Photorealistic Rendering with V-ray

Anja Rackwitz
Markus Sterner
15 June 2007

Thesis, 10 points, C level
Computer Science

Creative Programming
Supervisor/Examiner: Sharon A Lazenby
Co-examiner: Julia Åhlén
photorealistic rendering with v-ray

What makes an image photorealistic and how to pinpoint and understand how our mind interprets different elements in an image conditions? It is proposed that the phrase "imperfect makes perfect" is the key for the photorealistic goal in today’s 3D. There is a review of all the elements for the creation of one perfect image, such as Global Illumination, Anti-Aliasing and also a basic review of photography, how a scene is set up, color temperature and the nature of the real light. To put different theories to a test, the common three dimensional software 3D Studio Max was used with the V-Ray renderer. On a field trip to IKEA communications, we were assigned a project of a room scene containing a kitchen, with a finished scene model. A kitchen was created and experimented to reach a result where there is no visible difference between a computer generated image and the photography. Our result was not what we had hoped for due to many problems with our scene. We ourselves see this as a first step toward a scientific explanation to photorealism and what makes something photorealistic.

Keywords: 3ds max, V-ray renderer, Photorealism, Photorealistic rendering, light, lighting, color, Global Illumination, Anti-Aliasing, photography, perception psychology, IKEA of Communication AB.

Anja Rackwitz  
Markus Sterner

Email:  
anja.rackwitz@t-online.de  
mullvard_84@hotmail.com

Institutionen för matematik,  
natur- och datavetenskap  
Högskolan i Gävle

Department of Mathematics,  
Natural and Computer Science  
University of Gävle

S-801 76 Gävle, Sweden
ACKNOWLEDGEMENTS

First, we would like to thank Magoo as the company for taking us in under their wings as interns. It has been a great and very educational experience for both of us and without that experience none of this work would be viable. We were also assigned a great thesis on their account and lending us both knowledge and equipment to realize this research project.

Not only were we able to use their facilities, we also joined the CEO of Magoo, Anders, on a trip to Älmhult to visit the IKEA design studio. This leads us to our other great support, Bengt Larsson, who has helped us with both the structure of the work and provided us with a huge insight in the 3D and photography business. Other helpful people at IKEA that need mentioning are Sören Larsson and Maria Forsman, who helped us with the means to create our kitchen scene. Last but definitely not least, we also would like to extend our thanks to Sharon Lazenby, our supervisor and tutor for this course at the University of Gävle for supporting us during this period.
Figure 1: The original photography (1)
**TABLE OF CONTENTS**

Acknowledgements ........................................................................................................................................3

1 Introduction ...........................................................................................................................................7

1.1 Hypothesis .........................................................................................................................................7

1.2 Anticipated problems ......................................................................................................................7

1.3 Expected results ..............................................................................................................................8

1.4 Limitations .......................................................................................................................................8

1.5 Method .............................................................................................................................................8

1.5.1 Method of choice ..........................................................................................................................8

1.5.2 Method description ......................................................................................................................9

1.6 Questions at issue ............................................................................................................................9

1.7 Purpose of the research ...................................................................................................................9

1.8 Target group ....................................................................................................................................9

1.9 Earlier research on the subject .........................................................................................................9

1.10 Disposition of the paper ................................................................................................................10

1.11 Typographical conventions ........................................................................................................10

2 Theoretical framework .....................................................................................................................11

2.1 Color and Light – Realism in Reality .............................................................................................11

2.1.1 The Nature of Real Light .............................................................................................................11

2.1.2 How does color emit from objects? ............................................................................................12

2.1.3 Color models – striving for realism ............................................................................................13

2.1.4 Color profiles – sRGB vs. Adobe RGB ......................................................................................14

2.1.5 Color temperature ......................................................................................................................15

2.2 Rendering – Virtual Realism ........................................................................................................16

2.2.1 The V-ray Renderer ....................................................................................................................16

2.2.2 Global Illumination .....................................................................................................................16

2.2.3 Anti-Aliasing Filters ....................................................................................................................18

2.2.4 Bump Mapping ..........................................................................................................................20

2.2.5 Displacement Mapping ...............................................................................................................20

2.2.6 High dynamic range imaging ..................................................................................................20

3 Visual Response ................................................................................................................................22

3.1 Photography as a starting point .....................................................................................................22

3.1.1 Realism .......................................................................................................................................22

3.1.2 Making the picture alive – three main forces ...........................................................................26

3.2 Perception Psychology ...................................................................................................................30

3.2.1 Relative Brightness ....................................................................................................................30

3.2.2 Color interpretation ....................................................................................................................30

3.2.3 Shapes and forms .......................................................................................................................31

4 Process ................................................................................................................................................33

4.1 Study Excursion Description ........................................................................................................33
4.2 Choosing a room........................................................................................................................................... 33
4.3 Image Analysis ............................................................................................................................................... 34
  4.3.1 Analyzing the original image .................................................................................................................. 34
  4.3.2 Things to change in the 3D scene (Figure 22) ....................................................................................... 37
  4.3.3 Postproduction in Photoshop .............................................................................................................. 40
4.4 Experiment ................................................................................................................................................... 42
4.5 Results ........................................................................................................................................................ 43
  4.5.1 Final image ............................................................................................................................................. 43
4.6 Discussion ..................................................................................................................................................... 45
  5.1 Useful means when creating photorealistic CGI .................................................................................... 45
  5.2 Pro & Contra photography ....................................................................................................................... 45
  5.3 Pro & Contra 3D ....................................................................................................................................... 46
  5.4 What could have been made better, and how? ......................................................................................... 47
      5.4.1 The image ........................................................................................................................................... 47
  5.5 Further research on the topic .................................................................................................................... 47
5.6 Conclusion ................................................................................................................................................... 48
7 References ....................................................................................................................................................... 49
  7.1 Persons ......................................................................................................................................................... 50
  7.2 Websites ...................................................................................................................................................... 50
  7.3 Reports ......................................................................................................................................................... 50
  7.4 Books ........................................................................................................................................................... 51
  7.5 Table of figures .......................................................................................................................................... 52
1 INTRODUCTION

Photorealism is one the largest and most commonly used areas in the field of 3D. In the beginning of the 21-century, the Swedish furniture company IKEA started to digitally store all of their products in a large database. In the beginning of this project all the work was done by photographers. However, IKEA realized the potential and the opportunities of this new growing market simply named 3D. They started looking for exceptional artists in this specific branch when they realized that their own field of artists would not cut it. They found the company Magoo Studios this obvious step leads immediately to the research question. How does IKEA want their pictures created by Magoo Studios and what makes the IKEA products to look realistic in a 3D world? The picture will not only have to appear realistically, but also give the impression that it was taken by a real photographer with IKEA’s entire theoretical framework as background.

Today, the pictures created with various 3D tools are not similar enough to pictures taken by a real photographer in a studio instead of in the 3D room of computer software. For this primary reason, this research is needed and very valuable for a lot of individuals with the same interest.

In this research, the main objective is to reveal the secrets of professional photographers and implement their knowledge of their trade into 3D software. A field trip to IKEA’s main photo studio will be conducted to ascertain this information. Most of the testing will be accomplished at Magoo Studios office to find out how to reach this goal of a photorealistic picture and developing a procedure that can be repeated time after time with different models, materials and lights.

1.1 Hypothesis

Realism today is within the 3D creation, where not being able to tell the difference between two images, one made by a camera and one rendered by a 3D program. When you ask someone in the 3D business what they think will make a picture more realistic, the answer is almost every time: “irregularity, dirt, grain” or “imperfect makes perfect,” this conclusion is the same one as the one being brought to the test in this paper.

However, hypothetically we believe it is true.

1.2 Anticipated problems

Photography and photo-realism can in many ways be a very subjective issue. This is one problem that can become quite large and totally unmanageable. However, in most cases, this problem will not occur when it comes to a realistic feeling in an image, but in other cases it is not realism when an image is supposed to mediate a feeling, where different viewers may have different interpretations. Other problems that are in the photorealism area are the obvious problem with lighting contra material attributes. Different materials have different attributes that work proficient with other lights,
which leads to different lighting setups for different materials, even though it is the same model. For example, one very dull metallic material is created in the first scene A. To achieve the wanted effect on the material, a Fresnel value has been introduced which demands a lot more intensity on the lights. Fresnel provides a more realistic falloff to the reflections, and also facing the observer’s point of view. Therefore, if we use the same lights in scene B, where all materials are much brighter and do not have as in this case a Fresnel value, everything will become too bright. Accordingly, every scene demands different lighting attention even though it has the same geometry. Of course, even different geometry will require a different light setup.

Typically, the observer can define what does not appear realistic. This means that the human eye is familiar with a realistic surrounding, and detects even small divergences very easy. That is why a synthetic photorealistic image has to be very close to reality in some areas where the eye is very “sensitive.”

1.3 Expected results

Because of the fact that this paper has brought up an enormous subject, no absolute revealing truth will be declared, although hopefully some pieces to the vast puzzle that is called photorealism will be put in the right places. However, this research will summarize certain knowledge, maybe not of a global scale, nevertheless further information to help 3D professionals with their every day work.

1.4 Limitations

Since this research will be conducted in the service of Magoo Studios, it will only focus on the software that Magoo has at its disposal. The software consists of the 3D program Autodesk 3D Studio Max, which includes V-ray renderer. No comparison of the V-ray renderer to other renderers such as mental ray will be carried out, because it is not in the area of the research where photorealism will be researched. However, this paper will describe various problems and limitations of the V-ray renderer for realistic imagery. For that reason, this research is purely artistically, no mathematical issues or similarity will be researched within this thesis, as well as there will be no animation sequence and troubleshooting with avoiding flicker with any of the tools that we will use. Therefore, this research project is aimed toward Magoo, IKEA, and their guideline framework, where only still images will be processed and researched.

1.5 Method

When our research is to reach a result that is to be interpreted by the eyes, it is doubtful that one might not call it artistic. Just because of that fact our research, as a lot of other research in the computer science area, will be done in the manner of a constructive research, where the conclusions are based on empirical facts.

