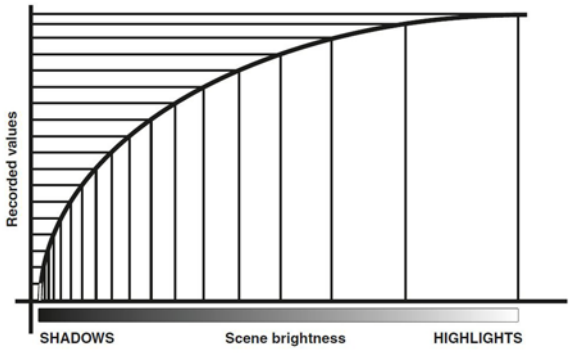

Image 36. Logarithmic sampling.

With *linear sampling* (image 37), like in the case of digital cameras, the steps of each brightness sampled are exactly the same throughout the tonal range. This results in finer steps in the highlights when compared to the shadows (Wheeler 2005, 95). Freeman (2009, 34) notes in relation to this, that in case of over-exposure, highlights will have a fairly sharp and obvious break that is different and harsher compared to that of the conventional film. Highlights in conventional film will have their tones grade gentler away, which is referred to as *roll-off*. Digitally shot footage should be later adjusted to correspond to that.

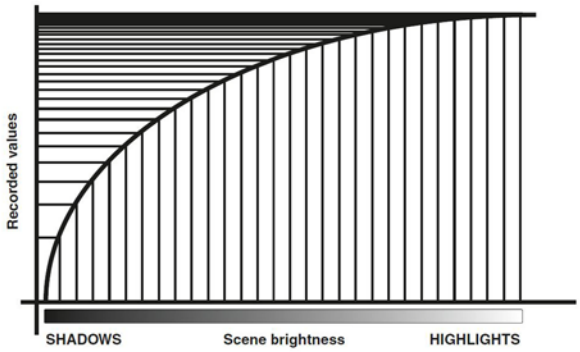

Image 37. Linear sampling.

A digital camera only counts the number of photons hitting its sensor, sampling light in a linear way, meaning that each value will represent actual light energy. Here, levels in light intensity correspond exactly to the numbers of photons captured, but in order to match the way the human eye works, a *gamma correction* curve has to be applied to

the image. Most computer screens will have that same kind of correction, which will in theory represent the correct value, making the physically linear light appear in a correct manner. The calculation of 'gamma' is as follows:

$$output_intensity = input_intensity^{(1/gamma)}$$

To make images appear consistent on a variety of output devices the sRGB color space was introduced. With sRGB a gamma of 2.2 can in general be assumed. Because of the applied gamma curve the brightness values on screen do not depend linearly on the pure RGB, which means that even the simplest of additions or multiplications of the RGB pixels can produce incorrect results. (Breidt 2009, 2–6.)

This is the reason why physically correct computer graphics will need to operate in a true linear color space with gamma correction of 1.0. This is especially true when working with global illumination or other physical correct light sources. Remember that a lot of images will be non-linear 24bit RGB formats with a 2.2 gamma curve applied to them. That is why we need to tell our graphic software, that images e.g. textures we import, will come in as non-linear to avoid having incorrect brightness. (3Ds max, 2010.)

To sum it up, when working with computer graphics, keeping your workflow linear as long as possible is of great importance. Only this way can we produce physically correct results. This will require a gamma corrected workflow and depending on the software is quite easy to set up. Finally, at the stage of output, we need to return to non-linear sRGB or similar, keeping in mind among other things how light intensity is effected by technicalities such as exposure and dynamic range.

4 The lighting process

According to Calahan (1996, 12) there are six lighting objectives which are important fundamentals when it comes to good lighting design; directing the viewers eye, enhancing mood, atmosphere and drama, creating depth, conveying time of day and season, revealing character personality and situation and complementing composition. Let us have a look at how to apply these.

The primary step was to decide on the size of the final image. To stay true with the movie *Blade Runner* the same aspect ratio as used in the film was chosen. The original cut of *Blade Runner* was short at the more unconventional 2.20:1 aspect ratio. To be more consistent with the majority of today's films and our reference material it was decided to use the *2.35:1 anamorphic* wide format apparent in the remastered Director Cut Version. These *Cinemascope* and *Panavision* processes use an anamorphic lens to squeeze the images horizontally onto a 35mm film at a ratio of 2:1. The image will later be stretched back to its intended size. (Wright 2008, 209–210.)

The following step was to set up the camera. While focal lengths between 35mm and 55mm create fairly neutral perception, shorter focal lengths can cover a wider angle and thus are useful for enhancing large vistas, landscapes and so on. They make everything appear larger and strongly accentuate perspective lines (3D world, May 2006). Wide-angle lenses greatly enhance the sense of depth. The lens distortion that occurs in wide angle lenses causes stretching in the corners, pulling the viewer into the scene by wrapping the image around him. They will also make the scene appear to extend beyond the frame. (Freeman 2007, 100.) Referring to our initial description in the visual style, pre visualization sketches and quick test set ups in a 3D software, it came apparent that a wide angle stock lens at around 24mm would work nicely. Also the distortion of the perspective would help enhance the desired mood.

4.1 Composition

Lighting also has a purpose in terms of composition: to tell us exactly where the focal point of a shot is – to enhance this whilst not drawing attention to anything that's of lesser importance (Brooker 2008, 307).

We will start off by deciding what our *focal point* for the image will be. Every strong composition needs to have a focal point – a dominant object providing fulcrum to the rest of the image, while everything else should try to complement or frame this element (Tonge 2006, 82). Calahan (1996, 14) notes that it is the lighting designer's job to direct the viewer in deciding the quantity, placement and intensities of the focal points. Care is to be taken not to overwhelm the viewer with too much of a good thing. Even though an image can have more than one focal point it is the job of the lighting designer to keep the audience's attention on the main focal point. Referring to the story it was clear that our primary focal point would be that of the little girl and every decision on composition would be made to complement that fact.

