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University of Applied Sciences

# Image Editing: Case Study HDR

Jussi Kääriä

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**Abstract**

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| **Author**<br>Jussi Kääriä | **Group**<br>BITE05K |
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When a photograph is taken, a single capture can represent only a specific amount of information from the captured scene when comparing what a human eye can detect from the same scene. A single capture cannot record the whole dynamic range of shadows, details and colors with only one exposure. The same problem continues when the image is reproduced on a display or on a print. That one print simply can't show everything that a human eye sees when looking at the same scene. People have become used to how a picture and a photograph look like, but it's actually quite far from the reality of the same scene. Technique called HDR (High Dynamic Range) imaging makes it possible to capture all the highlights and shadows from several different circumstances and can achieve impressive tonal and color results.

HDR is quite new technique in the field of photography and image editing. It is where photography and heavyweight computing unites. There are two parts to HDR imaging: shooting and processing. The shooting phase is usually consistent, but the processing phase varies widely according to the software in use and also on the different alterations that are made to the image.

This thesis is an investigation into the world of HDR imaging. The purpose of this thesis is to go through what is HDR, what is it for and how it can be produced. As a part of this thesis there is a case study that goes through part by part the whole imaging processes from shooting to final image.



**Key words**
HDR, Image Editing, Tonemapping, Photography, Exposures

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## Terms and abbreviations

| | |
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| **HDR:** | Abbreviation from the words High Dynamic Range. It is a technique that allows a greater dynamic range of exposures |
| **Dynamic range:** | A term used to describe the ratio between the smallest and the largest possible values of a specific quantity such as light |
| **Exposure:** | Term in photography that indicates the total amount of light to fall to the photographic medium that is the camera's image sensor or the photographic film of a film camera |
| **Image sensor:** | Device that converts an optical image to an electrical signal. Every digital camera has an image sensor |
| **Tonemapping:** | Technique used in image processing to map the appearance of high dynamic image for a media with a more limited dynamic range as: print-outs and CRT or LCD displays |
| **LCD:** | A liquid Crystal Display which is a thin flat display device made up of pixels |
| **CRT:** | The Cathode Ray tube is a display device of vacuum tube containing an electron gun (a source of electrons) and a fluorescent screen |
| **Pixel:** | In digital imaging pixel is the smallest piece of information in an image |
| **Digital SLR:** | A digital single-lens reflex camera is a digital camera that uses an automatic mirror system and pentaprism or pentamirror to direct light from the lens through the viewfinder eyepiece |
| **Clipping**: | In photography clipping is the loss of image information where a region of a photograph is too bright for imaging system to reproduce it |

| | |
|---|---|
| **Contrast:** | Ratio between the darkest and the brightest area in an image |
| **Codec:** | Device or program capable of encoding and/or decoding a digital data stream or signal |
| **3D:** | Computer graphics that use a three-dimensional representation of geometric data |
| **Noise:** | Term used in photography to refer to a lack of image quality caused by color speckles. Noisy images usually have a grainy look with improper changes in colors |
| **Gradient:** | Term used in photography referring for example to the rate of changes of color tone in a specific distance or area |
| **JPEG:** | Comes from the words "Joint Photographic Experts Group" and refers to very common way of compressing photographic images |
| **Compression:** | Term referring to a method of making a file size smaller |
| **White balance:** | In photography white balance refers to balance of white color in images. It changes the overall mixture of colors and is used for color correction |
| **Shutter:** | In photography shutter refers to a device that allows light to pass for a certain period of time to expose photographic film or light-sensitive electronic sensor |
| **Cropping:** | In photography and image editing cropping refers to removing unwanted areas from an image to improve overall composition |
| **Composition:** | In photography composition refers to the arranging of visual elements in an image |
| **RGB:** | additive color model in which red, green and blue light are combined together to create a large selection of different colors |

**TIFF:** comes from the words "Tagged Image File Format" and refers to a flexible and adaptable file format for handling images

# 1 Introduction

A lot has happened with photography and image processing during the last few years. The hardware and software have evolved tremendously and also the decreasing of prices has made it possible for amateur users to acquire all the time better and better equipment. The biggest change has happened in the digital camera markets. The prices of Digital SLR cameras (single-lens reflex) for example have decreased a lot within last couple of years. Also the range of different models tailored for every different consumer group have affected to the fact that millions of pictures are being taken every day. Software like Photoshop has brought the "digital darkroom" in many homes making the image processing phase more common. But even though cameras have evolved and there is so much you can do to an image with the image processing phase nowadays, there is still restrictions to what a single capture can record from a scene. We have used to how a picture or a photography from a specific scene looks like, but the fact is that a human eye can record a much wider range of highlights and shadows from that same scene. Technique called HDR photography makes it possible to produce images with much greater light range that is normally possible and creates an effect that reflects more closely how the human eye records the scene and often can go even beyond it.

HDR is relatively new technique, but it's becoming more and more popular all the time. It is very software based technique and requires a lot of patience and precision, but can produce close to painting like results. HDR photography has two parts: shooting and processing and both of them require specific hardware, software and technique. For the image to have wider dynamic range from one single exposure, several exposures of the same scene have to be taken. This makes the shooting phase more difficult because the capturing of several exposures from the same scene requires the camera to be absolutely still during the adjusting of settings and shooting of each frame. Also moving objects in the scene can cause problems for the shooting as sometimes it's necessary to take close to ten exposures of the scene. So because of that, HDR photography can be utilized only to a specific kind of subjects. After the shooting phase, begins the processing phase. Processing phase is in many ways the more important part of HDR technique. For this part there has to be suitable software for the image generation. After the different exposures have been taken, they have to be merged into one single image. This part is not difficult or long, but the single image is still not ready for viewing without the tonemapping phase. Most of the common Medias as LCD (Liquid Crystal Display) display and print-outs from a picture have limited dynamic range. This means that the generated single image from the several exposures cannot be displayed properly without tone mapping. Tone mapping is a process where high dynamic range picture is adjusted to more suitable form mak-

ing it possible to be displayed in Medias with more limited dynamic range. Tonemapping is accomplished with series of image settings.

### 1.1 Research problem and the structure of the thesis

The purpose of this thesis is to investigate HDR technique more in depth. This thesis answers to the research problem: "how are HDR images produced". The research problem is investigated both theoretically and practically. The whole process is relatively technical and has many phases. This thesis is written in two parts. The first part will go through the theoretical part of HDR technique. It includes information on the history of the technique, why was it developed, which different technical elements affect HDR and also how is it done from the capturing phase to the processing phase. The second part is the documentation of a case study where a HDR image is created from the start to finish. So in a way this thesis is a combination of a research project and a system project, but more than anything else this is an investigation of HDR technique.

Like mentioned before, HDR technique is becoming more popular all the time. It is in many ways one of the new "big" things in image processing and the importance of it will be growing in the future. When considering digital cameras, HDR function will probably be included to the picture modes of cameras in the future. HDR is nevertheless quite new concept to the average amateur photographer. This thesis can be used as a guideline or as an instruction guide for HDR.

## 2 Key points in the history of HDR

Even though HDR imaging is rather new technique, the basic idea behind the technique has existed for quite a long time. The popularity and the ever more growing use of the HDR technique today is largely due to the development of HDR software, the processing power of computers and the evolving of digital SLR cameras, but the theory behind high dynamic pictures dates back a long time.