1.5.1 Method of choice

Since this project is aimed with the line of work that Magoo Studios are conducting, so will this paper, although at somewhat wider span. The main research will be a scene taken by a photograph and then that photo (Figure 1 on page 4) will be mimed as similar as possible with the help of the 3D software at our disposal. What might be a problem with this method is if the photograph taken by the camera is not exactly like the way IKEA wants it, the research conducted may be heading in a very wrong direction.
1.5.2 Method description

The first step would be the recreation of the photographed scene with models and textures, placing all the objects in the right places and so forth. The big challenge is then to light the scene in the same way the photographer did, with the goal to achieve the exact same picture at the end or an even better result.

1.6 Questions at issue

How should a computer generated image be created to look photorealistic?
What tools are appropriate to use to reach the wanted result?
What are the limitations, problems, pros and cons for both photography and 3D?

1.7 Purpose of the research

In today’s society, 3D graphics is a rapidly growing market that mostly is established in television commercials, computer, console games, and special effects in movies. A raising demand for realistic 3D footage thereby is advancing. This leads directly to our research, which is mainly created in the service of Magoo Studios, however also for individuals who strive for a photorealistic result in the 3D graphics area. Due to the scale of this research and the huge topic of photorealism, we have narrowed it down accordingly to the limitation captions. We will focus on the creation of photorealistic furniture and home scenes, while trying to make them as realistic as possible with the time and tools we have at our disposal. With this task at hand every successive step in the right direction will be documented. In short, we will make a home environment and/or single furniture look attractive (a must have feeling), as well as appearing realistic.

1.8 Target group

Basically, this paper is written as a foundation stone for people working with photorealistic rendering. It summarizes ideas and knowledge about photography, light and color theory, and 3D, especially the rendering process. It can be useful for everyone who is interested in one of these topics.

1.9 Earlier research on the subject

In today’s creation of action and science fiction movies or television series, there is a very excessive amount of computer generated images used for the creation of either things that are impossible to make with raw materials or scenes that would be too expensive to create without the aid of computer generated imagery (CGI). Since every new effect or creation is different from the other, each one of these new effects requires some form of research to get the desired result. However, every tool that is used on the other hand has been developed by some sort of researcher; therefore one might ask them, what makes something a research? For example, the creation of the motion picture “Lord of the rings” directed and produced by Peter Jackson, huge armies were moving across middle earth. How could such a scene be made without CGI? To hire 10,000 extras and coordinate them, would be an almost impossible task and the cost would be tremendous. Instead, a studio of 3D individuals was hired and accomplished that task most admirably.
The goal of this research is to mimic a photograph taken by a real camera, which one cannot rule out the fact of all previous inquiries and discoveries produced in the world of photography. All 3D has photography influences. Therefore to exclude the history of photography research would be inevitable. To dig deeper into the category of photography physics is always to be found. Because of this, a lot of physical terms are used in today’s 3D graphics.

The issue that has been brought forth in this discussion is the fact that all of this has been already created on various levels, but it is also up to one another what you would call research. Though it might be hard to believe that anyone previous has made a research on how IKEA wants their CGI’s appearance. The art director at IKEA might have some clear ideas or have made some drafts of them. However, they might not have looked deeper into the subject of why they want a particular look, in a specific way or have a characteristic feel.

1.10 Disposition of the paper

“Photorealism in images can be seen as the art to find a balance and harmony between scientific structures and pure artistic work,” says Bengt Larsson. “To success with this combination we sometimes call a feeling for images,” directly translated from Swedish’s “bildkänsla” (2). That is why this research is divided with the scientific part about the theoretical background, whereas the artistic side of our work will be discussed thereafter in visual response. The practical work, described in part 3, consists of cloning a photo of one of IKEA’s kitchen in 3D (Figure 1).

1.11 Typographical conventions

Many of the translated technical words are taken from a wide-ranging dictionary on the Internet. (3)

The software 3D Studio Max abbreviates to 3ds Max.

Three-dimensional abbreviates to 3D.

High dynamic range imaging will be shorted to HDRI.

Computer generated imagery to CGI
2 THEORETICAL FRAMEWORK

The process of creating synthetic images that are indistinguishable from real photographs is called realistic image synthesis (4). To achieve photorealism with a computer is a challenging task and requires understanding of the fundamental physics and psychophysics of light. How does light interact with materials and surfaces in the real world? What happens when light rays enter the human eye?

In the 3D-world there are many mathematical algorithms that simulate this process. Light is bouncing around from a light source through the scene into the camera. Depending on the object’s materials the light creates reflections and refraction on surfaces or is scattering in a medium. There are several important terms and tools of photorealism such as v-ray, global illumination, ray tracing, anti-aliasing, and so forth. Since they are keystones in this research a thorough examination of these subjects is in order.

2.1 Color and Light – Realism in Reality

2.1.1 The Nature of Real Light

The Greeks have founded the base of today’s current theories of light. They believed that light was emanating from the eye and touching the objects that we see. Even first theories about reflection and refraction were described by the Greek mathematician Euclid, the astronomer Cleomedes and Ptolemy, mathematician, geographer, astronomer, and astrologer. New breakthroughs in understanding light were merely completed at great distances until the 17th century with Christian Huygens (1629-1695), a Dutch mathematician, astronomer and physicist and Isaac Newton (1642-1727), the regarded English mathematician, physicist, astronomer, natural philosopher and alchemist. Many breakthroughs in mechanic, gravitation, and optic were made especially by Newton. However, since their findings, light was interpreted as a wave motion and could be separated out into its color spectrum with a prism. Newton also published a theory that light particles are emitted from light sources and move in straight lines until they impinge on a surface. Thomas Young (1773-1829) and August Fresnel (1788-1827) studied the effects of polarization and diffraction. That gained credence to the wave theory refined by James Maxwell (1831-1879), who defined the light as an electromagnetic wave. In the early 20th century, Albert Einstein modernized the whole physical world, among others by introducing the use of photons to describe the photoelectric effect; the process whereby electrons are liberated from a metallic material which is rayed with electromagnetic radiation such as x-ray, ultraviolet light or daylight. The photon is the elementary particle in light explaining the electro-magnetic effects.
Today, the physics of light is defined as a combination of several different models such as ray optics, wave optics, electromagnetic optics, and photon optics. In computer graphics, ray optics is the fundamental and almost solely model for light calculation. (4) (5)

![Electromagnetic Spectrum](image)

Figure 2: The electromagnetic spectrum, which encompasses the visible region of light for the human eye

2.1.2 How does color emit from objects?

The process of seeing is much more complex than taking a picture with a photo camera. The picture on the retina in the eye is not only the reflection of the reality. This picture needs to convert to electrical impulses and to be interpreted by the brain.

Light falls onto an object’s surface. The light is absorbed, refracted or reflected in different wave lengths from the surface depending on what kind of material the object consists of. Then this certain wave length enters the eye and reaches the retina. The human eye has a tri-chromatic color sense, which means three different types of cone cells for red, green and blue light that that turns the incoming information to neuronal signals. If all the forms of cones are stimulated equally, the color is white. Black is seen, if none of them responds. This combination offers to apprehend the light’s wave lengths from 400 nm to 780 nm of the color spectrum (Figure 2, Figure 3). For human beings, this color spectrum is continuing and means that they can apprehend every color and light, but ultraviolet and infrared light. Some animals have this ability, for example bees. They are sensitive for ultraviolet light for everything but the red frequencies. The bees see red as grey tones.

Therefore, color can be defined as both subjective (what we see on an object’s surface), and even objective as the certain wave length that has been reflected from the object’s surface. (6) (7)

![The Visible Spectrum](image)

Figure 3: This image shows the visible spectrum of white light
2.1.3 Color models – striving for realism

The observer’s color impression is subjective. Everyone apprehends different colors. The present-day living is characterized by all thinkable forms of images in media. There are both printed media like papers, books, magazines, posters, catalogues, etc and non-printed media such as the web, film, computer graphics in video games, computer games, presentations, advertising and much more. To produce photorealistic images, the reproduction of the original will, appear exactly the same in an ideal case. The process for the majority of every reproduction for screen or print is digital today. This requires technically that all equipment display the colors in the exact same way, practically this is not possible.

The difference between printed or non-printed presents the main problem. Prints can only absorb or reflect a certain wave length (subtractive color mix with cyan, magenta, yellow and black), while screens of any kind are working with an adaptive mix of light (phosphors). The imagination in the ideal case is for example a monitor can display the equal copy of a picture with its color and intensity. As soon as the light in the room changes to dark, the original picture looses contrast and intensity, while the image on the screen appears to be brighter. The opposite happens when light meets the screen and the contrast nearly disappears. The human power of seeing is very adaptive and adjusts such variance in contrasts, color, intensity etc.

Even equipment working with the same technology can heavily distinguish themselves. These differences are often based on the equipment construction and functionality. A monitor uses phosphors to produce colors. A scanner or digital cameras has sensitive light sensors to capture data. Printer’s colors are generated by different pigments of CMYK color model. For example working with colored pictures with a scanner, a monitor, and a printer without using the same Color Management System (CMS) involves great discrepancies of color validity. Therefore, every device is delivered with its own machine profile, which has to be compatible with others, following the International Color Consortium (ICC) standard. Every machine working with the image should use the same color profile and even the same color model, as long as possible. With every conversion from one gamut to another (for example RGB to CMYK) some color information will be lost, because of their different color amount. (6)

Printers can only work with the CMYK color model, which is smaller than the RGB color model. That creates some problems for some colors are not printable. They have to be converted to an equivalent CMYK color mix. It appears always some divergence, especially luminous colors. Very bright white tones or very dark black tones are complicated to print. This is about up to 3-4 % color in white or more 95% of black. The printers cannot display this minimal amount of color and a sharp edge appears. Therefore, IKEA sets a limit to 247 for white (maximum 255) and 10 for black while working in the RGB mode. This limit has to be observed especially for border regions to prevent the object from floating out into the white background. Smaller regions like highlights in reflections are granted exception.
2.1.4 Color profiles – sRGB vs. Adobe RGB

The human eye can apprehend a color spectrum as represented in the CIE \( xy \) chromaticity diagram (Figure 4). This spectrum is much larger than any color profile. A color with three RGB values has also to be associated with a color profile like sRGB or Adobe RGB as two of the most common representatives. sRGB was created in cooperation by Hewlett-Packard and Microsoft Cooperation for certain use on LCD and CRT monitors, digital cameras, scanners and printers. If properly calibrated, they can nearly produce all colors in the sRGB’s color gamut (color space). The sRGB’s gamut is the smallest one and therefore limited for more demanding outputs such as professional photo prints. Working with Adobe RGB offers a wider gamut especially for green tones as shown below (Figure 4). However, due to the fact that those colors cannot be displayed on usual screens, this profile demands better and more expansive equipment. Assigning the sRGB profile to an image with the Adobe RGB profile could result in loosing color information. (8) Rendered images, delivered by 3ds Max, are untagged. Their color spectrum closely resembles the sRGB gamut with its color structure. “Therefore we can handle them in a fairly predictable way.” (2)

![Diagram showing the sRGB and Adobe RGB color gamuts](image)

*Figure 4: This image shows the sRGB gamut (the small) and the Adobe RGB gamut, both placed in the CIE 1931 color space chromaticity diagram. The outer curved boundary represents the spectral colors, with the light’s wavelength measured in nanometers.*
2.1.5 Color temperature

Principally every object reflects a certain wave length, but not the idealized black body which absorbs any kind of light. A light source’s color temperature meters the temperature that a black body has while lighting it with different lights. The color temperature is measured in Kelvin as in some examples in the table below (Table 1).