There are many fundamental theories on composition a lighting designer should understand with the primary objective to show the viewer where to look. Following are a list of important compositional elements that were considered in creating the final composition for the piece. When talking about composition we evidently will find ourselves confronted with the *Gestalt theory*. According to Freeman (2007, 38) the *Gestalt theory* underlines that the whole is greater than the sum of its parts. In other words that in viewing an entire scene or image the mind will take sudden leaps from recognizing the individual elements to understand the scene in its entirety. The *Gestalt theory* offers valid explanations about the complex process of perception.

Calahan (1996, 13–14) breaks these principles down into unity and harmony, emphasis, balance, scale and proportion, repetition and rhythm, line and contour, shape, value, color, compositional mood and transitions. Let us take a closer look at some of these. In accordance with these principles our perception works as follows.

Our brain tends to group objects that are close to each other into a larger unit which share properties such as size, shape, color or value. Negative or empty spaces will also be organized and grouped. Elements are divided into planes, such as foreground and background planes. Patterns or objects that continue in one direction, are perceived as being continuous, even though they might be interrupted by another pattern. One should note that too much *unity* can in fact be boring and if there is nothing to visually resolve, the eye will quickly lose interest. On the other hand it can help to unify a disorganized and busy composition by minimizing certain areas that would else distract the viewer and by emphasizing areas that should get attention. Brooker (2008, 325) elaborates on that by saying that too much emphasis on one extreme can lead to a too clearly defined image, which the viewer will imminently understand but find dull, but on the other extreme there is danger in not understanding it quickly enough and he will move on.

Contrast is also a great tool for emphasizing parts of the image. Contrast can be achieved with shape, size, color, texture, brightness and even motion. Contrast in value is the easiest to spot and therefore should be taken into careful consideration when deciding on light intensity. (Calahan 1996, 14.)

According to Tonge (2006, 83), *tangents*, meaning the area where two edges touch each other, should be avoided, because they create problems in reading the intersecting shapes. Calahan (1996, 14) states that the careful use of tangents, in a way that the edges don't touch, but come close to each other can in fact produce a strong point of emphasis and visual tension. Tangents were planned out extra carefully while creating the composition for the scene. Isolation of an object will call attention to itself. To still make it feel part of the image an edge of a shadow is a way to link it back to the group. We will see how this was implemented later on. A subtle form of emphasis can also be achieved by using perspective angles and other edges to lead the eye. A busy shape among many simple ones, or vice versa, will attract attention as do easy recognizable objects such as the human form.

Balance is very important for achieving a pleasant composition. An entire image can be off-balance, making the viewer uncomfortable. This can be a desired effect if it manages to enhance the mood of the story. Visual balance works in two ways, horizontally and vertically. When we talk about *horizontal balance* we refer to the level of the horizon within an image. It is a good idea to keep the horizon off middle.

(Calahan 1996, 16.) Having it lower or higher will both have their function. In this project the horizon was set rather low. This was done to have the character visibly low in the shot for it would make her appear more submissive. The low-angle shot would help to make her feel more isolated by exaggerating the size of the environment and architectural spaces. (Brooker 2008, 321–323.)

With our preliminary compositional set up we came up with something similar to image 38. You will see that the texturing process had already started and in addition a few more 3D models were created. The little girl you can see sitting on the bench was later created in 3D. Though there is no lighting visible at this point the author had created a mental image on possible lighting decisions and written down notes he would later consult.

Image 38. The Carnival. Early test on possible composition and camera settings.

The second aspect of balance is the *vertical balance* of which the easiest recognizable form would be that of the symmetrical balance. Here both sides of the image would mirror each other. (Calahan 1996, 14.) The more common kind of balance is *asymmetrical balance*. If you would picture your image as a scale with the central point being some sort of pivot then a large form located a certain distance from the central point of the image will need to be balanced out by positioning an equivalent force on to the opposite half of the image. (Brooker 2008, 324.) This balancing act can be done with a multitude of different combinations, for example by using values, colors, shapes, textures, positioning, perceived physical weight of objects, and scale and proportion.

(Calahan 1996, 17–19.) Brooker (2008, 313) notes that larger objects attract us more, but if only the smaller object is fully within the frame, this is reversed. This was kept in mind when placing most of the larger objects in the scene. Here as well, if you later consult the final composition, you notice that the large objects on one side of the image had been balanced out by a larger amount of smaller objects on the other side. These same principles apply to the set up of the different lights. The chosen camera roll will also play its part in balancing the scale.

Freeman (2007, 48) highlights another nature of composition, that of *rhythm*. Where there are several elements in a scene, their arrangement may under special conditions create rhythm. Repetition is a necessary ingredient of rhythm but does not guarantee it. Rhythm has more to do with how the eye scans the image as much as repetition. Brooker (2008, 321) elaborates on this by saying that repetition of shape and color can not only bring about a sense of harmony to an image, but can also set up routes through the image, which the eye will naturally follow. If there should be only two repeated elements, then the path is a linear one and our attention will be drawn to objects located along it.

Even though a strong sense of rhythm is not necessarily created, there was a conscious effort in creating the feeling of depth with the use of repeating elements. Image 39 demonstrates some of these elements in their isolated form, whereas especially the light sources will draw attention to themselves and as such greatly contribute to the composition.