High dynamic range images were first introduced to the public by a man named Charles Wyckoff. His detailed pictures of nuclear explosions that had wider dynamic range appeared on the cover of Life magazine in the mid 1940s. Charles Wyckoff devoted much of his life in developing of 3-layer photographic films that worked for the basis of today's HDR technique.

The main idea behind the 3-layer film was to capture different exposures of the same subject and the image of nuclear explosion that covered the life magazine was one of the first in kind. It depicted the explosion with high dynamic range from darker outer parts to inner core. HDR technique evolved gradually after this and it wasn't until 1985 when the whole technique took a big step towards to what it is today when the high dynamic range imaging file format was developed by a man named Gregory Ward. The new file format was called "radiance RGBE file format" which was the first and still the most used HDR imaging file format. RGBE stores pixels with more information allowing pixels to have extended range and precision. In 1997 a researcher named Paul Debevec introduced the technique of several differently exposed images generated into one high dynamic range image to the computer graphics community. This was one of the pivotal stages in the history of HDR technique. (Freeman 2008, 7.)

After the introduction of the HDR technique in 1997, the technique has evolved bit by bit to its current form. The two important persons for HDR, Gregory Ward and Paul Debevec, have played a big part in the developing process and they have contributed a lot in the popularization of the technique. In 1998 Gregory Ward developed Photosphere which is one of the first HDR software. It allows user to browse, tonemap and generate HDR images. In 2001 Paul Debevec developed a technique called Real-time High Dynamic Range Texture Mapping which allows representing and displaying high dynamic-range texture maps (HDRTMs) using current graphics hardware. In 2002 a man named Ranaan Fattal developed Gradient Domain High Dynamic Range Compression, which is probably the most popular tonemapping operator that is used for example in the popular Photomatix HDR software. In 2004 Paul Debevec continued his HDR research by direct HDR capture of the sun and the sky. In 2006 BrightSide Technologies developed MPEG-HDR video file codec that becomes the very first video file format for HDR imaging. (Freeman 2008, 7-8.)

### 2.1 Use of HDR today

Today many of the photography forums and magazines have the term HDR mentioned in many contexts. It is one of the most popular new techniques in photography and image processing. The development of computers and image processing software and decreasing of camera prizes have affected also for the popularization of the technique but also the really impressive results it can give have caught the eye of many photographers around the world. But the professional and amateur photographers aren't the only ones using the technique. Nowadays HDR imaging is widely used in the movie industry for movie special effects. HDR images are

essential in movie industry when fitting CGI (computer generated imagery) into live-action scenes. HDR is a technique that is used for example in such films as The Matrix and Spider-man. Architects use the technique as so does many different kind of publishers. HDR is also widely used within gaming industry and 3D (three-dimensional) designers.

HDR is still a new technique and its benefits have been recognized by several different industries. There is still a lot that can be developed, like the actual shooting phase, and this will most likely have an impact for the future of many areas, like the future camera models.

# 3 Theory behind HDR imaging

To really comprehend everything that is evolved in HDR imaging, it's best to divide it into pieces. It's not probably necessary to know every technical detail in order to make final HDR images, but HDR is a technique that addresses many of the common problems in photography and image processing and is therefore best to examine in theory also.

Most of scenes have a large variety of brightness range and the most problematic for photography are the scenes in which the highlights are much brighter than the shadows. This causes shadows to lose detail and it's also common for the image to be under- or overexposed causing the picture to be too light or too dark. HDR makes it possible to get the exposure right and to overall expose to scene correctly. There are several factors that have to be understood before the tone mapping process. They include brightness, lightness, luminance and reflectance. These are especially important because many HDR software applications usually isolate one or another of these and work on them separately in the tone mapping process. (Freeman 2008, 10.)

## 3.1 Light, brightness/luminance and reflectance

Light is radiant energy that is experienced through the human eye. Eye has pigments and other factors that cause us to be sensitive to some wavelengths more than to others. For photography light is everything. Photography depends on light, but even understanding fully what it is and how we see it; it still causes problems for even the most experienced photographer. It isn't always clear what the best way to light a scene is. HDR makes it easier because of several exposures. (Freeman 2008, 11.)

For HDR imaging the most important quantity is luminance, which indicates how bright a specific surface appears. Luminance describes the amount of light that is passed through or emitted from a surface or an area. In tone mapping process luminance is one of the main variables that affect on the final image. Brightness is though the more common and more used term. Brightness describes the perception of luminance and is not objective and is therefore hard to measure. It still describes the appearance of luminance for many. Lightness is also a perceptual term and can in many times be connected to brightness. (Freeman 2008, 11.)

Reflectance is the ability of different kind of surfaces to pass on some of the light that falls on them. When this happens, the surfaces modify the falling light in many ways. When it comes to high dynamic range images, the range of brightness when compared to different surfaces under the same light is quite narrow. The big difference in brightness in HDR images comes from illumination which determines how the image interplays with light and shadows and where is the light source in the image, which parts of the images, are lit and which are under shadows. (Freeman 2008, 11.)

### 3.2 Dynamic range of a scene

There are several variables that affect on the dynamic range of every scene. Two very important ones are the range of light falling on a subject and the reflectivity of surfaces where the light is falling. When these two are combined, the dynamic range is potentially very high. If a scene doesn't have any bright white reflections or surfaces, no strong mirror like reflections nor any dark shadow areas, the scene can be captured fairly naturally on the image sensor of most of the cameras. This kind of scene has a low dynamic range and a photograph from it has no "clipping" where regions of the image would be too bright or too dark loosing image information. However, when the scene has a clear sky with clouds, sun shining, reflections from water and wider shades of shadows, the dynamic range will rise. On top of that if the scene has a straight sunlight towards the camera, the scene will have even bigger dynamic range. Straight sunlight also causes more shadows to the image. This causes problems for the image sensor in all cameras. This is also where HDR imaging comes to play. (Freeman 2008, 12-13.)

HDR technique and tone mapping can be utilized in almost any scene, but it is not at all always beneficiary. The tonemapping process can be easily overblown causing unnatural characteristics to an image. Tonemapping can be even used for a single image with only one exposure. But all in all it comes up to taste and common sense when HDR should be applied. This

is entirely up to the dynamic range of the scene. If the scene has a high dynamic range with bright lights, shadow areas with a lot of information and large variations on contrast of the scene, HDR gives great results.

### 3.3 Dynamic range of displays/print-outs

As HDR imaging addresses to the problem of cameras inability to capture all the information from a scene that can be captured, the problem continues with displays and print-outs. In most cases the problem gets even worse when displaying the image. These two methods of displaying the image neither come even close of the tonal range of a high dynamic range image. A CRT (Cathode Ray Tube) display has a dynamic range of 200:1 or less, and the more modern LCD displays has only a small improved dynamic range of 400:1. Even the best paper print has only 100:1 dynamic range. For comparison a scene in real world can easily have a dynamic range of 10000:1. LCD displays have taken over almost completely the computer display markets from CRT displays and also the TV markets for that matter. LCD displays use a uniform backlight and they don't suffer from maximum brightness limit as do the CRT displays. However, unlike the CRT displays, pixels of LCD displays can't be turned off even when it displays black. This causes the pixels of LCD to leak light from the backlight that is constantly on. This is one factor that lowers the dynamic range of a LCD display. Displays are evolving all the time of course and a technique called LED LCD brings a new kind of backlighting system for LCD displays where the displays uses small led lights for the lighting. This enables the display to light only the needed region of the display making the black colour more natural and enhancing also the dynamic range of the display. (Freeman 2008, 18.)