**Common Color Temperatures**

<table>
<thead>
<tr>
<th>Source</th>
<th>°K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Candle flame</td>
<td>1900</td>
</tr>
<tr>
<td>Sunlight: sunset or sunrise</td>
<td>2000</td>
</tr>
<tr>
<td>100-watt household bulb</td>
<td>2865</td>
</tr>
<tr>
<td>Tungsten lamp (500W – 1k)</td>
<td>3200</td>
</tr>
<tr>
<td>Fluorescent lights</td>
<td>3200-7500</td>
</tr>
<tr>
<td>Tungsten lamp (2k – 10k)</td>
<td>3275-3400</td>
</tr>
<tr>
<td>Sunlight: early morning, late afternoon</td>
<td>4300</td>
</tr>
<tr>
<td>Sunlight: noon</td>
<td>5000</td>
</tr>
<tr>
<td>Daylight</td>
<td>5600</td>
</tr>
<tr>
<td>Overcast sky</td>
<td>6000-7000</td>
</tr>
<tr>
<td>Summer sunlight plus sky blue</td>
<td>6500</td>
</tr>
<tr>
<td>Skylight</td>
<td>12000-20000</td>
</tr>
</tbody>
</table>

Table 1: Real world color temperatures, starting with the lower temperatures going from red, through white light to blue. (9)
The light is red if the color temperature is around 2400°K, yellow at 4800°K and bluish at 9300°K. Daylight is defined around 6500°K (Figure 5). (10)

![Figure 5: The color temperature placed in the CIE 1931 color space chromaticity diagram.](image)

Even when knowing all about color, color models and profiles, color temperature, etc, still leaves hundreds of questions unanswered. Bengt Larsson expressed himself this way: “For me color seems to be a mix of voodoo and marshy ground.” (2)

### 2.2 Rendering – Virtual Realism

#### 2.2.1 The V-ray Renderer

V-ray is a rendering plug-in for the 3D software 3D-studio Max which supports almost every feature in 3D-studio max. The plug-in is made by a Bulgarian company named Chaos group. V-ray is an extremely powerful tool when it comes to rendering. V-ray has large arsenal of tools to its disposal, for example ray traced reflections, indirect illumination, caustics, anti-aliasing, etc. There will be a short description later of some of the excellent tools that is provided with the v-ray plug-in, which also involves our research. (11) (12)

#### 2.2.2 Global Illumination

Global illumination or GI is yet another tool for photo realistic images. Global illumination is a set of algorithms that can be used in 3D, for example Ray tracing, beam tracing, ambient occlusion or photon mapping. All of these Global illumination methods use algorithms named diffuse inter-reflection and specular reflection. Diffuse inter-reflection is described by light hitting an uneven surface, bounces off it again and hits other surfaces, thereby illuminating them as well. While specular reflection is a
reflection coming from a perfect even surface such as a mirror or a lake on a clear day and therefore reflects the rays in a straight angle according to the “law of reflection.” This law states that any incoming light that bounces off a surface and is reflected will have the same angle as the incoming light. (13)

The main goal of global illumination is to enable a correct calculation of the light’s intensity at any point in the model. Without using global illumination the image often appears flat and synthetic and loses its realistic touch, for example color bleeding. The coloring of the surface from the reflections of the spheres can be simulated with global illumination, otherwise with radiosity or colored light (Figure 6) (14).

Figure 6: A render without (l) and with (r) global illumination on.

The majority of the global illumination algorithms that have been developed are based on two major techniques: Ray tracing (point sampling) and radiosity (finite elements). Both of them have their strengths and weaknesses. Hybrid techniques are combining the best of both. (4)

2.2.2.1 Ray tracing

Ray tracing is a method used mostly when creating photo realistic images. However because of its precision and excellent quality, it also is a very demanding rendering method. What the ray tracer does is similar to the name, which is misleading. First, the ray tracer’s software determinates the position of the camera in the scene. Secondly, it calculates the angle where the camera is pointed and its field of view. After that phase, the ray tracing algorithm sends out a ray for each pixel in the viewport out into the scene. Then the software calculates the color of each pixel, depending on the ray sent from the camera and bounced on the targeted surface that it hits later. Ray tracing is thought to be the most accurate measure of rendering possible. However, it also has flaws, such as depth of field. It cannot be rendered, because with a ray tracing algorithm everything gets perfectly sharp and even. (15) (16)
2.2.2.2 Radiosity

Radiosity techniques were developed and introduced by a team of researchers at the Cornell University at 1984; some years before the ray tracing methods was established as an alternative model. This alternative finite element method is a global illumination algorithm handling the interaction of light on purely diffuse surfaces. This method’s innovation consists in object-to-object reflections. Earlier light reflection models did not account for the interaction of Lambertian (diffuse) surfaces and therefore incorrectly calculated the global illumination effects. The surfaces in the scene are divided up into smaller patches, which are rendered in turn. For each pass of the algorithm, the total amount of light at each patch is calculated, meaning that light bouncing off a surface hitting another is added as well in the next pass.

Later radiosity could handle more complex reflections models, however no specular or glossy surfaces. Radiosity is quite efficient in simple scenes with diffuse materials, but it becomes very costly in terms of rendering time and storage requirements when it comes to complex models and non-diffuse materials. (4) (17)

2.2.2.3 Caustics

Caustics are called the reflection patterns that appear when light is reflected on a metallic surface or refracts through transparent objects such as glass, water or ice. These patterns depend only on the light source’s position as shadows, not the observer’s point of view similar to reflections. In the rendering below (Figure 7), there are caustics on the flour and in the glasses. This image is generated with the aid of a v-ray tutorial. (18)

![Figure 7: Especially when rendering glass and metallic material caustics can be generated, as in this image on the floor.](image)

2.2.3 Anti-Aliasing Filters

Originally aliasing is an alias of one unique sample, when you use the same information over and over again, a pattern of these identical parts may appear if you have not sampled the original information high enough, and form a distortion in the image edge. This problem commonly occurs when an image is given a lower resolution. Anti-aliasing is exactly what it implies, a counter measure to these aliasing effects, a mathematical cure to the problem with under-sampling or low resolution images. What an anti-aliasing filter actually does is that it distorts or blurs the original shape edge, fooling the eye where it is more exact than it actually is. There are many different types of Anti-aliasing filters, found in the rendering window.
Some of them just blur the jagged edges, others jitters the original pixel while other methods changes the tone of the color tone.

V-ray offers both sharpening filter as well as softening filters. The default filter is the area with a variable-size filter. The parameter can change from 1.0 to 20.0 where smaller size means a sharper result, as for example 1.5 which is at default. The Blackman works equal to the sharpen filter in Photoshop, though without extra parameters to control. The Catmull-Rom gives a similar sharpen effect like the Blackman, but it even slights the edge-enhancement. There are no controllable parameters in this filter either. Another sharpening filter is Sharp Quadratic 9-pixel reconstruction filter from Nelson Max. Especially in animation sequences it is not always wanted to sharpen details, but provides a smoother look. The filters such as Cubic, Quadratic, Soften or Video can be applied. Some filters can both soften and sharpen, for instance Cook Variable with values of 1.0 to 2.5 for sharpening and higher values to blur the image. Even so Mitchell-Netravali is working, where the user is given to value anisotropy to blur and ringing. Both values vary from 0.0 to 1.0 while 0.33 is default. While rendering shots using depth of field it can be recommended to apply Blend, since this filter blends between sharp areas and Gaussian soften filters.

It often takes some experimenting time to achieve the best result for a particular image. (9)

2.2.3.1 Quasi-Monte Carlo

Monte Carlo is an algorithm simulated by computers and used in a wide area of expertise. This simulation is most useful when calculating things that have a large degree of freedom, such as cellular structures or floating liquids. Monte Carlo has also proven to be very valuable in computer graphics, whilst calculating the global illumination because of its unique ability of randomly finding the correct result, as well as being very precise. The only downside in this context would be the highly demanding calculation times.

Quasi-Monte Carlo on the other hand is pretty similar to the regular Monte Carlo method. The difference is that the Quasi-version works with numbers that are in an ordered sequence, while the regular one uses pseudorandom numbers, which means that the numbers seem to be random but are not. This is why the Quasi-method is faster in generating a result.