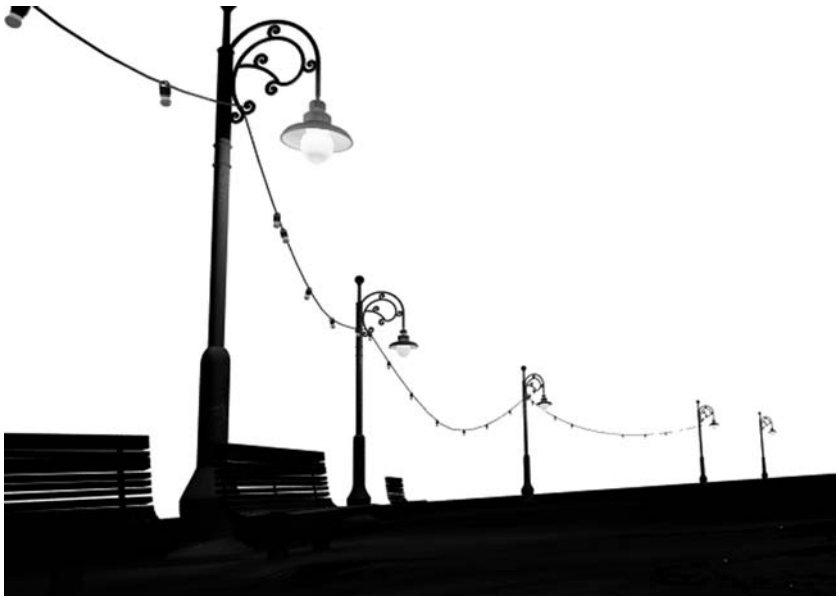

Image 39. The Carnival. Repeating elements.

Note that in addition to the streetlamps, the chain of light bulbs and benches, there were other elements in the final version of the scene such as the row of similar shaped tents, trees and even the rollercoaster with its continuous pattern that were laid out in a way to further enhance the illusion of depth.

Edges that are carefully placed and emphasized can help in leading the viewer through the composition. These may include among others linear elements, the angle of a shadow or the highlighting of an edge. These lines don't always have to be obvious, but rather can be implied by positioning a series of points whereas the eye will make the connection. (Calahan 1996, 21.) Take the example of the streetlamps in the scene. Even without the chain of light bulbs these lamps when lit will automatically help guide the viewer through the scene. Calahan (1996, 21) continues to say that a line doesn't always need to be physically visible, but rather is felt as a mental connection that exists between two elements. This is what we call a *psychic line*. This was implemented, by having the girl look into a certain direction, as though she would be looking at something or someone lying out of the frame. Horizontal lines can imply stability, vertical lines imply motion and diagonal lines imply dynamic motion and depth. To build on tension and volatility a slight camera roll was employed. As Brooker (2008, 321) states , this is a common technique used, where all horizontal and vertical lines are set at a slightly more dynamic angle giving the shot an uneasy look and placing objects to look somewhat unbalanced.

When planning your composition one should look out for how *negative spaces* in an image are shaped and positioned around the *positive spaces*. According to Calahan (1996) negative spaces are not necessarily areas devoid of detail, but areas that don’t catch the audience’s attention. A lighting artist needs to balance between the incorporation of separate elements into an integrated whole, while at the same time drawing out certain elements in order to make the image immediately identifiable.

As Calahan (1996, 22–23) points out contrast in value and color will have a strong effect on our composition. Contrast in value will provide spatial cues for depth perception, having greater contrast advance in to the foreground while other areas recede. The creators of *Blade Runner* knew this just too well. And like we earlier discussed they used a lot of fog which helped them minimize contrast in the background and create the illusion of depth. We will use this to our advantage as well.

Framing is sometimes useful, especially in a complex composition in order to add cohesion and help draw the viewer into the picture and hold him there. Framing can be achieved through shapes and strong silhouettes to help guide the eye to areas of interest such as the focal point. (Tonge 2006, 83.) In the scene "The Carnival" a good use was made of this principle. Especially the tree in the foreground and its cast shadow really help frame and direct the eye. We finally arrive at our composition as pictured in image 40 and as you can see we have used a lot of the principles discussed.

Image 40. The Carnival. Final Composition.

4.2 Color script

A color script can be a valuable tool and it is recommended to do at least a couple of thumbnails, meaning tiny sketches of your scene to see how the colors work with each other and as a whole. One does not need to be the greatest painter to do these and neither is one restricted to do them digitally. Pixar Animation Studios always create astounding color scripts (image 41) for each scene in their animation giving them a quick and efficient overview on how color schemes contribute to the mood. One is able to comprehend the whole movie just by looking through these 3x4 inch small thumbnails.

Image 41. Pixar Animation Studios. Color script from the movie Up.

It is always good to come up with a color scheme early in the process. Though that should not mean that one needs to get too rigidly attached, but leave room for later improvisation (3D World, June 2006).

Important when working on color scripts is the ability to shift your brain to think only in color. What that means is to forget about all of the details and only think in terms of color, color relationships, color temperature, value, saturation, contrast and of course color psychology. This is why it is important to keep your thumbnails small while working on them and just add large areas. This has the advantage of being able to quickly experiment on different color schemes without getting too attached to what you are doing. More than often these small sketchy images will provide enough information to keep on working or to communicate with your coworkers. In some cases though, if working for a client, you would feel the need to work on them a little further. Color scripts are also a good way to come up with new ideas for your image.

Image 42. The Carnival. Color scripts.

4.3 Light set-up

Like mentioned in the introduction, every type of project will call for their own lighting solution. In the end it will all come down in finding a balance between quality and speed. Speed referring to how fast a solution can be set up and primarily how fast it will render. To know which lights to use in what situation will come with experience. The rendering engine you choose will affect your lighting choices, possibilities and the end result. The goal is to keep this from being none software specific as much as possible. There might be some parts that will be software related. Nevertheless, many of the things mentioned here are applicable in the majority of different 3D software, higher end renderers and compositing software. Some things might have different names in different software. This will by no means be a step by step explanation on what lights to use and how to set them up, but rather an insight on different choices that were taken and the reasons why. For your information, this project was completed in *3Ds Max* and rendered using *mental ray*. Postproduction was done using *Adobe After Effects* and *Adobe Photoshop*. No further software was used.