Technical instruments like LCD displays will undoubtedly evolve all the time and the dynamic range on them will grow even more in the future. But still for most photographers and most people in general the most common "media" for images is still a print. There are only a few things that can affect to the dynamic range of a paper print. One main thing is the quantity of reflectance that the paper can reflect; other is the combination of maximum pigment absorption and minimum reflectance. Glossy surface can also give an appearance of better contrast, but it only can be achieved when changing the viewing angle and getting the right amount of light reflecting from the surface. But all in all even with these enhancements the maximum dynamic range for a print is still around 100:1. (Freeman 2008, 18-19.)

When we think of the dynamic range of a real scene to the dynamic range of a print-out for example, the difference is huge. Along the way from selecting a scene and pressing the shutter

button of the camera to processing the image on a computer and making the print, a lot of information has been lost. This is the problem that HDR and tonemapping tries to solve.

### 3.4 Tonemapping

The benefits of HDR imaging are noticeable when comparing a normal single exposure images with HDR images. But still at this moment HDR images cannot be used without a process called tone mapping. One of the critical issues with HDR imaging is how to take all the brightness information of a real-world scene and compress it so that it can be viewed with a limited dynamic range media like LCD display or print-out. This is where tonemapping comes to play. Computed tone mapping is relatively new thing within image processing, but getting more and more popular with HDR imaging in general. Tonemapping is highly complex process and it includes many different phases, but the purpose here is to go through just the key points of it.

At this moment there is only one display device on the market that can display the full brightness range called a Brightside monitor. But it is very costly and still quite new technology, so it isn't yet very reliable. With tonemapping HDR images can be viewed on a normal LCD display that can be found from almost every home. The purpose of tonemapping is to simply compress HDR image to equally fit into much smaller scale. When you start the generation of HDR image, you can have even ten different exposures of the same scene. Those exposures can have a wide variety of brightness levels between them and for them to be generated into one photograph, tonemapping is used. This allows user to squeeze huge amount of information into one image and it is in many ways the most important and the most demanding phase of HDR imaging. During tonemapping there are numerous different variables that can be adjusted and which will affect the final image. Knowing how to adjust these variables is the challenge in tonemapping. In the end it comes to personal perception and taste which adjustments are proper. Usually these can be discovered through trial and error because there are also many problems in tonemapping and in HDR imaging in general which are examined in chapter 3.4.3. (Freeman 2008, 70.)

#### 3.4.1 Tonemapping operators

All the available HDR software on the market, designed entirely at photographers, are based on specific research projects. The pioneers of HDR imaging, including Gregory Ward, Paul Debevic and Ranaan Fattal were the ones who put everything into motion. In the beginning

of 1990s their researches resulted in a way to compress the huge range of real-world brightness into a viewable form. The researches resulted into several pioneering tonemapping operators (TMOs) which basically determine how the picture is being treated in the tonemapping process, which pixels are manipulated and how. These first TMOs are well documented and the source code for them is available for example in the internet and they can be experimented with PFSTools package which is a set of command line programs for writing, reading and manipulating HDR images and video frames. There is however practical difference between this research software and the software aimed at the consumer markets. The aim of the research software is quite academic and they usually lack some of the tools designed to achieve in the more natural look of HDR images and they also go much more in depth of the technical aspects of HDR imaging. All the tonemapping operators used in the most popular HDR software, like Photomatix from HDRsoft, are nevertheless based on these pioneering TMOs. (Freeman 2008, 72-75.)

Tonemapping operators are usually divided in two main categories, global operators and local operators. With the global operators the tonemapping processes are applied to every pixel in the same way and the pixels with the same original value will get the same treatment. So every pixel will be mapped the same way, regardless of the value of the surrounding pixels. Local operators take account of the pixels surrounding each pixel which is being worked on. The most common local area is 3 by 3 pixels block and with local operators it is possible to for example adjust contrast selectively by location within image. The division of tonemapping operators into two groups is not so distinctive nowadays anymore because the HDR software are being evolved all the time. It is possible also to combine the both groups and use local operator in global (whole image) context. Beyond global and local operators there are other two different ways of tackling the problem of separating luminance (light falling on a scene) from reflectance (light reflected from surfaces). The first one is frequency domain operator. Mathematically, it is possible to encode images by their frequency, like sound. Low frequencies are the large-scale contrast and the high frequencies are the small-scale contrast, details to be exact. Working with frequencies makes it possible to cut down big differences in low frequencies while preserving or altering the high frequency details. In this way it's possible to work both in global and local way. In a relation to this is there are gradient domain operators. Low frequencies, big changes in the image, tend to have long gradient changes from dark tones to light. However, the high-frequency changes at the detail level change more steeply across a small area within the image. So, the contrast gradient can be used to distinguish local and large-scale contrast. These gradient domain operators are heavily used in commercial HDR software. (Freeman 2008, 76-77.)

Even though there are more than 20 tonemapping operators available, there are only a few practical software choices. There are several reasons for this, but few of the main are the number of tools available, precision, operating platforms and the support for detailed issues like RAW format, which is examined more in chapter 4.

### 3.4.2 Single exposure tonemapping

In HDR imaging tonemapping is vital for enabling the images to be viewed with normal displays and print-outs, but tonemapping is not only for HDR imaging. Tonemapping can be also used for single exposure images and basically for every photograph. When simplifying the tonemapping process, ultimately the basic goal of it is to make beautiful images. For this purpose the tonemapping process of any image editing software is ideal. There are so many different controls for the user to use for editing the image and many of them might be missing from the basic functions of image editing software.

### 3.4.3 Tonemapping problems

There are of course several issues with HDR imaging that can cause problems. The actual shooting phase has few issues that have to be taken into consideration which are examined in the capturing chapter. The image generation phase though has several issues that have to be taken in consideration. In many ways the phase after shooting is the more important phase and it is also the more technical phase. With the technicality come more variables which affect the final image.

One of the first problems that can occur in tonemapping is the problem of content. There are many controls that the user can use to affect the image, but there are of course limitations if the sources, meaning the exposures, are not shot with enough information. If the exposures are correctly shot they will be combined for a one image. After that begins the actual tonemapping with several technical issues. Ghosting is a term used for movement in the image. Ghosting occurs when there is a moving object like a branch of a tree that is moving as a result of windy circumstances. In every exposure the branch is little bit in different position and when the exposures are combined, it seems that the branch is out of focus in the final image. Halos are one of the biggest issues with HDR images. Halos refer to a glowing effect that is located in a picture where there are sharp boundaries between dark and light areas. Within a scenery picture for example where there is a building with a blue sky behind it, the area where

the roof of the dark building ends and the blue sky begins, there is a zone of light glow. These bright luminosity edges are caused by tonemapping operators which adjust contrast in relation to local surroundings. Noise and dirty textures are a common issue also with HDR imaging. With several exposures comes the added risk of noise in the final image. Tone mapping settings are adjusted to maximize fine detail in an image but they also tend to exaggerate noise and other small artifacts in the image. So it's important that the tonemapping is not taken too far in order to keep the natural and noise-free appearance of the final image. Lens flare is a problem that can occur usually with all kind of photography. Lens flare is basically light that is scattered throughout an image in most cases in unwanted way. When shooting against a light source, light can cause over bright areas in the image and also color aberrations. These can be especially problematic for HDR images, because tonemapping tends to exaggerate these effects. Including with the above said problems, one important issue is the user. One of the things that are always linked to discussions about HDR imaging is naturalness. It might be tempting to overdo the tonemapping phase and this might cause the final image to lose its natural appearance. This is ultimately in the hands of the user. (Freeman 2008, 70-71.)