As written in the help files for the V-ray renderer: “The Quasi-Monte Carlo method for computing global illumination is a brute-force approach.” This is extremely true. Within the boundaries of Global illumination, the Quasi-Monte Carlo method re computes all pixels in the whole scene that are shaded and calculates upon it individually. This might seem peculiar; however, it is also extremely accurate. (11)

2.2.3.2 Photon map

As previously mentioned, radiosity and ray-tracing-based methods are combined in hybrid techniques, since radiosity is efficient at diffuse reflection whereas ray tracing creates good specular reflection. Photon mapping takes an alternative approach than the hybrid techniques. With photon mapping, the information is stored as points in the photon map, which is a separate independent data structure. The lights emit photons that are traced through the scene, reflected, refracted, absorbed or scattered, building the photon map that contains information about all photon hits. Especially in very complex models, this process called photon tracing simplifies the representation and makes the rendering process more efficient. This advantage is based on the functionality of the photon map’s illumination that is decoupled from the geometry and allows handling even arbitrary surfaces. The photon map can be seen as a light cache in bidirectional path tracing, which means sampling the image both from the light sources (such as caustics) as well as from the observer’s point of view (such as mirror reflections). In the second pass the image is rendered using the information in the photon map. (4)
2.2.4 Bump Mapping

Bump mapping is a method where the camera has been tricked to interpret a surface different from what it actually seems to be, with the help of a bump mapping texture. Applying a spotted texture to a sphere, it will appear similar to a ball with many semi deep holes in it. There are two methods for Bump mapping in the field, real Bump mapping and fake. The real Bump mapping method takes each pixel from the Bump map texture and calculates a height map from it, penetrating the surface normal and bi normal at each rendered pixel of the surface.

The fake methods of Bump mapping, also called dot3 Bump mapping, is often used in 3D graphics for games. It works similar to Normal mapping, because it uses a texture map with color instead of a grayscale, delivering a lot more information, which on the other hand is more time-consuming, too. The colors blue, green, and red represent the normal's x, y, and z in 3D space. Each pixel in the Bump map texture is treated as a vertex, which is placed upon the material, where the object has a whole new appearance. (19) (20)

2.2.5 Displacement Mapping

Displacement mapping gives a similar result as bump mapping, except it does not alter the way the camera interpret the normals. Instead, it alters the actual geometry, which can cast shadows, occlude other objects, basically everything a real geometry does. The first renderer available, that could create a Displacement map, was Pixar’s Renderman. The Renderman renderer used a method called micro polygon rendering. Every pixel in the texture for the Displacement map was treated as a polygon. In programs such as z-brush, this map for the Displacement can be created and then applied to the object in the 3D program. (21)

2.2.6 High dynamic range imaging

The human eye works very efficient when it comes to fast adaption to changing light intensities. It has the possibility to distinguish millions of detail in color and intensity both on the beach, a bright summer day, and in a dark room lit up with candle lights. Even if the daylight is much brighter than the candle light, the eye can adapt to the intensity. This adaption makes it possible to see details both in a dark room and outside the bright window. A standard camera cannot adapt to several different exposure times. That is why the image has either “over white” areas as in the window, or “over blacks” in the too dark room.

Today, High Dynamic Range Imaging or HDRi is a frequently used lighting technique in 3D, which means getting the maximum of contrast in a picture. An HDR image has an extra floating point value associated with each pixel that used to define the persistence of light at that point. When it comes to describing the light values per pixel precisely, a low dynamic range image (like every usual jpg-picture) has a limitation of 250:1. The dynamic range for human eye is about 10.000:1. Some of the HDRIs can have a range of over 100.000:1. The only problem is that a common screen, monitor or printer cannot reproduce this high dynamic range because of their limitation to 256
intensity values. Therefore, you have to convert the HDRI to a LDR with a process called *tone mapping*. This includes a range of different methods to get an infinite dynamic range to a limited (0 or 1). (22)

An HDR image can be taken as series of several pictures with changing exposure times. It has to be a still picture, photographed from the same position. The shifting intensity in the pictures from *over white* to *over black* demands the compositing process afterwards.

HDRI is mainly used for coherence because of its ability to mime the real world, especially useful when working with reflective objects. For instance, an HDRI image can be taken of the environment and then be applied to the objects scene in 3D.

It can also be very useful for Image-based lighting, where the HDR image (Figure 8) is used for emitting the light or photons from a sphere around the scene. It is one application where a high range of color and intensity is required to illuminate the scene in a realistic way. Often those images are also panoramas, to be employed on a sphere. Such a 360° angled images can be taken photographing a special mirror sphere that reflects the whole environment, but not the camera itself after retouching the picture. Because of the spheres rounding the image, they become stretched similar to the fish-eye effect. Then the HDR image has to be mapped on a sphere in the 3D scene. (23)

![Figure 8: A High Dynamic Range image for image-based lighting](image-url)
3 VISUAL RESPONSE

In this chapter, visual response, the artistic side of imaging will be analyzed deeper. What makes a picture appears good or comfortable, interesting and modern? What of does the image’s harmony consist? What is meant with a feel for images?

3.1 Photography as a starting point

During our research period we obtained the opportunity to visit IKEA Communications AB, in Älmhult, Sweden. IKEA Communications is the headquarters for all IKEA image synthesis and photography. Most of the photographical theory, such as setting up the lighting, is based on the photographer’s experience, and therefore does the following study mostly reflect IKEA’s feeling for images.

3.1.1 Realism

3.1.1.1 Lighting

3.1.1.1.1 Basic three-point lighting

Lighting can virtually be seen as a modeling tool that is why the three-point lighting has become standard in lighting three-dimensional forms. As the name implies, the lighting setup consists of three lights, with a specific function for each one of them.

The key light or main light defines a scene’s dominant lighting with the highest intensity of the three lights and also casts the main shadows. It generally is placed above the subject to some degree and beside the camera. On the other hand, a room set may require the key light at the position of a bright window, illuminating the scene with daylight. Even placing it behind the object can be desirable to emphasize a more dramatic feeling, presenting only the object’s silhouette.

The fill light’s main function is to light up the scene from the key light’s opposite position. This light is especially needs to open up the key light’s shadows, reducing their density. Rendering with ray tracing and global illumination already includes that light is bouncing back on surfaces, indirect illuminating the scene as the fill light does, but even more realistically.

More depth can be achieved with the help of a back light, which is essential for separating the object from the background, especially while working in similar tones. This light is can also be called as hair light or shoulder light, when filming portraits, giving a touch of glow or highlight to the edges.

In the photo studio, the fill light and the back light can also be just reflector planes, which open up shadows or reduce some bright, unwanted reflections. These planes are often white or black, but even silver can be useful for secondary lighting. (9)

3.1.1.2 Hard and soft light

Different types of light intensity and power cause different expressions. Hard light creates a strong contrast with bright highlights and dark, sharp shadows. Direct light
from a lamp can often generate such hard light, which often provides suspense and drama and intensity to the scene. An indirect lighting creates softer shadows and softer highlights on the objects. This can be achieved through turning the lamp around and illuminate a big white or metallic reflector, where the incoming light from the lamp bounces off and into the scene. Especially for a cozy indoor furniture scene, such lighting will be desirable. And especially for scenes with window lighting up the scene, indirect light is more realistically, since the outdoor light is bouncing around a lot before hitting the window.

### 3.1.1.1.3 Warm and cold light

As seen in IKEA’s huge photo studio, the photographers act similar to artists until the final picture is taken. They are modeling with light to achieve the best contrast, depth and feeling in the image. But not only reflectors and white lamps are essential for the creation of the image, but even the light’s color temperature. Having a closer look to the “white” lamps with special measuring instruments, quite huge aberrations from “white” can be detected. In some cases the color temperature is even shifting from bluish to yellowish, for instance. While the photographer may bestruggling with these effects, the mathematically exact light in 3D may need a few more of those lively lights. As the photographer can experiment with several colored, transparent plastic foils, the synthetic lights in 3D can change color. As described before, the light’s color temperature varies a lot depending on its type of light source, such as daylight with 6500° K, as white light, or a candle light with about 1900° K, as very red and warm light.

The whole trick to achieve a harmonic balance in the image is to mix cold and warm lights (2). Cold or very light is often coming from outdoor, though a window or door, for example while lamps of the brand tungsten (between 3200-3400°K) in indoor lighting spread “warmer light,” creating a balance between blue and yellow, or cold and warm in the scene. It will furthermore generate a feeling of depth and spatiality, as the play with the back light.

![Figure 9: Using warm and cold light in an image generates a feel of depth.](image)

### 3.1.1.1.4 Indirect and dirty light

Without even having turned on one single spot in a light setup, so called indirect light (2) from the surrounding, the photo studio is bouncing around and lighting up everything. That is a large amount of light in comparison with the virtual, totally black 3D scene. This indirect light comes from other lighting setups, reflected on walls and ceilings or windows, spreading daylight, and is nearly impossible to control. Though, this light can lift up the scene immensely, making it more alive.

Even with the best and most expensive lighting equipment, a lamp can never generate a totally even spectrum of light. There are always minimal irregularities, when the light from the lamp is shifting from warm to colder light, which can provide some useful and suggestive unbalances. This light can be seen as “dirty” light.
3.1.1.5 Shadows

Shadows are essential for the image and the image’s expression. Without light there is only shadow, and without shadow there is no depth. In a real world scene, light always casts shadows. In 3D the shadow can be turned off, while the light is on. Those light settings can create excellent artistic effects, although they can cause an unrealistic feeling in the image, too, because of the lack of shadows where the observer expects them.

3.1.1.6 Reflections

The usage of reflections in photorealistic images is very important, because of the eyes amazing ability to notice irregularity and things that seem out of order, such as a glass that will not be reflective at all or reflects something that is totally out of order. This is an excellent topic to include HDRI. Because of the HDR images abilities integrated in a 3D program, the image delivers very useful, crisp, sharp and realistic reflections, which improves the feel that the surroundings are realistic.

3.1.1.2 Perspective

In reality, different cameras are used to either generate photography or film and movie production. In 3D, applications the camera is capable of both, making the render process possible. In this research, we are concentrating on the photography aspect. Even rendering from a view port is in fact working as a camera although creating a camera will provide the user with valuable parameters to control.

*Perspective* is achieved through different camera lenses, where for example 50 mm is the standard lens for 35 mm cameras. Changing the lens’ size leads to the illusion that the cameras distance to the objects has changed. This includes distortions of perspective. A 35 mm lens is called a light *wide-angle*. A 25 mm lens is a stronger wide-angle, which stretches the perspective even more, with the result that it gets a bigger fisheye effect. A wide-angle has a short focal distance, but a wider angle of vision. Standing in front of a big tower for example, can require a wide-angle to fit the whole building in to the picture. An 85 mm lens is called little telephoto lens or portrait lens, because of its little loose of perspective. This results in a portrait with lower depth, which means flattening the face a little bit, where the nose is not sticking out too much. Zooming with lenses with a 100-135 mm will decreases the depth and the image appears more flat. A large telephoto lens is about 200 mm. Depending on which effects are wanted, the camera distance to the object and/or the lens size has to be adjusted.