Knowing that it was going to be a still image, decisions were made that compromising rendering times in terms of quality would be an option. All in all the lighting setup was pretty straightforward. It is better to keep the set up as simple as possible in order to avoid causing distraction, but like discussed earlier, help in leading the eye of the viewer to areas of interest, compliment on composition, enhance mood and atmosphere and create the illusion of depth. When placing your lights it is a good idea to handle each individual light separately. Like we mentioned with *chiaroscuro* the process of lighting a scene is the process of modeling with light. It is therefore important to have all of your objects and lights carefully named and preferably have them distributed into specific layers, which makes selecting and deselecting, hiding and unhiding, activating and deactivating objects, lights and shadows a fluent and continuous process. This way you can easily see how each light in your scene will contribute to the overall lighting solution. A further tip might be to temporarily change the color cast of each light to a fully saturated color to see more clearly the parts in the scene it will affect.

The scene would be shot at night and it was obvious that all of the light sources functioning as practical lights would consist of artificial lighting. It is here we need to mention that all practical lights in the scene, meaning we hereby exclude all of the pictorial lights used, have their settings primarily adjusted to correspond in terms of intensity and color temperature with their real world equivalent. For example, in the case of the street lamp, an Internet search provided correct data to use and an incandescent light bulb of e.g. 120W would be set at 120W. This was not always 100 % the case, but it gives us a good starting point and keeps us from running into surprises in the end. The same would need to apply for every other setting as well. This should by no means be too restrictive in terms of artistic freedom, unless the goal is to achieve photographic reality, but rather helps us in making predictable changes and imitate real world occurrences that will make the end result look much more believable. Furthermore, all of the practical lights will have their fall-off set in accordance to the inverse square law. Note as well, that for this to work correctly your scene will have to be set up with physical correct values.

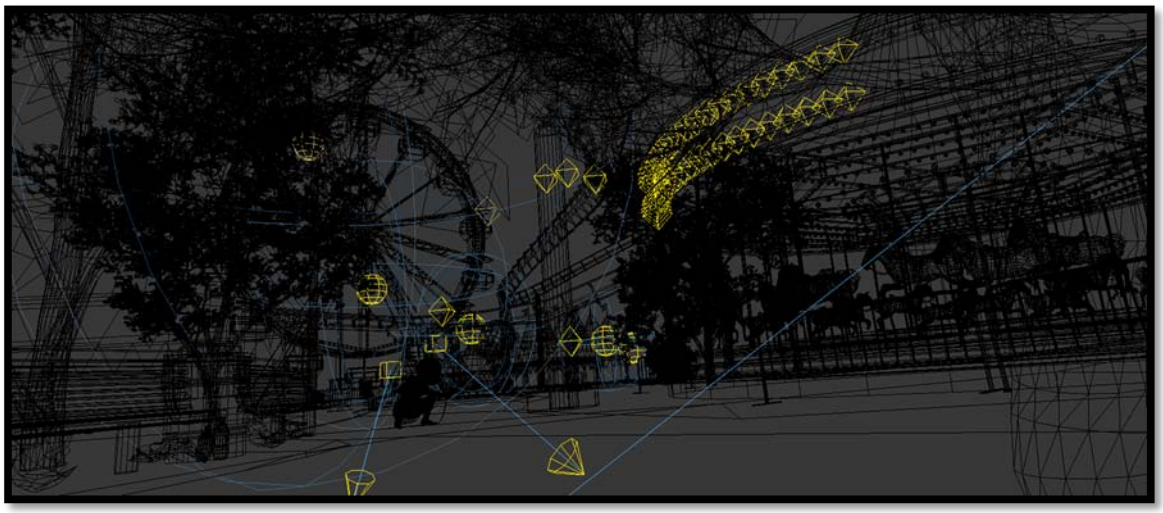

Image 43. The Carnival. Light setup.

The first decision that was to be made was on the position of the key light. Already before settling on the composition the mind was made up that the primary key light would be visible in the scene and represented by one of the streetlamps. Compared to the rest of the streetlamps it was only the first streetlamp that was set to cast shadows. Rendering shadows is one of the most render intensive things and thus it was decided to only use shadows where it was absolutely necessary. According to Brooker 2008, 165) most streetlights use sodium, which appears to have a yellow-

orange tint to it. The same settings were applied to the initial setup. It was after we made changes to the overall color balance and after the color grading process that they received their cool white color.

The primary fill light was an off-screen light, not visible on screen, coming from the right side of the scene. The intention was to create the illusion that the set would extent further away than visible in the scene. Secondly it should act as the motivation for the girl to look into that direction, as if there would be something of interest, something we can't see. There was also the idea of a shadow coming from the tree, hitting the ground to help with the composition and framing of the shot.

Image 44. The Carnival. Key and fill lights.

Careful attention was paid to how the shadow would hit the ground and that in fact it would get softer the farther it moved from the trunk. A nice side effect was the pattern it created on one of the benches. This fill light didn't work as much as a true fill light then it did for motivating the direction of the fill lights used. There was an additional directional spotlight used to serve as a fill light aimed and confined to the girl that was much easier to control. Another spotlight with a warmer color was setup in the back of the girl, simulating bounced light coming from the light of the streetlamp after hitting the ground. Additionally there were a couple of lights especially designed to only create highlights in the eyes of the girl and on the balloon. Another bounce light was directed at the tree in the front to better help reveal its shape.

Image 45. The Carnival. Early test render of the little girl.

The merry-go-round with all its nice detail was the second focal point in the scene. This is why it got the second most attention. The light bulbs on the inside of the roof were set up with a self-illuminating material that would be able to illuminate its surroundings when rendering with mental ray in conjunction with *Final Gather*. According to the 3Ds Max help file (2010), Final gather is a technique for estimating global illumination, whereas *Global Illumination* enhances the realism in rendered images by simulating all light inter reflection effects in a scene. This would include the effect of *color bleeding,* in other words *radiance*, which is the effect we have already discussed in chapter 3.1.

The bulbs were assigned two different color temperatures to add variation and some of the bulbs were left turned off as if they would be broken. For the outer lights on the merry-go-round a more creative approach was chosen. After some reference study it became obvious that carnival lights have a typical light distribution to them (image 46). Light distribution refers to the way light is distributed from a light source (Brooker 2008, 39).