Even though there are several problematic issues with HDR imaging and especially tonemapping, the positive thing is that many of them can be solved. Some of the issues are constant and unchangeable but most of them can be dealt with attention to details and with knowhow of the tonemapping process. It is also vital to know at which stage of the image processing phase these issues have to be dealt. Most of the tonemapping software has functions specially designed for these common issues.

# 4 Capturing

In order to get to the tonemapping phase, the exposures have to be shot first. In HDR imaging everything starts usually with the capturing. When the subject is being chosen, it is vital to have knowledge on every technical detail that is involved with the capturing. It depends on the circumstances of the shooting environment on what kind of different settings there has to be used and for example how many exposures are needed. There are countless different settings and properties with modern day DSLR cameras, but in this chapter the purpose is to go through some of the most important ones when concerning HDR imaging.

### 4.1 RAW format

As the digital age in photography has taken over, the use of film cameras has diminished noticeably. With most of the DSLR cameras there is an option to shoot with two different formats, normal JPEG (Joint Photographic Experts Group) format and RAW format. JPEG compresses the shot images into easily viewable form and is the most common and most used image format. RAW format in the other hand is much more versatile format for image editing. While shooting with JPEG the camera not only compresses the shot image, but also adjusts some qualities of the picture. With RAW you get basically the digital negative of the image. There is no compression and enhancements of any kind. This allows the user to adjust the qualities of the image more freely afterwards. One big advantage is for example that the white balance of the image can be changed afterwards, while with JPEG it is that what is chosen at capturing. There are also other properties that can be adjusted which are not available with JPEG. So in a way where as the image processing of JPEG images is being done in the camera during shooting, the user does the processing to a RAW image after the shooting. Even though RAW files take much more space, with HDR imaging it is always recommended to shoot with RAW for the extra freedom in the processing phase. (Ang 2003, 35.)

### 4.2 ISO ratings

The term ISO comes from the words International Standards Organization, but in photography it has a specific meaning. ISO refers to sensitivity. With film cameras ISO described the sensitivity of conventional silver-based film. So for film cameras there are films with different ISO rating depending on which kind of situation or subject is being photographed. With digital cameras the ISO rating can be changed for each shot if wanted. So in that sense also digital camera is more convenient to use comparing to film camera. (Daly 2000, 39.)

But what is ISO for? Originally it was basically a standard measure of how sensitive film was to light. Because sensitivity affects the exposure required for an image, ISO ratings were described as "film speeds". With digital cameras user can change the exposure time with changes in ISO ratings for each shot if needed. So the purpose of altering ISO ratings is simply to change the exposure time and shutter speed. When shooting for example in low lighting, the exposure time gets longer. This usually causes the picture to be out of focus especially when shooting without a stand. ISO ratings have a big affect on how the exposure time is calculated and it works incrementally. For example if exposure time (how long the shutter will be open) would be 1 second with ISO 100 value, doubling the ISO value one full stop to ISO 200

would half the exposure time to 0,5 second. So increasing the ISO value, will give faster shutter times, making it easier to get sharper pictures with low lighting. But there is a downside to it also. When changing the ISO rating, it is usually assumed that the sensitivity of the image sensor is being changed. In fact this is not the case, but rather it changes the strength of the signal passing through the sensor, known as signal gain. The more gain and the bigger the ISO value, the more noise (digital grain) in the image. So for HDR imaging it is important to shoot with as low ISO value as possible to maintain best image quality. HDR images are usually shot with stands so there is no risk of out-of-focused images. (Lezano 2008, 50.)

### 4.3 Exposures/shutter speeds

With HDR imaging the capturing phase is basically all about exposures. The whole idea is to take several exposures with different shutter times to capture the whole dynamic range of the scene, as much information as possible. With different shutter times the image sensor is exposed for several predetermined periods of time. User can adjust the exposure time manually with DSLR cameras. Knowing from which exposure time to begin is important with HDR imaging. Almost all digital cameras have a LCD display from where the user can preview all the taken pictures. Most of the DSLR cameras have also so called clipping indicator. If the taken picture has an area with overexposed highlights, the camera will "flash" the clipped area in the LCD display. When starting the capturing for HDR images it is usually good to start with the darkest exposure where there is just some clipping of the highlights. Then the exposure is reduced a fraction of a stop until there is no clipping. The actual shooting starts from here. After the first shot is taken, the shutter speed is increased by two stops and the second stop is taken. For the next shots the shutter speed is increased always by two stops. The last frame of the sequence is usually the one where the darkest shadows of the scene are properly exposed showing all the detail. Most of the last frame is usually over-exposed showing only white, but it is important that the darkest areas still have information. The number of exposures needed for a specific scene depends entirely on the lighting and details of the scene. So there is no common rule on how many exposures are needed or at from what shutter speed the capturing should begin. Big influence is on the contrast of the scene. In many cases it might be enough to have only three exposures, but some scenes might require close to ten of them. (Freeman 2008, 40-41.)

### 4.4 Auto exposure bracketing (AEB)

Some elements and functionality of the HDR capturing process will probably be included in the future camera models, but there is already a function in many of the cameras in the market that can make the capturing process for HDR imaging easier. All of the DSLR cameras in the market and also most of the compact cameras have a function called auto exposure bracketing in them. In photography one of the more challenging things is to know how to expose a specific shot. There are many different kinds of scenarios that can cause the metering system of the camera to expose the shot wrongly giving the image an overexposed or underexposed look. This is especially a problematic thing for newcomers in photography. Auto exposure bracketing is developed mainly for this problem. The idea with this function is that when used the camera takes multiple photographs of an identical scene or subject, but using different exposure settings. This results into three differently exposed frames of the same scene for the purpose that at least one of them has been exposed correctly. The camera works in a way that one frame is exposed as the cameras metering system sees ideal, the other is underexposed and the last is overexposed. So the result is one "normal" image, one underexposed and one overexposed. For the under- and overexposed images the exposures are incremented with at least one stop up or down comparing to the "ideal" exposure, but the user can set the increments to be larger to get more visible changes for the second and the third image. AEB gives the luxury to compare the image sequence later on and the user can then decide which image is exposed correctly. This function is very useful in situations where it is hard to determine how to expose the shot, but it can be used also for HDR imaging. (Lezano 2008, 64.)

AEB function can make the process of capturing HDR images very easy, but it can't be used in all of the situations. When using AEB function the camera does most of the work for the user. When the shutter button is pressed and held down, the camera takes all three exposures automatically. So the camera changes automatically the exposure settings in between shots according to the predetermined settings. Sturdy tripod is still needed, but other than that the user has only to compose the shot and press the shutter release button. For a specific kind of scenes these three shots can be enough and they can be processed into HDR image. But because the camera takes only three shots, it can't be used in all situations and circumstances. For example in a scene where there is large contrast variations with dark shadow areas and bright highlight areas, the AEB cannot capture all the details that are needed to produce a HDR image of the scene. For this kind of circumstances it may need over ten different exposures and for that the user has to change the exposure settings manually between shots.