3.1.1.2.1 Depth in the image – Depth of field

An image is always two-dimensional, even if it was created in 3D. One of the major problems to struggle with is the illusion of depth in the image. Many photos appear flat and distracting. The whole trick is to catch the observer’s glimpse and lead it through the image. There are several ways to do this, whereas the tools are always the same: the lines and forms in the image, their relations to each other and light and shadows. In the later case the photographer can for example chose a darker foreground, while the main focus lies in the brighter background. The observer absorbs into the picture. Even if the contrast is not that extreme, the light intensity decreases getting nearer to the picture’s corners. This creates an invisible border that keeps the observer inside the picture.

The feeling of depth can also be accomplished through a technique called *gradation* (24). If an element, a detail or a part of the scene partly covers or hides another, the observer immediately realizes one object as near (in foreground) as the other (in background) (Figure 10on page 25).
Figure 10: We immediately recognize that the black sphere is nearest, since it is largest and in front of the red and the white one.

The human eye is trained to see things every day. From the beginning, we have been studying objects and especially their size. This experience is important to estimate distances and speeds in the real world and in an elaborated photo as well. The longer the distance between the eye and the object, the “smaller” the object appears to be. “Bigger” objects are often placed in the foreground (24). Nevertheless, the relationship between objects is much more important in this case. A tall tree requires a comparison to other objects, for example a human being or a house, so that our experience counts as true or realistic.

An additional method to attain spatiality in the image is to work with the depth of focus in photography or depth of field, as it is called in 3D. As mentioned before, the human eye can only see sharp with the cells in the center of the retina. However, since the eye is permanently moving around, our brain gives us the illusion that we see sharp the whole time. The dalliance between the moves is too small, less than we are realizing them. But in photography, the depth of focus generates a center of attention in the image, and leaves the murky parts as respectively, fore- and background. There are two types of depth of focus: short and wide. As its name implies, a short depth means that only a little part of the scene lies in the sharp region, while the rest is murky. Using a wide depth of focus, hence the name, everything in the image looks sharp (24). This is common to use for more technical pictures, as for example IKEA’s Guideline images for their product’s database or the clean presentations in their catalogue.

Depth of field in 3D works principally the same way, though it is very expensive in rendering, in the sense of time consuming (Figure 11).

Figure 11: An image rendered with Depth of Field on, with the focus on the black sphere.
3.1.1.3 In contrast to 3D

3.1.1.3.1 Noise, Softness

During the 19th century, there started a new epoch in both literature and art that is called classicism. The artists were searching the truth mainly in nature. The French artists and chemists Louis-Jacques-Mandé Daguerre and Joseph Nicéphore Niepce created the first permanent photography based on the principle that a silver and chalk mixture darkens under exposure light, discovered by J. H. Schultz in the early 18th century. From this moment the photography reflected the reality in a way oil paintings never could. It took a long time until the colored film really broke through, where the photography felt as trustworthy as today. Nowadays, most of the huge photo productions for IKEA are made digitally. (24)

Producing a photo with a digital camera includes minor noise, while rendering generates totally “crispy” and clean images. This noise is generated from the camera’s change coupled device or color capture device (CCD) chip. This device uses light sensitive material on a silicon chip to electronically detect the light’s photons. This incoming signal is transferred further along a row of separate pixels (picture elements) where it can be stored as color information. When the pixels are arranged in rows and columns, the assemblage is called two-dimensional. A color image CCD sensor uses a checkerboard pattern of color filters, representing the three primary colors red, green and blue. Alternatively, three separate CCD sensors are applied, on for each color. (25)

3.1.1.3.2 Rounded corners

Building object in 3D is similar to creating them in a mathematical correct way. A polygon object is made of faces without a physical thickness as in reality. Even a thin sheet of paper has a depth. An equal problem appears on corners and edges. Real objects can hardly be as hard-edged as they are in 3D, when starting with the creation. The modeller has to be aware of those problems and correct them, at least for photorealistic rendering.

3.1.2 Making the picture alive – three main forces

3.1.2.1 Flaws in the perfected

Even if the human eye is physically and biologically not the best or sophisticated one, it co-operates perfectly with the brain. This provides us with the capability to recognize people, movements, pictures, and patterns of every type. Particularly, when it comes to symbols and signs the human being is quite fast and flexible to communicate with other people, due to the evolution. On the other hand, in some areas, this exactly ability to recognize a pattern is not wanted, for instance in design and imagery. Recognition of patterns leads often to a feeling of boredom, although the observer wants to experience excitement, suspense and harmony, or just detect a thought or story behind the image.

The secret of producing harmony do not lay in the construction of strait lines and angles or in an image, precisely divided in equal pieces, but rather in a fine interruption of lines and surfaces. Although the question about good, bad, beautiful and unaesthetic is very subjective, there are three main ideas to create a good-looking image: content, (clipping) detail and composition (24).

3.1.2.1.1 Content

The content should reflect the photographer’s meaning behind the image or what he/she wanted us to see or feel, even if the observer produces his own truth about the picture.
3.1.2.1.1 Propping

Propping means to place several objects into a room’s furniture or equipment, as for example a couple of books in a bookshelf. Visiting IKEA’s store or browsing the catalogue, it becomes clear, why propping is very useful. Above all, a bookshelf filled with books and things will be better sold than an empty one. Propping makes it more realistic looking and personal; it provides the feeling of someone actually living in the chosen environment. It can also inspire the customer how to combine their own belongings. A room set’s propping produces the illusion of people’s presence, and can also tell the viewer more about who lives there and how they live. Fine details can for example reveal whether it is a family with children or a young couple with pets. This is essential for photorealism, especially for IKEA. However, it still has to be accomplished well and considered. Colors have to match to each other and all objects should be placed harmonically and in the sense of the content. The meaning with propping is to illustrate the functionality or to emphasize the design with forms and colors (Figure 12). The number of propping elements depends on the scene, the light, the composition for all. Less propping offers more own reflection by the observer, though the trick lies in finding a good balance in-between the “overcrowding” and the emptiness. That motto for minimalism is called “Less is more.”

![Figure 12: Propping personalizes a room (26)](image)

3.1.2.1.2 Clipping and formats, 28-32, 55

The borders of images can decide as well how the image feels and what it. By clipping off some essential details, the content will change, too.

There are various formats, rectangular or quadratic. The first one can either be landscape also called lying format, or portrait as a standing format. As the name implies the landscape format appropriates for wide angled views, whereas smaller subjects as a person, a portrait, comes out more harmonic in a smaller, but longer format. Choosing a portrait format for a landscape picture, can convey a restricting and uncomfortable impression to the observer, standing in a room, watching through a door (24).

Already 300 BC, the Greek mathematician Euclid described in one of his books the godly proportions, the Golden Ratio. It can be explained as a line, divided in two pieces A and B in such a way, that A is to B, as B to A+B (Figure 13).
The Italian mathematician Leonardo Fibonacci (c. 1170-1250) found a series of numbers, the Fibonacci numbers, which make the Golden Ratio more understandable: 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, and so forth, building the algebraic sum of the precursor numbers.

2000 years ago, the Greek architectures build their temples in this “perfect” ratio, as well as many formats especially for papers and magazines are orientated to these proportions until today. The most common format for photos is 13 x 8 cm as shown below (Figure 14).

The quadratic format seems as a very static and unchangeable one, and therefore even boring. It can be very exciting in combinations or for itself claiming an interesting content and composition.

3.1.2.1.3 Composition – Imperfect makes perfect

No matter the clipping or the content, an image needs a structure and some kind of considered composition, to be able to communicate with the observer. The composition shall emphasize the image’s message and the context, in which the image is placed.

Centering an object in the exact middle of the picture will generate an axial composition, which means symmetry, since the human eye often longs for calm and order. Placing the center of attention out of the middle of the picture, the photographer produces more excitement and life. The asymmetry profits from empty spaces and their relation to the center of attention with different objects. An asymmetric placement of equipment offers sometimes an easier method to catch the observer’s attention, so he finds a way into the image. It is also possible to arrange the composition by the Rule of Thirds (24), cutting it into three parts and placing the main object of attraction in the left or in the right division. This method is similar to proportioning according to the Golden ratio.
Good compositions can also be created with contrasts in size, form, color, and so forth. This kind of composition is about to emphasize certain parts in the image with the help of opposites and their effect to each other. This can accentuate for example a little detail in the scene. The “rule” is to avoid placing two objects of the same kind next to each other, with the same color value, saturation, or size and form (24).

Another method to elicit action and dramatic from an image is to construct a diagonally direction with elements, surfaces and lines. The eyes automatically follow the lines into the depth of the picture, some kind of centered energy. However, the diagonal is also a very symbolic element, especially for Western people, writing and reading from left to right. When the line is striving up from the bottom left corner to the upper right, it is a symbol of success, positive progress and opening, while the opposite direction often means blockade and prohibition.

The question is why does IKEA of Sweden want to place its furniture in a “closed” angle? Bengt Larson (2) provides a plausible, probable explanation: It is totally right that a main diagonal gives a strait direction and speed to an image, but it is just as important which objects are placed in the scene. The image consists of balance and often several fields of attention, where diagonal lines are useful among others. IKEA’s Guideline furniture is always placed on a diagonal, “falling” lines with an angle of 5° or 11°, depending on the object’s size. Therefore, even if the main direction is a diagonal, the object offers other lines that are striving up again. The image of the sofa (Figure 15), that Bengt has sent us makes this idea clearer. The observer’s eyes wander from left to the middle of the image, where they will be stopped and lifted up over the back support. This little, short break, which the eyes take in the middle of the sofa, create a pleasant feeling of resting and relaxing, which is definitely wanted. (2)

Figure 15: Bengt’s explaining image of the IKEA angle. The sofa above is positioned in the “right” angle, while mirrored the sofa below generated unwanted feelings, when it comes to furniture.
When mirroring the image horizontal, the sofa stands on the rising diagonal, and then other unwanted by-effects will appear. First of all, the arm rest is blocking the observer, while the eyes try to wander from left to the right. The sofa feels more repelling, not inviting. And while the first piece of furniture catches the observers view and returns him a comfortable feeling, the second one forces him to slide out of the sofa, meaning he is not staying on the furniture. Details will be lost and the image cannot create the wanted pleasurable feeling of rest. (2)

Summarizing, it supplies one main factor to consider while creating a good composition. An image without objects has no composition. That is why, the compositor shall be aware of all visible objects in the scene and how their lines are working in combination and relation with each other.