Image 46. The Carnival. Light distribution.

This can be achieved in a multitude of ways. For one, when using mental ray, there are *photometric lights* that behave in a physical correct way. They offer, among others, settings for light distribution. Here, it is possible to load photometric data files, known as *IES* (Illuminating Engineering Society) files directly into your setup. These files are provided by a multitude of light fixture manufacturers and are easily obtained through searching the Internet. In addition to light distribution they also contain information on light intensity. Photometric lights will respond the most accurately of all available lights, however they can be quite render intensive. Bearing in mind the amount of lights that would be needed for the merry-go-round, it was decided to fake the light distribution. In short, the choice was made to use standard, non shadow casting lights and use a hand painted projection map to simulate light distribution. A projection map works the same way as e.g. a data projector in real life, where the light source projects an image onto the surface it illuminates. This is a great way to cheat a lot of different things that otherwise would be very time consuming to render. After initial tests a close enough result had been achieved in mimicking the light distribution (image 47). This solution had almost no effect on render times and thus might be an especially good solution when lighting for animation. Here as well, with reference to *Blade Runner*, different colors for different lights were chosen. Furthermore, additional backlight, coming off-screen, was set up behind the merry-go-round which was added to better help shape it out and to further enhance the shapes of the horses. The Ferris wheel and the chain of light bulbs followed the same principle as the light bulbs inside the merry-go-round with a slight difference. Because these were so to speak tinted lights they would have a gradient map assigned in their self-illumination slot.

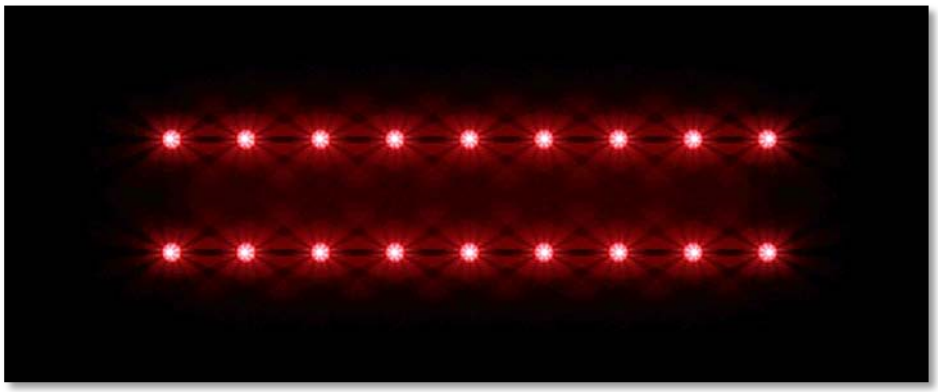

Image 47. The Carnival. merry-go-round light distribution test.

There was one more light setup and that concerned the large pole of the rollercoaster splitting the image in two. There were three lights set up so they would simulate the specular reflections coming from the outer lights of the merry-go-round. This was an idea inspired by a scene from *Blade Runner* as pictured in image 48. The same pole was lit by an additional light source that would only cast the shadow pattern of the foliage from the tree on the left hand side. This was done to break up the evenly lit pole and better unify the image as a whole, making the pole feel integrated and tying it all together. The technique used was similar to that of the light distribution in case of the merry-go-round and serves as an example of the 'throw' quality of light and how to successfully apply the cookie principle we earlier discussed.

Image 48. Blade Runner. Inspiration material.

4.4 Rendering

Rendering can be a very time consuming and costly process. There is nothing more frustrating than having to wait hours before your final image is rendered only to notice there are problems in the scene, like having a light set at too high an intensity or a light that by mistake is left turned off. The more complicated the scene the more likely things go wrong in a way not even post processing will fix. To avoid this problem it is crucial to have a lot of dummy renders. This usually means rendering out your scene with much lower quality settings and resolution compared to the final output. If a scene doesn't look right at a low resolution it will not look any better once blown up to its full scale.

When rendering it is crucial to have the exposure settings set up accordingly so your renderings will show up in a physical correct way. With mental ray you have the ability to enable MR photographic exposure control that corresponds to the real world equivalent of a camera. You will find settings on shutter speed, aperture, film speed and white balance among others (image 49).

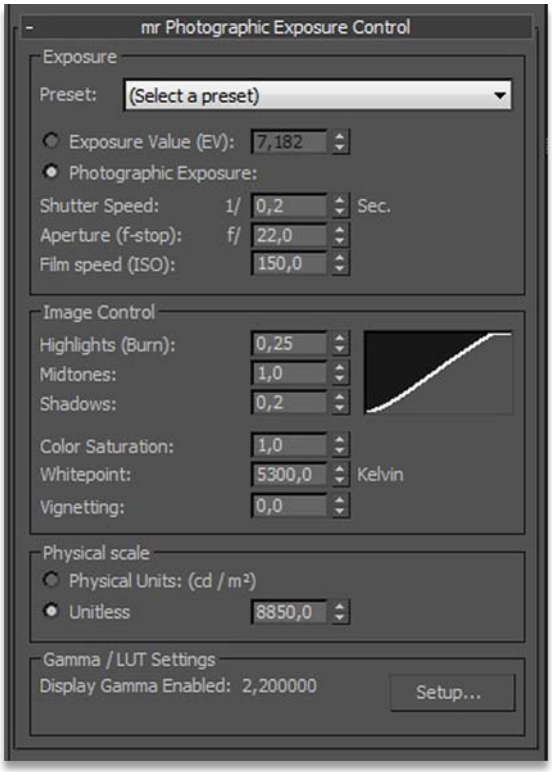

Image 49. Exposure Control.