## 4.5 Histogram

Histogram is one of the most useful tools in digital photography to help to get the exposure right. It is usually available for most of the digital cameras, compact and SLR. Histogram is basically a two-dimensional graph that represents an image's tonal range. Histogram can offer a big help to photographer to expose an image correctly when it is interpreted in the right way.

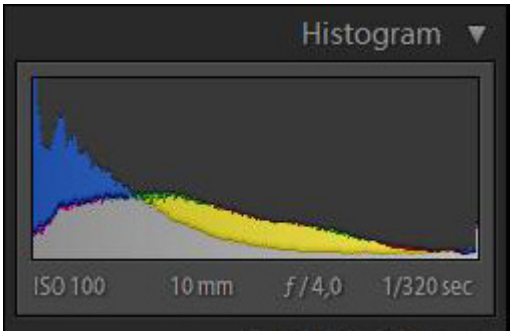


Image 1

Image 1 represents a histogram of a one single exposure image. The horizontal axis indicates the picture's extent from pure black to pure white. Pure black is represented by value 0 (far left) and pure white is indicated by value 255 (far right). The vertical axis illustrates how many pixels have the corresponding value. So if the graph is on the left side, the image is quite dark. If the graph is on the right, the image is light and possibly over-exposed. The middle point of the histogram represents mid-tones. User can use the histogram during the shooting phase to check how the image is exposed. In an ideal histogram for normal photography the graph would be spread through the whole axis with the highest point located on the mid-tones. So the graph would have a mountain like shape. (Lezano 2008, 66.)

In HDR photography histogram is especially useful. It might be difficult to know where the capturing sequence for the different exposures should begin and where to finish. The first image of the sequence is usually the one where the graph is heavily spread to the left and where the part that indicates white tones of the graph is in the middle. Then several exposures are taken and the last one of the sequence is the one where the histogram is heavily spread to the right and the part that indicates black tones is in now in the middle. So histogram helps to expose photographs correctly and it also makes the capturing phase in HDR imaging easier.

### 4.6 The process of shooting

The practical part of the capturing phase is quite straightforward. As already mentioned, every scene requires several exposures. For all the exposures to have sharp quality and little or none moving objects, it is vital to have a stand for the camera. It is possible to use surroundings for that, like fence or stable rock for example, but the best option is to use a tripod. Tripod has three separate legs that can be adjusted according to the surface. Then the camera is mounted to the tripod and it's ready for the composition of the image. When the image is composed it's time to adjust the shutter time for the first shot and then the different exposures with different shutter times can be shot. It is also beneficial to use a remote release for the shutter to eliminate camera shake. Even the smallest movement might be recorded to the image, because some of the exposures can be quite long, causing the ghosting effect in the final image. When the final image is shot, the capturing phase is basically finished and the processing phase can begin. (Freeman 2008, 43.)

In addition to the above said settings and properties, there are several features that can be used to affect the final image, like aperture, white balance and metering of the scene. Most of these are irrelevant for the actual structure of the capturing process, but many of them can be adjusted afterwards when shooting with RAW format.

## 5 Generation and processing

After the different exposures for the HDR image have been taken, it's time to move them into the "digital darkroom" meaning the computer and some image editing software. Before the tonemapping phase can begin, the actual HDR image has to be generated. For this there are several software in the market, which are discussed in chapter 6, but the working method in all of them is quite similar. In many of the HDR software there are clear tutorials for the generation of the image and the tonemapping phase. To begin the generation the software first asks for the differently exposed images. Then before the exposures are combined, user can choose from several options that the software will do to the image in the generation phase. Many of the software can for example try to reduce the affect caused by moving objects in the images. User can also choose a different white balance for the image before generation. After all the selections the exposures are combined into one HDR image. It usually takes a while for the software to process the image. The generation part is quite simple and almost everything is automated. After it is done, the HDR image will appear on the computer screen. But like mentioned already, this just created image is not yet ready to be viewed with normal LCD display

and it will look considerably unfinished. For the HDR image to have its final form, it will be tonemapped. (Freeman 2008, 46.)

When the tonemapping button is pressed, a new window will open with several tabs and sliders for many different kinds of settings. These settings include for example: strength (controls the overall strength of the tonemapping process), colour saturation (adjusts the saturation in all colour channels equally), light smoothing (affects in the way in which light is smoothed out across the image), luminosity (adjusts the overall brightness and contrast of the image), white point (sets the point beyond which outlying pixels will be clipped to absolutely white), black point (sets the point beyond pixels will be clipped to pure black), gamma (darkens or brightens the image without clipping highlights or shadows), temperature (controls the overall colour temperature) and microcontrast (controls the local contrast on a scale of several pixels. With these and many other settings it is possible to affect on the final image. Here it ultimately relies on the user what kind of end result will be produced. It may be tempting to take the tonemapping too far and the final image will lose most of its naturalness. This is one thing that the HDR images are being criticized for, the unnatural look. But with good taste, knowledge on the affects of the different settings and precision the end result can give really impressive impact. (Freeman 2008, 78-79.)

### 5.1 Post-processing

After the generation and the tonemapping phase, HDR image is practically finished. But like in all photography and image editing, even the so called final image can use some post-processing work. For this there are also several different software in the market, but Adobe Photoshop is by far the most used. Ultimately it comes once again to personal taste what kind of post-processing work will be done for the image. But even though there are countless of opportunities that can be done with the image, HDR image is close to its final form already after the tonemapping. Usually with tonemapped HDR images the post-processing work is quite small because of the already large variety of settings that are usually applied in the tonemapping phase. The common things that are done in the post-processing phase to HDR images can be for example: cropping (resizing the picture for a better composition or eliminating unwanted parts of the image), framing (giving decorative frames for the picture), and general enhancements (changes in contrast and other general image properties). When HDR image goes into the post-processing phase, purpose there is basically just finalizing the image.

# 6 HDR software

Like it was already stated in chapter 3.4.1, there are over 20 tonemapping operators but only few practical software in the market that are generally used. All of them have the same basic functionality and principle with some deviances. All of them could be a subject for an extensive report, but the purpose here is to go through some basic information on them.

Photomatix is currently the most controllable and the oldest consumer tool in the market. It is the most used and the most common HDR software. It was developed by a French company called HDRsoft. The first version of Photomatix was released in February 2003 as a result of a research project started in July 2002. The popularity and the great usability of the Photomatix software are largely due to development based on user feedback. Photomatix is the software that is used also in the case study part of this thesis. (Freeman 2008, 78.)

Besides Photomatix there are only couple realistic choices for usable HDR software. Adobe Photoshop is one of them. Adobe introduced HDR capabilities in the popular Photoshop in its CS2 version which is the ninth version of the software. There wasn't any big marketing behind the new HDR feature, but the functionality is such as good when comparing to the actual HDR software. When comparing to Photomatix and Photoshop one of the big differences with is the huge price difference. The full licence for Photomatix cost around 100 Euros while Photoshop can cost ten times that much. But of course with Photoshop you get the whole image processing package. HDR features are only a very small part of Photoshop. Along with Photomatix and Photoshop there are FDRTools and EasyHDR. FDRTools has some specific features that distinguish it from the other HDR software on the market. FDRTools integrate the HDR image generation with tonemapping which expands the whole process making it possible to adjust the source images to affect the final image. FDRTools include the tonemapping processor called "simplex" which is a local operator with additional global actions. But nevertheless FDRTools is not as user friendly and as versatile as Photomatix. EasyHDR is software that runs on Windows only, so it cannot be used with Mac OS for example. The most powerful features of this software are in local operator, but it combines them with global operator which enables post-processing of locally tonemapped image. So there are advantages with this software, but only for the Windows users. (Freeman 2008, 84-98.)