3.1.2.1.4 Virtual photorealism

There are many details in the real world that the observer sees unconsciously and takes them for granted. While the interior decorator irons things as blankets, pillows or mattresses to get them crease-free, the 3D-artist struggles with creating accessories and fabric furniture with seems and stitches. This is achieved with the help of bump maps or displacement maps. The photorealism lies somewhere in-between, depending on material, lighting and distance from the camera (2). Materials shall live: creases in fabric and cloth, natural irregularities in surfaces such as wood! Nothing is dead level and uniform. Breaking the perfectness makes it more acceptable for the eye and therefore even more correct, or photorealistic.

Even the variation of textures is very essential for photorealism, since there are no repetitions of surfaces or texture in the real world. It facilitates the work of the 3D-artist, having a huge texture library at his disposal.

3.2 Perception Psychology

Psychology is the study of the mental processes and behavior of a brain. Perception in the field of psychology, on the other hand, involves how the brain interprets objects using the senses. In this research, only one of the senses will be investigated, the vision, which is the ability to detect and understand electromagnetic waves of light.

3.2.1 Relative Brightness

A very strange and subjective question is how bright are things? A good example is described in a book, written by Arnheim (27): "It has often been observed that a handkerchief at midnight looks white, like a handkerchief at noon, although it may send less light to the eyes than a piece of charcoal under the mid-day sun." This proves that brightness is a relative thing; it all depends on the distribution of light in the environment or image and the optical psychological process of the eye of the observer, as well as the nervous system. This is also relative on the objects material ability to reflect light. Another example is if someone sits in a room at dawn and watches television, focuses their eyes on the television screen, and someone walks in the room later on and states “Why are the lights not turned on?” flips the light-switch, and it becomes clear that the sun has set and the environment is much darker without ever noticing. This is also the human mind working together with the pupils of the eyes, the pupils grow wider to catch more light, as well as the mind compensating with understanding of the environment. (28)

3.2.2 Color interpretation

The physical principles of how humans acquire and interpret the color in our environment have already been covered in the second chapter, but not what the brain does with the information gathered. A ball that comes rolling across a field can easy be identified because of its movement, or its shape, maybe its texture but probably
because of its color, unless it is green, which would help it blend in with the green grass. Although a red ball would clearly paint a clear image of colors' importance for recognition. With a few exceptions of physical defects and cultural and religious background, everyone interprets color the same way. Even though almost everyone has a unique taste or sense of color, we all have a common understanding for all colors because everyone relates to the same thing. Everyone knows how a green apple or the color apple green looks like. (28)

### 3.2.3 Shapes and forms

Shapes can be very subjective depending on the viewer’s earlier experiences and ability to understand and realize, very often the use of objects so that the shape can be identified as a class of some sort, for example an animal or a kitchen accessory. For example, if a person went to bed late at night, when it is dark outside and most of the lights are out, and sees a black shape on the bed. If this person lives alone, this can be very troubling, where if you have a partner that has gone to bed earlier, it is almost expected, and the shape is instantly recognized for what it is.

Or, if two different persons, one very proficient in kitchen equipment, the other not quite as skilled, and both individuals are introduced to a new sophisticated type of blade sharpener. The first person might understand the use of the object instantly, while the second one would not have a clue unless explained to him/her, this strictly because of the shape of the object. (28) (29)

[Diagram: A flowchart illustrating the process of concept and perceptual knowledge, hypothesis generation, and feedback from experience.]

**Figure 16:** This abstract scheme explains how the brain and the eye work together to perceive the environment.

### 3.2.3.1 Optical Illusions

Optical illusions are stimuli that lie in the border lands of what the human mind can comprehend. An optical illusion in most cases appears when the mind makes an assumption that is wrong, or when a constant recalibration is forced by the mind. As in the image above, there is a perfect example of how the brain tries to help the eyes understand images (Figure 16). The brain reads them from left to right and takes straight lines as an aid, as well as continuity. This precise problem is common in
computer graphics, in theory there is nothing wrong, but in the practical sense, the mind destroys the image (Figure 18). Therefore, it is important, not to let colors burn out over a long range, keeping in mind that the eye can swiftly adjust to such “burn out areas” and recognize details in them. So wide regions with exact the same color are not photorealistic (Figure 17below).

**Figure 17:** The difference between physically and perceived intensity reveal how the eyes deceiving us.

**Figure 18:** The square A has the exact same color as square B, as the samples show. Color always depends on its surrounding.
During the first weeks, both of us had been researching the background information for the introduction part and the theoretical framework, in chapter 2 “Theoretical Framework.” We have found some especially interesting articles and even books that were partly available on the internet.

Then, we went to IKEA of Communication in Älmhult, southern Sweden, and learned a great deal about the photography process and their 3D studio. That inspired us both a lot especially for the background information for chapter 3 “Visual Response,” which is the additional information to balance the theory of rendering. The Theoretical Framework was more difficult to structure and make choices on what was most important for our research, and what to avoid keeping this research paper from being too broad.

The practical part of our thesis work consists of improving the old 3D image and getting it more similar to the original photo.

4.1 Study Excursion Description

Seeing and walking though IKEA’s huge photo studio, we gained a great deal of experience and an insight to the photographer’s process. The problems, which photographers are struggling with, are of course not the same as for the 3D artists. The photo studio is built as a wide hall with lots of black and white draperies, thin walls, reflecting walls, and adjustable roofs. The remaining construction components for each room, equipment and furnishing varies, depending on which object, furniture or room setting is going to be photographed. Bigger objects as sofas, beds, or room setups demand more time, space, and often naturally a more advanced lighting setup. The studio has large windows around the building’s walls; therefore the photographer has the possibility to make use of the incoming daylight; although he has to be aware of that this light is changing during the day, which also can cause problems. Sometimes, they cover the windows with matt, transparent plastic foil, or just black, isolating draperies.

The photographers work in different ways, some of them work on their own and some in larger teams of two or more persons, depending on how huge the objects and/or scenes are.

4.2 Choosing a room

During our field trip, we asked Bengt Larsson for an original photograph of a room setting, which we can use as reference for our 3D production. He found an excellent image of a white kitchen that has been printed in the IKEA’s catalogue two years ago. This avoids security or publishing issues for our thesis research paper as well.
The immense advantage with this image of the kitchen is that IKEA had already modeled, textured, and lit a whole scene in 3ds Max and rendered a quite good-looking image, as a test for pure 3D generated room setups. Our job is to improve this 3D product and achieve a more photorealistic result.

4.3 Image Analysis

4.3.1 Analyzing the original image

Before starting with actual work in 3ds Max, both the original photo (Figure 1) and the 3d image (Figure 22) has to be analyzed. The main aspects are modeling, lighting, texturing, rendering, and remaining issues such as camera settings. We have discussed why the 3D picture does not feel as photorealistic as the original image does.

Light and Reflections

“HDRI” reflections:
Metallic materials reflect the environment (behind the camera), giving more depth to the image

Light sources:
there is “cold” daylight emitted from the window(s) (right) and the the other room (left) and warm light from the lamps over the table and the stove

Figure 19: The original image with a light analysis
Color/Contrasts is repeating

Figure 20: The color composition is important to give a certain feeling to the image. This kitchen feels quite clean because of the black-white contrast. The other colors attract the observer’s attention and make the room livelier.
Variance/Propping

Figure 21: Propping is important to show who is living in the room and how it is used.

Propping can be everything related to the room and its functions, as in this case cups, glasses, kitchen utensils, food, plates, etc.

There are no perfect matches of doors. Straight lines are easy to recognize for the eye. Gaps between doors are also varying a bit.

Irregularities make it more realistic-looking and feel alive.

color shifting: red-blue
4.3.2 Things to change in the 3D scene (Figure 22)

4.3.2.1 Modeling

Our main goal is to achieve a photorealistic superior-looking image. Since there is an original photo to refer to, the 3D kitchen has to be as identical as possible. This is why even some modeling changes would have to be realized in the beginning process.

Starting from the top to the bottom (Figure 22), some of the glasses positions have been moved around, to avoid too much of a straight order in the glass cabinet. The door handles seemed too big and had to be moved up slightly. The metal bar under the glass cabinet was moved down and scaled up, as well as the mounting equipment. The water tap was rotated several degrees to the left, the dish soap’s bottle was scaled down one third and one of the dish brushes was rotated too, where they do not hang on the bar in the exact same way.

Both ceiling lamps, hanging over the table, were too large and had to be scaled down some centimeters. A great deal of re-modeling work was needed on the air exhauter over the oven, scaling up the lamps and giving some depth to the underside.
The oven seems very flat, therefore it was repositioned slightly and the oven door is now open, creating a natural, narrow gap. The same phenomenon occurs on the kitchen doors, too, where the gaps were too small. We changed the bump map with the modeled, real geometry.

4.3.2.2 Lighting

The lighting is very essential for the whole appearance of colors, shadows, and even the models. After analyzing the 3D image, some changes had to be achieved. First of all, a main light is missing, which lights the kitchen cabinet in the front of the picture. This lamp seems to be quite bright, maybe as white as daylight.

The second daylight source from the window has been changed; its light focus is moved more to the middle of the kitchen instead of illuminating only the right side. To achieve the original photo’s brightness and feeling of openness, this light is the key light.

The floor is build of dark brown wood boards, somewhat reflecting. That requires plenty of light, where it does not appear as a homogeny black floor. Three different “cold” lights are blending together on the floor: from the window, the front, and the second room in the left of the room at the back.

The ceiling lamps over the table are more yellowish than in the 3D image. To obtain a balance between warm and cold light in the scene (as in the original photo, Figure 19), the ceiling lamps can be opposite pole to the incoming daylight from the windows. These lamps are already illuminating warmer light; however the lamp itself shall shine more yellowish, not white. This can be part of the texturing process. When the texture of the lamp’s inside was finished and looked good, there appeared other artifacts, such as yellow dots all over the image from the lamp reflections. Therefore, we decided to achieve a realistic lighting in the whole scene and eventually render the “yellow” lamps separately and post them afterwards.