If you are working with Mental Ray, you have the possibility to generate your Final Gather (FG) map before your final render (Patton 2008). This can be very useful. Note that the following is based on the author's own observations. One way to work with that, would be to generate a low version of your FG map first. This will give you a rough, but quick estimate on your lighting solution and possible areas that might cause problems will show up. Indeed, when everything looks to be fairly in order one might still want to double check any important areas in the scene by confining the renderer to render specific regions. Rendering smaller parts of your scene will help to quickly see how those areas will look in the final render and corrections can be made if necessary. The next step would be to generate your final version of the FG map with optimized settings and with the final output resolution and save it to a file. This will keep you from having to recalculate the FG map every time. Note that if you are going to make drastic changes in your light setup you might need to recalculate the FG solution. Nevertheless, at least when working in 3Ds Max, changes in camera position will not destroy your FG solution, but calculations will be added to previous ones which can save you a tremendous amount of time. Another useful implementation of this technique is the ability to render out selected objects in separate passes and still be able to have FG working for you.

When talking about passes, it is of great benefit to have a workflow where all of the various elements in the scene are split up into their individual elements to later have full control over them in post production. One useful way to separate your objects is to assign different *object IDs* to each one. When using the *OpenEXR* file format, as such was the case here, it will let you include all the different channels such as *object IDs, material IDs, zdepth* channel and so on, into one single render. To further explain this, if for example objectIDs have been assigned, it will be possible to isolate any scene objects in your compositing software and do color correction and/or other effects that will only apply to that given object in the scene. OpenEXR is a high dynamic-range (HDR) image file format developed by Industrial Light & Magic for use in computer imaging applications. The features of the OpenEXR file format include a higher dynamic range and color precision than existing 8- and 10-bit image file formats. It is a format that supports up to 32-bit, *floating point* images, with additional channel buffers, and modern, lossless compression technologies. (Bracy 2004.)

Working with OpenEXR is known as *linear workflow* and the advantage is profound. The 32-bit floating point images can store a far larger amount in light information

compared to the more conventional 8-bit per channel images, which leaves us with a lot more possibilities when doing our tone mapping as a separate process. To make this more accessible, you could compare it in a way to a digital camera and shooting in RAW compared to jpeg. The other factor is simple mathematical. Like we previously discussed in chapter 3.4 8-bit per channel images will have a gamma curve applied to them while floating point images will remain linear. This means that all our changes to light intensity will have correct results. Note that the mental ray exposure control becomes obsolete when tone mapping in external applications and it might be a good idea to turn it off when doing your final render.

When adding to this all the different render elements such as separate passes for diffuse, diffuse illumination, direct illumination, ambient occlusion, reflection, specularity, transparency, translucency and self-illumination among others, one can see how this can quickly add up and get really confusing. To handle this complexity a solid workflow has to be established. Here again, it needs to be stressed that careful naming of files, objects, lights and layers are necessary in all accounts throughout the project.

The final project was rendered out at a resolution of 1828x727 pixels. Even though the final output would be smaller in size it is good practice to render out images at about one third larger than the intended size.

5 Post production

Having rendered out all of our separate layers, passes and elements it was time to import them into Adobe After Effects. The choice for tone mapping the project in Adobe After Effects was partly based on personal preferences and the possibility to use certain plug-ins. As of 3Ds Max 2011, the node based compositing tool *Toxic* is included, capable of fully handling OpenEXR files and offering a well equipped alternative to the post processing process. According to the 3Dsmax help file the proper math for compositing layers using the *Arch & Design* materials, with the A&D materials being mental rays propriety materials that attempt to be physically accurate and have high dynamic range output, in mental ray is as follows:

*Beauty = Level Diffuse * (Raw Diffuse Direct Illumination + (Raw Diffuse Indirect Illumination * Raw Ambient Occlusion)) + Level Specular * Raw Specular + Level Reflections * Raw Reflections + Level Transparency * Raw Transparency + Level Translucency * Raw Translucency + Self Illumination*

If we would take this into After Effects we get something similar as presented in image 50. Note that this image represents only half of the truth. Each layer marked with "[]" are in fact pre-composited layers and some of them might hold up to 10 different layers themselves.

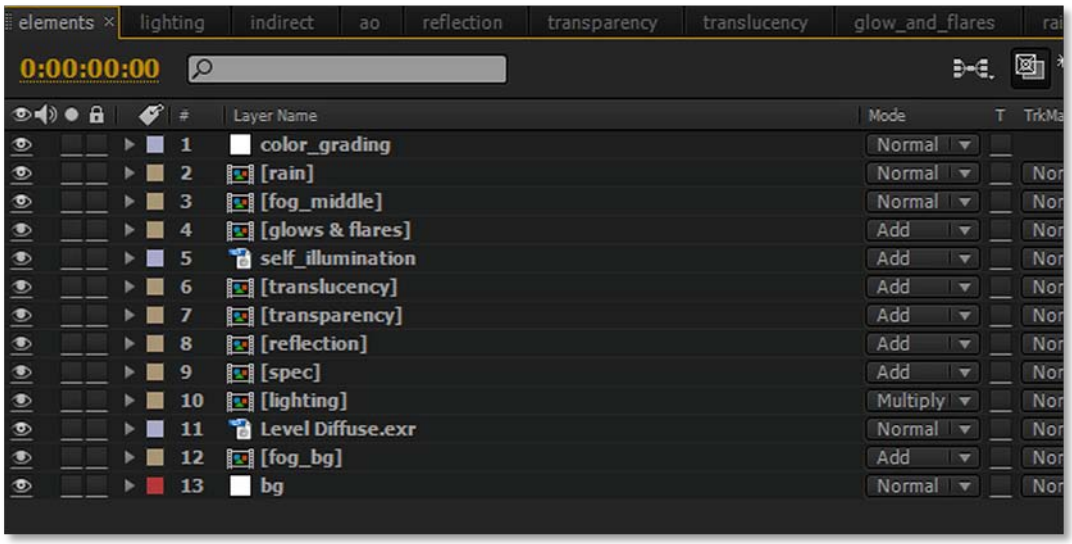

Image 50. After Effects. Compositing.