There are some differences with the different HDR software on the market and all of them have their user groups. Photomatix is the most popular, mainly due to good product development and reasonable price, but all of the software can produce impressive HDR images.

# 7 Case study: Producing a HDR image

The purpose of this part of the thesis is to go through all the steps in producing a HDR image. Every step from capturing and generation to tonemapping and post processing will be documented. First a normal single exposure image of the same scene used for the case study HDR image is examined. Then the capturing process for the HDR image is documented following the tonemapping and post processing work. Then the single exposure image is compared to the HDR image in order to get a clear view what are the benefits with HDR technique.

## 7.1 Single exposure image

Image 2

This picture (image 2) represents the same scene that will be used for the HDR image in this case study. The single exposure image is shot using the cameras exposure metering. So the

image is shot using the ideal settings for this kind of scene with specific other settings. It can be clearly seen that this kind of scene of evening sundown is quite difficult to expose. First big problem is the sky. In order to get at least some of the detail and dynamic range of the foreground to show the sky has to be over-exposed. This means that most of the detail in the sky is lost. Second problem is the woods and bushes close to the middle point of the picture. The over-exposed sky causes the detail also in the woods area to lose detail and dynamic range. All the trees and bushes lack color. Third issue are the leaves in the foreground of the picture. Even though there is color on the leaves, the overall colouring is quite dark. This causes some of the dynamic range to be missing. Also the detail under the leaves is completely missing because of the shadows that are casting from the edges of the leaves.

The purpose of this image is to show some of the common issues with this kind of scene when considering exposure. There are means to get better results even in the shooting phase with exposure correction for example. With exposure correction it is possible to under- or over-expose the picture with small adjustments already when shooting. The image 1 is shot with JPEG format so there is already some image processing and compressing involved. If the image 1 would have been shot with RAW format, some of the exposure issues could have been solved with RAW post processing. HDR technique solves all these issues and gives so much more to the image.

### 7.2 Capturing the exposures for the HDR image

The capturing phase for the different exposures was completed with the technical regulations needed. Sturdy tripod was used to minimize the ghosting effect, RAW format was used for extra freedom for the post processing work, low ISO rating was used for best image quality possible and to minimize digital noise and the shutter speeds were incremented by two stops from the first exposure. It depends on the dynamic range of the scene how many exposures is needed for the HDR image. For the scene used for this case study, ten exposures were needed to capture enough of the dynamic range and for the shadow areas to show detail.

### 7.2.1 The set of exposures with shutter times:

Image 3

Image 4

Image 5

Here are the first three exposures of the capturing sequence. Purpose of these first underexposed images is to give detail and dynamic range to the highlight areas in the final HDR image. Image 3 is shot with exposure time of 0, 8 seconds and shows texture and detail on the sky. The image also shows the evening sun going down. Image 4 is shot with 1, 3 second exposure time. It gives more detail to the sky and shows little bit already the leaves in the foreground area. Image 5 is shot with exposure time of 2 seconds and starts to give more detail to the foreground.

Image 6

Image 7

Image 8

The next three exposures begins to give more detail overall and especially on the mid-tones. Image 6 was shot using exposure time of 3, 2 seconds and on this image the sky is close to being correctly exposed for one exposure image, but this causes still the foreground to be un-

der-exposed. Image 7 is shot with exposure time of 5 seconds and as the foreground starts to get more detail, the sky starts to lose color detail. Image 8 is shot with 8 second exposure time and as sky starts to get over-exposed the foreground details can be seen better.

Image 9

Image 10

Image 11

The next exposures give more depth to mid-tones and especially to colours. The exposure time of image 9 is 13 seconds and the exposure time for image 10 is 20 seconds. They both show details in the foreground and start to show colours also on the trees and bushes in the middle of the pictures. Image 11 is shot with the exposure time of 30 seconds and it shows the sky already almost completely over-exposed with all the details lost.

Image 12

Image 12 is the last exposure of the capturing sequence. It is shot with the exposure time of 60 seconds. This image shows the detail under the leaves and also enhances the overall col-

ours. The sky area is now totally overblown with all the pixels clipped. All the information in them is gone.

These ten exposures cover most of the dynamic range of this scene and are suitable for HDR image generation. Even though there is no apparent movement in any of the images, there of course is movement on the clouds in the sky area and they will be seen on the final HDR image. Nevertheless it will be small movement and for some HDR images the small movement in certain parts can even create a nice effect. From here on the next step is the generation of the HDR image where all the exposures will be combined into one image.

### 7.3 Generating a HDR image from the exposures

After the shooting phase start the more demanding generating and tonemapping phase. This is where HDR image processing gets more technical. If the exposures are shot correctly they can be generated into HDR image with any HDR software. But like already mentioned Photomatix Pro will be used in this case study. When the Photomatix software is run, it will open the following screen:

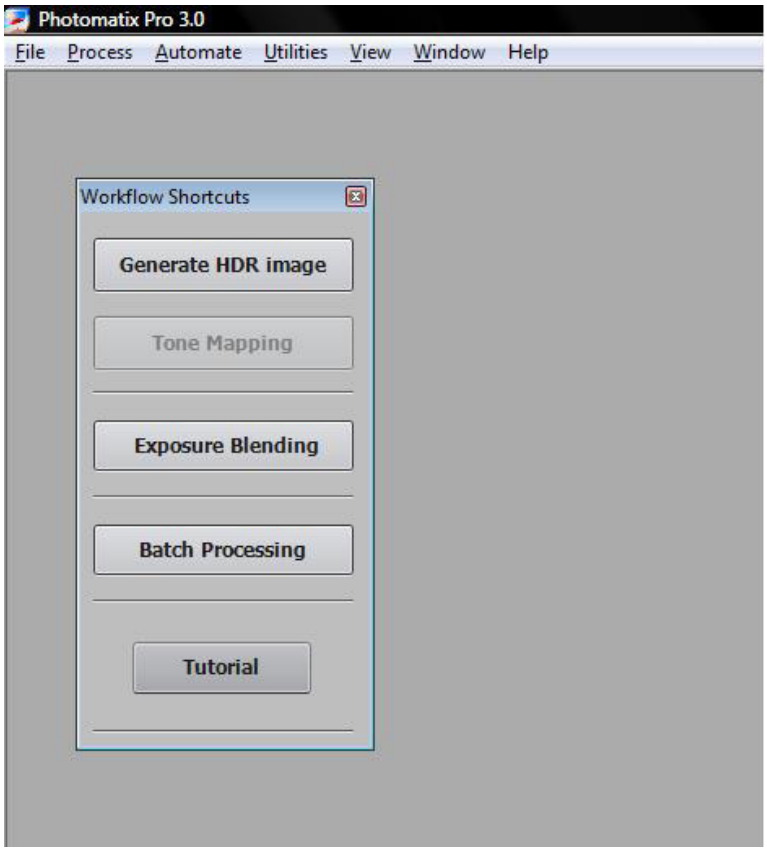


Image 13

The workflow shortcut is opened by default and it makes the generation phase quite simple. The generation begins by pressing the "generate HDR image" button. After that the software requests the exposures that will be combined into one. After user selects the exposures shot in the capturing phase, the following window opens:

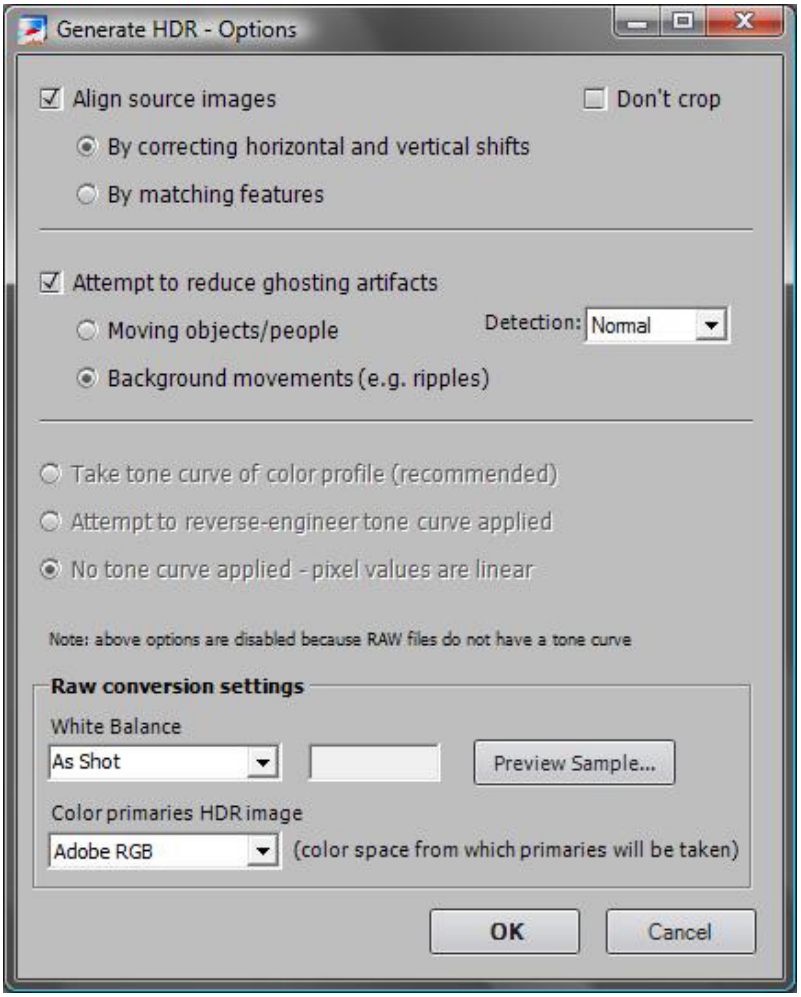


Image 14

Generate options window (image 14) opens always as the last window before the actual generation of the HDR image. It is possible here to influence to the final HDR image with some of the predetermined Photomatix settings. By clicking the "align source image" checkbox Photomatix will try to align the source images correctly and also tries to reduce any changes in the cameras position that may have occurred in the capturing phase. The aligning can be done by correcting horizontal and vertical shifts or by matching features in the exposures. Photomatix can also be made to automatically crop the image using software settings, but this is best done afterwards manually. Before generation it is possible to attempt to reduce the ghosting artifacts like movements on trees or other moving objects in the scene. If the scene has possible background movements (like in the case of the scene in this case study with the movements of

clouds) that option has to be selected. Depending on the possible movement, the detection for the movement can be selected to normal or high. When shooting with RAW format (as it is recommended) there are at this stage only few RAW settings that can be changed. If the white balance is not set correctly in capturing phase to match the circumstances of the shooting environment, it can be set here before the generation. Also the color primaries can be set, which is usually always Adobe RGB by default.

After the generation settings have been set, the actual generation is started by pressing the "ok" button. It depends on the number of different exposures how long the generation takes, but in this case with ten exposures it took about a minute. When the generation is ready, a new window is opened with the generated HDR image.