All metallic materials appear very lifeless and dull. When the lighting is adjusted, it can still require a HDRi in the texture.

Overall, we find that the kitchen in the 3D image was too dark and hazy. An improved lighting is essential to accomplish the original image’s light and open feeling.

4.3.2.3 Texturing

The texturing process is often very time-consuming, since every material has to be adjusted to the lighting. Settings like color, reflectivity or displacement maps often need various tweaks.

As mentioned before, the metallic materials have to be more realistic, reflecting a HDRI for example. The kitchen doors are also rather too matt, while the real doors are varnished. The glass tops in the glass cabinet are too green, and should have a more bluish texture. Details such as fixing a label for the transparent bottle by the sink can accomplish more photorealism, because it is more trustworthy with realistic details.

The oranges do not appear very delicious. The texture should be more orange than yellow, as well as the fruit should be rotated a bit, where it reflects the light from the ceiling lamps. They need to feel fresh and kind of shiny. Photographing food is a science of its own.

The pot-holders are more similar to towel fabric. Since the camera focus lies in the background, details of the pot-holders are blurred. Towel material will provide a softer touch to the image.

In the original image, it is obvious that the wooden floor consists of boards, while the 3D floor is flat, not having any gaps in-between. This lack of modeling can be arranged with the help of a displacement map.
4.3.2.4 Rendering

The final image was rendered with the following render settings:

Global Switches: No hidden lights, no default lights,
Anti-aliasing: Adaptive QMC, Catmull-Rom
Adaptive QMC image sampler: min subdiv 1, max subdiv 2
Light cache: Subdivs: 500-800 for web, 1500 for high quality images (3000 px), number of passes = how many processors are available
Environment: skylight on (color white), reflection/refraction on
rQMC Sampler: Noise threshold: 0.0005, Min samples: 16, Global subdivs Multiplier: 3

4.3.2.5 Problems

Most problematic are our insufficient computer capacity. The scene turned out very complex and time consuming to render on my computer or the one at Magoo, which we had at our disposal. Even rendering a small region took a very long time. Therefore, we were not able to render a whole image to see the results. Switching off as many layers as possible, accelerates the process, however it can even include problems with different settings or later, invisible artifacts.

After changing light settings, there always appeared unwanted changes on other objects. It was really difficult to set the light from the window, which should imitate very bright daylight. We tested a v-ray light of a dome form. That one sends acceptable light into the scene, but created even artifacts on and in the glass cabinet. We also tested a bouncer, which theoretical should send a softer light into the room, although it did not. The lighting appeared nearly the same as with the dome light. We also found a number of excellent tips on the 3dtotal website, where a target directional light was used to imitate sunlight through a window. However, the result did not come along as wanted; therefore we returned to the dome light and continued adjusting its settings.

We have also struggled a great deal with the kitchen tiles to develop them more realistic, “round,” reflecting, and deeper. The final texture is a blend material with a simple white background and a coat material similar to the shiny surface that kitchen tiles always have. Adding mapped noise avoids too straight reflection lines over the area. An image mapped on the v-ray displacement created the depth structure of the tile wall. Since we were working in different scenes at the same time, it took several hours to find out why this texture did not work in the new scene, combining both older versions. An omni light was the problem, sending light into cracks, where they “disappeared.”

After having succeeded with our first complete render on the render farm at Magoo about 10 hours later, we found half of the textures where not there, since they were linked to their original directory. This was only the beginning of our rendering problems. The render farm at Magoo was very busy at the time when our deadline for our thesis was coming to an end; therefore we were in a hurry to start rendering the image. We decided to build our own render farm with the schools computers. After several days, we found nothing was working there either. We set off rendering a strip of the image and when returning the software had crashed on every computer. It took several days and some tips from Sören to figure out what the causes of the crashes. Finally, we figured that the displacement map on the floor was too heavy to render, therefore we composed it with the bump map instead. This procedure worked much faster, without crashing and provided an acceptable result.
A lot of effort was put into a displacement map for the tile wall and now with the obvious problem with displacement mapping the kitchen tile wall do not look photorealistic at all. This problem occurs when there is not enough power hardware that is required to render the whole kitchen wall in one big render on a single computer. When we render different parts of the tile wall on different computers there is different light that is computed which leads to a very negative result in the lighting on the wall.

Another problem that was encountered was the glass cabinet at the top of the image. When rendering glass with our current ray tracing methods, the light is very easy caught in all the reflections and cannot find its way back to the camera. When this occurs all the glass is rendered black. To achieve more transparency and highly reflecting glass, a very long lifespan on all rays of light is required as well as that the glass material allows the light to be passed through the glass as many times as required. After many test renders we attained a method to get the glass pretty close to the acquired result, through increasing the max depth for reflections/refractions in the rendering window, under global switches.

The depth of field is according to Sören a luxury, meaning very time-consuming unless you have the right resources or are rendering a very small image. He refers to a plug-in for Photoshop that can generate the depth of field effect, too, which we used instead.

Even some other smaller changes were created, for example moving the cucumber out of the bowl and placed among the oranges on the cutting board.

To reach our result, we have also made a couple of changes in the rendering settings with some help from Sören. These changes were made to maximize the quality and get a shorter rendering time. The change that was made was.

Adaptive QMC image sampler: min subdiv 1, max subdiv 4
Light cache: Subdivs: 600 sample size: 0.02.

rQMC Sampler: Noise threshold: 0.01, Min samples: 8, Global subdivs multiplier: 6.0

4.3.3 Postproduction in Photoshop

Due to the lack of enough computer power, the image had to be rendered in several pieces. All pieces were composed together and masks for all layers were created as the first in the image editing process (Figure 23).

Some areas needed more attention for correction than others. The glass cabinet was color corrected a bit: the glass shelves more bluish, the green plates saturated to white. The overall lighting was adjusted a bit, too, since there were glowing areas behind glasses.

The table to the left of the image did not require that much modification. There was only some kind of strange light artifacts on the edges, which had to be removed, since the eye expects a shadow there.

The tile wall appears not satisfying even after the editing in Photoshop, although it looks better. It took some time to get a regular and even lighting over the wall, since the displacement was rendered with different light. Although from the exact same scene file and work station edges of the pieces had to be smoothed out and their contrast and intensity had to be adjusted to an equal level. Because of the different regions that the tile wall was rendered in it had different light intensity over each different region.

There were other smaller troubles with edges, unwanted color appearances or light that had burned out. All these problems were handled in Photoshop afterwards. One obvious example is the kitchen bench to the right, which is just too white.

Even focal depth was added in Photoshop with the help of a plug-in called depth of field generator pro, since it was impossible to render the image with depth of field on.
Figure 23: This is the composed image of all the rendered pieces, at the beginning of the image editing in Photoshop.
4.4 Experiment

After some long days and tiresome nights the images began to start looking like something close to an end result. However, because all of the unexpected problems we encountered there is no use for an experiment with test groups. It was thought to have three different test groups. Group one we wanted to test where professional some people working at Magoo and IKEA who have both wide experience and practice in photorealistic imaging. Group two would be people experienced in 3D but not in this specific field, not as experienced in this current branch as group one. And the third group would be people that are totally inexperienced with 3D. The use of this kind of survey is obvious to see, how easy it is to tell the difference between real and “fake” and also, of course, how well the task has been carried out. But now in obviously there is no time to make such a review and no need because of the obvious flaws in our image.
4.5 Final image

Because of the nature of this project, scientific answers are hard to deliver. However, on the other hand, a subjective opinion can easily be documented. (Figure 25)

Figure 24: This is our final image, rendered with v-ray and adjusted in Photoshop.
The result of our final image (Figure 24) is not what was expected. In some areas the image is really good, however in some areas not quite at all as good. For example, the floor and the kitchen table in the left part of the image looks in our subjective opinion really good, more intense and alive then the original photograph which has such dull and numb colors. On the other hand the lighting on the kitchen tile is completely burnt out with white light.

4.5.1 The little things

A very important component in a realistic image is propping, little decorating things, and small details of objects everywhere in the scene, as for example books on the table shelf, the fruits, the oven hatch, potholders and even the cracks in the wooden floor. Without accessories like this a kitchen might still look like a kitchen, but not like it is made to be used or that someone might want to use it. “Disorder” is another key for the same result; if everything is strictly organized and mathematically perfect the observer gets the feeling that something is wrong.

4.5.2 Flaws

One of the obvious flaws that have previously mentioned is the kitchen tile. The lighting upon it has been discussed and redone over and over again without obtaining a satisfying result. It is not only the lighting on the kitchen tiling is of high enough quality, but also the texture does not have the same quality as the rest of the image. The reason why things have turned out this way has already been explained and do not need further mentioning.
5 DISCUSSION

No matter what the “rules” are today, for producing perfect photorealism, there are always trends and feelings involved, which are changing, too. It is also a question of marketing and what sells. For example, IKEA prefers very shiny fabric on sofas, arm chairs, chairs, etc, while the original furniture is not that reflective.

5.1 Useful means when creating photorealistic CGI

In this ongoing project a lot of neat tricks and other methods of choice have been discovered. For example, HDRI images on the environment map slot in on the texture for metal materials work really nice to get a sharp, bright reflection.

New for us was testing the v-ray light: dome. The dome is said often to be used as a skylight, and it has worked really well in this production as daylight, although it can be found hard to control and fine tune.

The lights to the left, above the table with the fruit and vegetables on, are called target point light. Instead of using an intensity value and a color on the light, a particular color temperature (Table 1) can be set, specified in Kelvin. When familiar with how the color temperature system works, this is a very fast and efficient way of instantly receiving the light that is “real.”

Depth of field is a great tool for any 3D artist to get a more lifelike environment and a realistic feel to a scene. It helps or even forces the eye to interpret the image as if it had the depth, which the depth of field implies.

There are also a few obvious things that need mentioning. For example shadows, it is very easy to forget and not even notice that something does not have shadows, but with shadows the scene becomes much more realistic and the eye does not mediate that something is wrong.

Another method of choice that everyone should already be aware of is the necessity of maps. Maps such as displacement map, bump map, opacity map, reflection map, and as previously mentioned environment maps. When creating a realistic material the use of all these different maps helps a great deal. A plain texture upon a material will not provide a realistic feel of an image.