With our project set up, the first step was to do the tone mapping. The original render was fairly dark and most of the details were barely visible. This was due to the fact that we previously disabled the exposure control. Nevertheless, because we were working with 32-bit float, all of the information was there. It was just up to us to retrieve it. The specularity and reflections were tweaked, sometimes on isolated objects. Exposure settings were adjusted, keeping in mind that we wanted a dark but rich image and shaded areas would need to preserve their details. During the color grading process the decision was made to depart from our original color scripts. This was done purely out of subjective reasons. In addition the highlights were compressed in order to have the image resemble more that of a scene out of a film. Remember us talking about films having a limited dynamic range.

5.1 Post effects

In order to make an image look even more convincible, it is common practice when working with CG (computer graphics), to add artifacts and errors that occur when shooting on film. These artifacts can be traced back to properties of camera lenses, film stock or even lab processing. Manufactures constantly try to correct these errors. Interestingly enough, the CG artist will try to do the opposite. It is very important to note that here as well, subtlety is the key and overuse of any of these will only make the product look more artificial than it already is.

One of the things beginning artists often find themselves using is *lens flare*. This has almost become some sort of a cliché in the realms of computer graphics, because of its frequent use. Freeman (209, 142) describes lens flares being caused by light interacting with the surfaces of the lens elements and internal structures of the lens barrel, such as the aperture diaphragm and barrel walls. Lens flares are the direct result of shooting towards the light and will especially be apparent when having a wide aperture and full exposure. They will vary in size and shapes and are easily simulated in a variety of imaging software packages.

According to Birn (2006, 181) in many cases one can avoid the use of lens flares and instead simulate *halation*. Halation is the glow and occasional streaks of light visible around bright light sources and is caused by light reflecting off the back of the film plane of a camera or the scattering through the film itself. Widescreen movies, that are

filmed in anamorphic film format, will have their light scattered on the film while the image is squashed. After the image is stretched back to its intended size so does the halation making glows around lights appear as elongated bars of streaks (image 51) instead of being circular. Freeman (2009, 144) further states that most kinds of flare will involve over-exposure and for the halation to work well it needs to grade smoothly into the clipped area.

Image 51. Aliens 1986. Anamorphic halation.

In the scene "The Carnival" halation was added using two different approaches. For one, a lens shader was used in conjunction with Mental Ray that enabled the user to render halation as a separate render pass to be later composited in AE (Adobe After Effects). The second approach was to use filters directly in AE.

In addition a subtle *DOF* (depth of field) effect was added using the z-depth channel we in cooperated in our OpenEXR. Wheeler (2005, 135) describes the DOF being the distance between the nearest and the farthest subjects from the lens that will appear to look sharp. In other words, an image that is exactly at the distance the lens is focused at, will be in focus at the film plane. Instead of using the conventional blur producing unnatural results we made use of a plug-in to mimic real life lens blur more accurately and furthermore simulate the effect of *bokeh* (image 52).

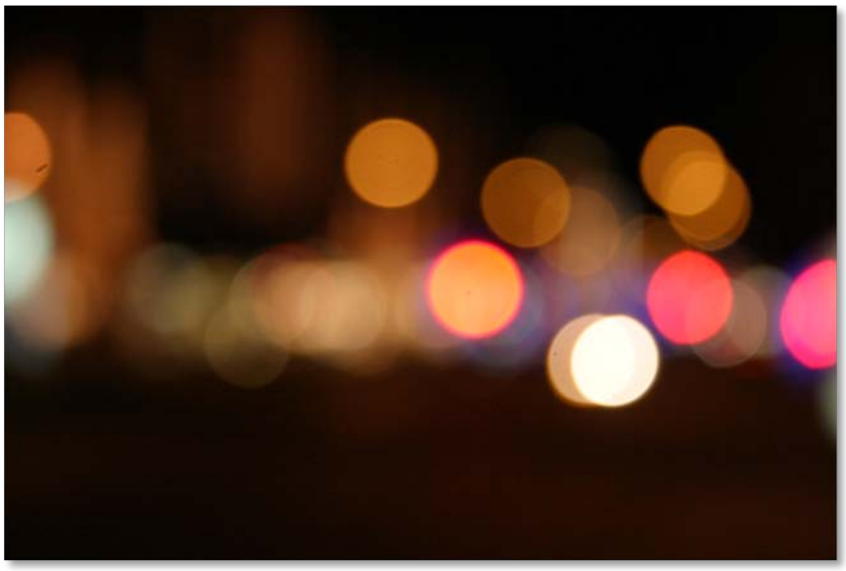

Image 52. Bokeh.

As of 3Ds Max 2011 a DOF lens shader is included that will give you the possibility to include bokeh in your renders. For earlier versions one should take a look at *bo_exposure_photographic.mi* (Hot Chip 2007), a free lens shader with a lot of useful and render time saving features. Now as mentioned, this was indeed a very subtle effect. The amount of DOF and bokeh is always related to the focal length you have chosen.

As a final touch fog, clouds and rain were added with the help of masks and filters. The image was then exported into Adobe Photoshop to do a little touch up, among other things painting little drops of water, adding some dirt and grass and so on. It was at this stage that the little girl was repainted (image 53). It felt like she would be better integrated into the overall scene with her head tilted to the other side. Fixing her head in 3D and rendering her as an isolated object would have been an option. However, keeping in mind that the end product was going to be a still image and the focal point would remain rather small in the final resolution, over-paint seemed to be a reasonable approach in order to save time.

Image 53. The Carnival. Little girl, over-paint.

As a last addition in order to break up some of the "CG:ness" a subtle grain was added to the overall image. According to Wheeler (2005, 71) grain is the texture we see in a print that appears as a texture not associated with the original scene. *Film grain* depends on the emulsion of stock film and its appearance will differ accordingly. Fast, highly sensitive film emulsion will normally appear grainy. On the other hand, a fine-grained film emulsion has more often a high resolution and poor sensitivity. Advances in technology have narrowed the gap between the two.