5.2 Pro & Contra photography

The traditional way of producing the images for the IKEA catalogue or database with photography includes a lot of disadvantages. The very reason why IKEA wants to proceed to 3D production is the inefficiency of photography when it comes to larger furniture and room settings. It takes loads of resources as craftsmen, studio space, equipment, and especially time to construct, decorate, and break down everything again. All this costly arrangement is usually create for probably only one final image. Even the high technology cameras, the photographer’s equipment, the lights, filters, bouncers, etc are expensive in comparison to a 3D production. Especially a kitchen
scene similar to ours will take about a week to construct with tiles on the walls, building the kitchen furniture, and propping. Sometimes they even have to fix electricity and water pipes. And when the final shot is completed, everything has to be disassembled again, and this includes a great deal of manpower. No further shots can be taken for instance with a different camera position or angle, or with a different lighting or just for changing one type of a stove for another. Those modifications have always been completed during the retouch in Photoshop.

There is always a retouch needed, since all objects have to be extracted and placed on a neutral, white background. Another disadvantage for photography is the heavy flash light that can hurt the eye’s retina.

5.3 Pro & Contra 3D

In comparison to photography, it is much harder to experiment with light in the scene. A photographer can easily try different reflector screens or bouncers and light intensities where the changes are immediately visible. When it comes to 3D, every change has to be rendered before the artist can decide on the results. This process can be very time-consuming, especially for heavy scenes as room sets. Even little modifications of one light can affect the whole scene. This becomes impossible to illuminate an object with light the same way as a photographer.

![Figure 26: Photographers working with light; they can analogue adjust the intensity of bouncers.](image)

The rendering algorithms cannot be completely controlled by the user, as Sören said: “They are cheating a lot when it comes to material and textures.” Bengt Larsson also gave a metaphorical explanation: “People think they can trust the technique. While crossing an intersection if the light is green, even it demands checking both sides to be sure.” (2)

A similar problem is the output of the images, which obtains the sRGB gamut. This is a more limited gamut especially when producing images for professional prints, such as the IKEA catalogue.

The greatest challenge is still to create natural reality in 3D, to balance the imperfect with the perfect, which is the subject of this thesis research paper. It is regarding to tricking the eye and making it believe that there is perfection, even though there is not. The 3D artist has to create with the motto “imperfect makes perfect.” Photographers do not have to struggle with this problem.

The enormous advantage for 3D is of course the ability to use the scene over and over again. If modifications have to be made, such as changing colors of kitchen doors or
tile walls, replace the stove with another, adjusting or replacing the furniture such as
tables or chairs to a new product line, it is simple. It is even easier to reuse models and
scenes and place them together in new creations. Reaching this level is IKEA’s main
goal. Another useful aspect of the 3D is the cost. If you would have two photographers,
three engineers working on one scene to make it within 2-3 days, one single 3D
professional with the qualified skills and experience could create this scene in less than
one week. That equals three times the productively working with 3D.

5.4 What could have been made better, and how?

What could have been made better? Nothing created by man is flawless, since there is
always something which can be improved. Once the project is done, it is very simple to
point out what is wrong and what looks bad. However, our subjective opinion is that
we have done everything we could, within the strict time limitation to get the image as
good as possible.

5.4.1 The image

As previously mentioned, nothing is flawless. In our image, the light set up needs more
time for a revision. In the overall image the light is pretty even and good except for
some areas that are too bright or too dark. However the clear, realistic feeling has
gone missing. We have used a classic three point light setup, one main light, with the
highest intensity from the right side, coming in through the window. A light from the
front, one large light from the same position as the camera with a low intensity and a
smaller light in the background coming from the left, mostly illuminating the floor. This
setup fills its purposes; however it delivers not the feeling of a bright sunny day. To
achieve a more accurate lighting in the future instead of a dome from the outside the
use of a “target direct light” has been known to give a nice direct highlight. We tried
this method during the process of lighting of the scene, but without a good result.
With more time to fine tune this type light a more suitable result might be reached.

The next troublesome area of our image was the kitchen tile. It has been made with a
special “double sided” material with stone in the tile and a specular layer above to get
a realistic result. Upon the tile a displacement map was added to get an accurate
geometry. For some reason, that is still unknown to us, it did not appear as we
expected. Bright reflections on the edges are missing and in between the cracks some
of the depth is lost where the light is intense. A possible solution to this problem might
be to use a different kind of material to get the inquired result, or maybe model the
tile in hard geometry and control the result that way.

5.5 Further research on the topic

Our topic, “Photorealistic rendering,” is an extremely broad subject. To think, that one
thesis could capture all the knowledge needed to explain photorealism, would be plain
ignorance. However, we like to think of this as a foundation for continued research.
For example, one research topic might be “Photorealistic lighting for indoor
environments” or maybe “Texturing solid materials for photorealism.” The previous
mentioned topics are pretty scientific, and might not be the best entrance to an
answer that will pinpoint the essence of photorealism, just because of the fact that
photorealism is such a subjective field of expertise.
6 CONCLUSION

The purpose of this research thesis was stated that this research would try and evaluate methods or at least try and identify what makes an image photorealistic. Because of all the problems that we ran into the last two weeks, there was no time for a final experiment and therefore to draw a conclusion upon much of the theories in this thesis is not viable. However, to be able to create photorealistic images with 3D software, it is a requirement to understand all the pros and cons with photography and 3D. A common belief amongst many 3D artists is that they do not need photography and that they are the new breed of photographers. Seeing that almost every tool in today’s 3D software has a background from photography or the printing business, without any knowledge in these areas a 3D artist will become very limited.

No two room settings are alike. Because of this, a new approach is required every time a new scene has to be made. Therefore, when creating each new scene, it is a time-consuming process to test different light setups and tune it to perfection. Only with very high knowledge in this certain area of expertise and a lot of practice this development procedure can be abbreviated.

The hardest part in our experience would be the lighting. Once a material has been created, it should be represented as it is. The lighting on the other hand is more of a relative area. Therefore, it is very important to know how lighting works and how the different rendering methods render light. When lighting a room scene, it is mostly common to have a main light from one side, preferably the right and a support light from the front/above to illuminate the scene in a soothing way, and finally a small extra light from the left/back to give the extra touch to the image, for example to lighten the shadows a bit. There can also several secondary lights added, as in our scene from the oven fan or above the kitchen table, which have to emit light as well.

A significant discussed topic is the light’s temperature, to generate a more lively feeling in a scene with the use of warm and cold light. One simple rule of thumb is daylight or lights that come from an outside environment should be cold and kind of blue with a high color temperature, while indoor lamps have a low color temperature, a yellow touch, a bit dim light and not that intensity as the bright cold light. However, it seems like this paper has captured and summarized a good portion of knowledge in that certain area and hopefully reflects it outward as well.

A great advantage, when rendering is to have a big resource of hardware power. For example, a render farm is essential for big rendering project, since few 3D artists can afford a high powered computer to work on. Otherwise, the texturing and lighting procedure can become frustrating and nerve-racking from time to times, as for us.
7 REFERENCES

1. IDS, IKEA Design Studio.

2. **Larsson, Bengt.** technical image responsible. s.l. : IKEA Communications AB, april 2007.


16. **Purcell, Timothy John.** *RAY TRACING ON A STREAM PROCESSOR.* s.l. : stanford university, 2004-03.


26. **Rackwitz, Anja.** pictures, taken at IKEA’s photo studio.


### 7.1 Persons

IDS, IKEA Design Studio.

2. **Larsson, Bengt.** technical image responsible. s.l. : IKEA Communications AB, april 2007.

25. **Rackwitz, Anja.** pictures, taken at IKEA’s photo studio.

### 7.2 Websites

http://www.dict.cc.


http://java3d.j3d.org/tutorials/quick_fix/dot3_bumps.html.


### 7.3 Reports


16. **Purcell, Timothy John.** RAY TRACING ON A STREAM PROCESSOR. s.l.: stanford university, 2004-03.


### 7.4 Books


7.5 Table of figures

Figure 1: IKEA Design Studio.................................................................4
Figure 2: ACEPT W Group, Depart. of Physics and Astronomy, Arizona State University,
http://accept.asu.edu/PiN/rdg/color/color.shtml, 26 December 1999.........................12
Figure 3: Gamproducts, Inc, http://www.gamonline.com/catalog/colortheory/spectrum.gif,
2007-05-29 ......................................................................................12
Figure 4: ciexyz29082000.pdf: Gernot Hoffman, CIE Color Space *with own modifications. ....14
Figure 5: ciexyz29082000.pdf: Gernot Hoffman, CIE Color Space.....................................16
Figure 6: Own render............................................................................17
Figure 7: Own render............................................................................18
Figure 8: Paul E. Debevec, 1998, http://athens.ict.usc.edu/probes/ ..................................21
Figure 9: The CGSociety, http://features-tempcgsociety.org/gallerycrits/140159/140159_1177689272_large.jpg, 2007-05-29....23
Figure 10: Own render...........................................................................25
Figure 11: Own render...........................................................................25
Figure 12: Picture taken at field trip to IKEA, April 07, (25) ..............................................27
Figure 13: Own illustration.....................................................................28
Figure 14: Own illustration.....................................................................28
Figure 15: IDS, Bengt Larson.................................................................29
Figure 16: Gregory, Richard L. Knowledge in perception. S.L.: Department of Psychology,
University of Bristol, 1997 .....................................................................31
Figure 17: Gregory, Richard L. Knowledge in perception. S.L.: Department of Psychology,
University of Bristol, 1997 .....................................................................32
Figure 18: Edward H. Adelson; Prof. of Vision Science Dept. of Brain and Cognitive Sciences
Massachusetts Inst. of Technology,
Figure 19: Own photomontage/illustration ..................................................34
Figure 20: Own photomontage/illustration ..................................................35
Figure 21: Own photomontage/illustration ..................................................36
Figure 22: Linda Ferroni, IKEA of Communication, ca. 2004 ....................37
Figure 23: Own render.............................................................................41
Figure 24: Own work - final image ..........................................................43
Figure 25: Own photomontage, IDS ..........................................................44
Figure 26: Own pictures taken during the field trip to IKEA.............................46