There are a variety of ways to achieve film grain in post production. For a more convincing result Adobe After Effects, at least as of version CS4, will have a collection of presets that let you choose the kind of film grain in relation to the film stock you intend to simulate. Depending on the look you are after it might be advisable to keep this effect to a minimum.

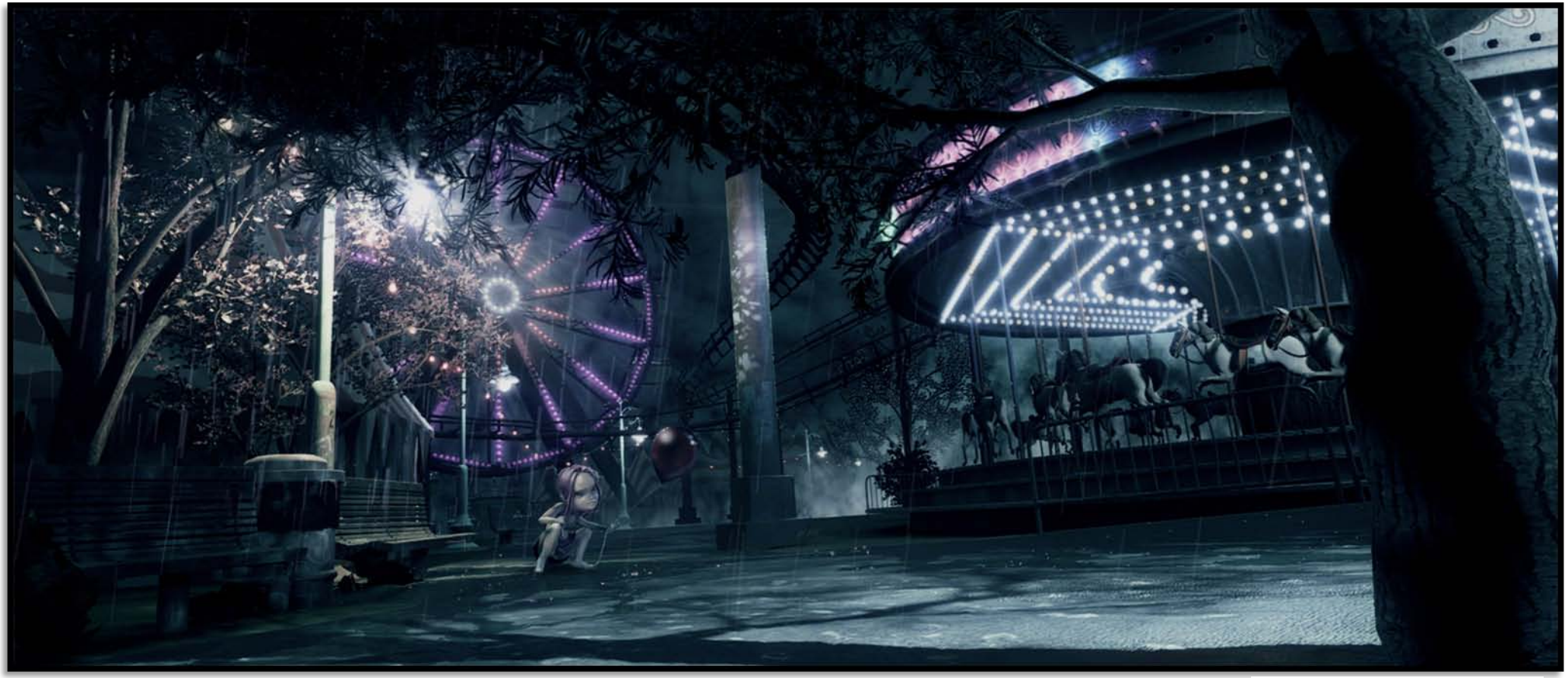

Image 54. The Carnival. Final image.

6 Conclusion

In this thesis we have managed to cover most of the things we intended to. As we moved along we noticed that there were a lot of additional subjects that were of relevance and needed to be mentioned. The saying "the more you know the less you do" might fit here perfectly. As we have seen, light can be a powerful tool in many aspects. Anyone working in visual arts, no matter what field; modeling, animation, painting, drawing or film, should at least be somewhat familiar with the subject. Light can also help in hiding flaws in your 3D models and it can direct the viewer to this special area you have spent a lot of time and effort on. Another aspect that needs to be highlighted one more time are the advantages of linear workflow. It is definitely worth learning, because it can save you a lot of time. If you had to go back into your 3D software every time you would need to readjust your lighting, manually make changes to individual lights and re-render elements, it would take a conceivable amount of time. Especially render times are your worst enemy when on a strict deadline. Linear workflow gives much more freedom to do changes at a later stage during the post process.

The feedback on the final image has been positive. It was chosen among eleven others as qualified "winners" and is currently posted on Jeremy Birn's homepage (www.3drender.com). Some of the initial ideas didn't make it into the final product and some unexpected issues were encountered. A personal advice would be to stay as flexible as possible in your approach. Even though you are working on a 3D scene, it doesn't necessarily mean that you are confined in using 3D tools only. Rendering times were quite high which called for a more optimized workflow and at times it was rather difficult to work within the scene, causing some frustration. Reasons for that lay among others in the high poly count of the foliage and in the use of somewhat outdated hardware. This is where we could really benefit from object layers and object isolation modes. It was quite interesting that without intent the author's own style became such apparent. In the beginning there might have been slightly different ideas on where to take this image. Still, one shouldn't be confined too much to original ideas and sketches, but rather use them as a tool to assist your creative process.

Hopefully you found this thesis to be helpful. If you want to learn more on the subject and get a hands on approach say hi in the upcoming CGTalk lighting challenges. They are a wonderful opportunity to get valuable feedback on your work and to improve your skills.

Resources:

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