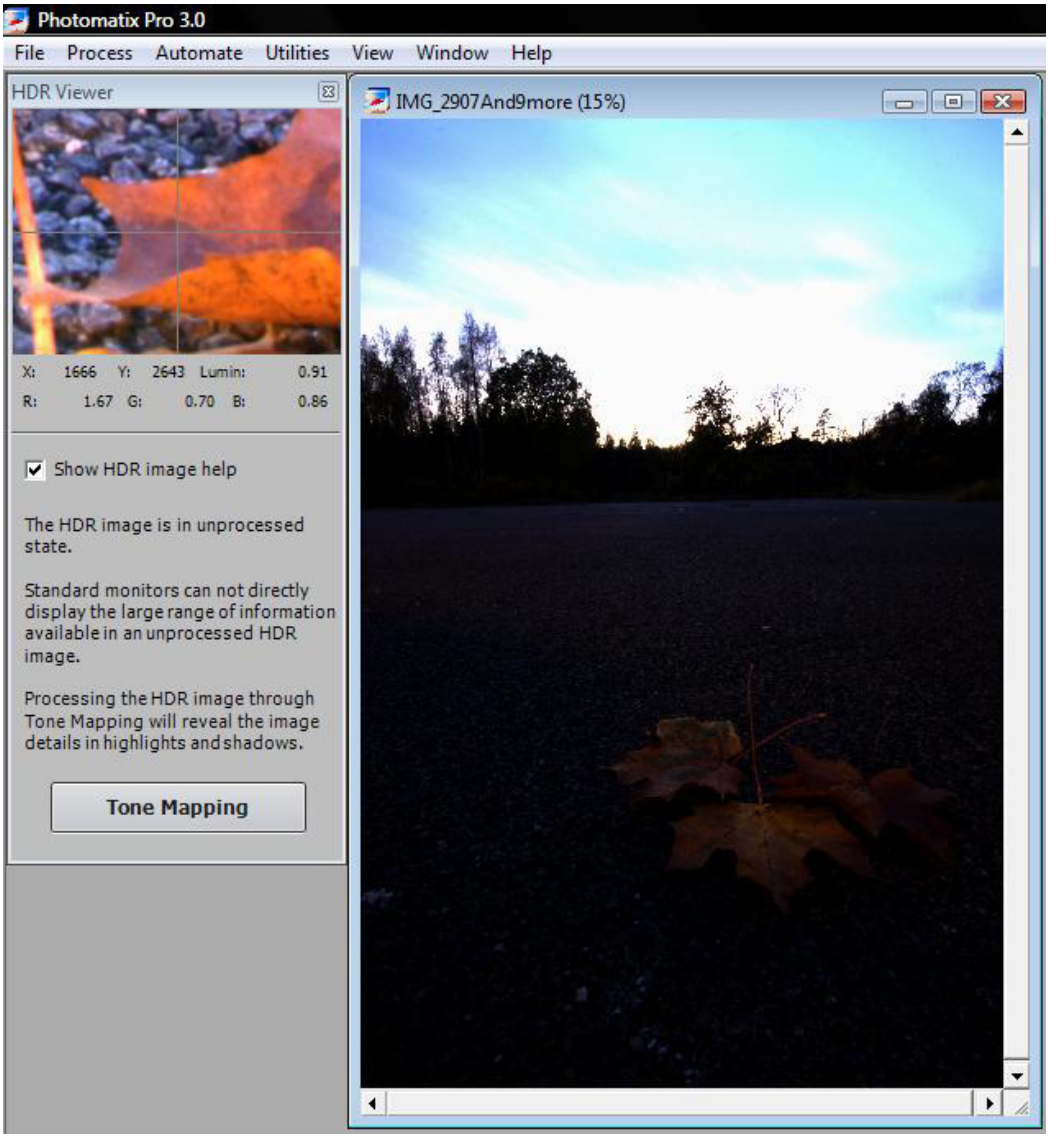


Image 15

After the HDR image generation is finished, Photomatix opens the generated image and also HDR viewer window opens (image 15). The HDR image looks like a radically under-exposed image, but like the HDR image help informs under the HDR viewer, the HDR image is in unprocessed state. This is where the limitations of standard monitor and also print-outs come to play. The limited dynamic range causes the image to look like that. When user moves the cursor on top of the image, Photomatix shows all the information of the image on the small window of the HDR viewer. In this case the cursor was placed on one of the leaves showing the colors and detail on that area of the image. Like the HDR image help also informs, the image has to be tonemapped before it can be viewed with wider dynamic range.

## 7.4 Tonemapping the generated HDR image

The tonemapping of the newly generated HDR image begins by pressing the "tone mapping" button. Tonemapping is by far the most technical part of HDR image processing and it is also the part where user's creativity comes to play. When the tonemapping begins, tonemapping settings window opens as does a preview window of the generated HDR image (image 15).

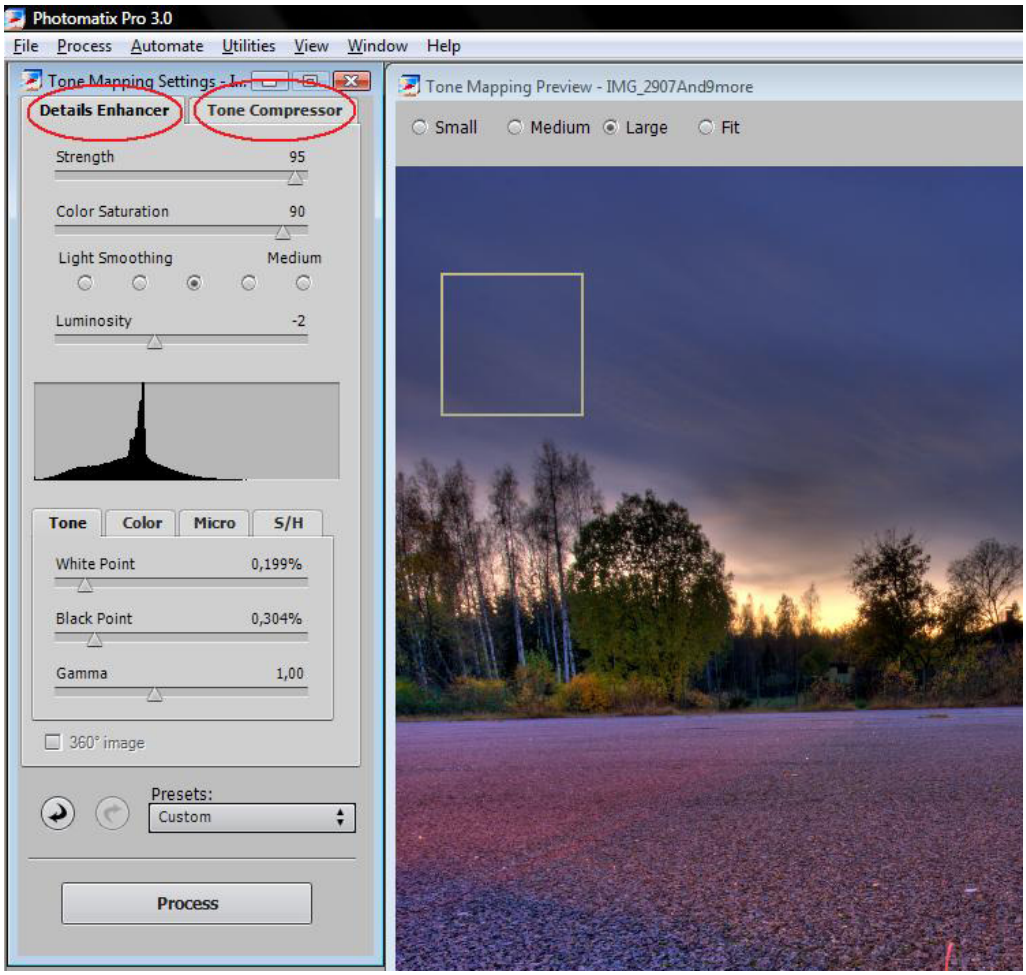


Image 16

With Photomatix Pro the tonemapping is possible to do with either local or global tonemapping operators. In image 16 the tonemapping operators are circled with red circles. In Photomatix Pro "Details Enhancer" operator belongs to the category of local operators which enable to work with only a specific area of the image. "Tone Compressor" belongs to the category of global operators which treats all pixels in the image the same way. The biggest advantage of global operator is the fact that the processing is fast, compared to local operators where every single change of settings might take a few seconds to process before the affect can be seen on the preview image. Local operators take longer to process, but they are better at producing good looking images as human eye adapts to contrast locally also. (HDRsoft. General FAQ 2008.)

For this case study it was selected to tonemap the image using details enhancer for the more detailed and overall better results. The process begins with setting the overall strength of the tonemapping, color saturation, light smoothing and luminosity. The strength is set to 70 out of 100 by default, but usually it should be increased for more natural results. For this case study it was set to 95. Moving the strength slider to left lightens the image overall and reduces any halos but with the expense of naturalness. Moving the color saturation slider to the right increases the strength of color in the RGB channels equally. The default is 46 out of 100, but as one of the main purposes of HDR imaging is to bring out the color in images, it should be set quite high. For this case study it was set to 90. Light smoothing is the variable that affects on the naturalness of the image most. It affects on the way light is smoothed out across the entire image. It also affects on the distribution of halos. Light smoothing is available in five settings only; because of the way the computations work. The radio buttons toward left give more artificial look for the image and also distinctive halos. The radio buttons toward right give more realistic look and the image is slightly darker.

Image 17

Image 17 shows the big difference in the image between only five steps of light smoothing. The left side of the image is set with the most left radio button and the right side is set with the most right radio button. Finding the best setting for each image is vital to keep the more natural effect, but still displaying most of the dynamic range. For the image in this case study the middle radio button gave the best results giving good colors while preserving naturalness. Luminosity is also important for factor as it adjusts the overall brightness and contrast of the image. The luminosity scale varies from -10 to +10 and the default is 0. Moving the slider to the right opens up more of the shadow detail and also brightens the image. Moving the slider to the left lowers and darkens the contrast in the shadow areas. This is also an area where personal creativity and eye of the user comes to play. It is important not to overdo the first setting of the tonemapping process. Luminosity was set to -2 for this study. (Freeman 2008, 78.)

After these first settings which affect on the overall look of the image, it's time to move to the more detailed settings that affect the finer areas of the image.

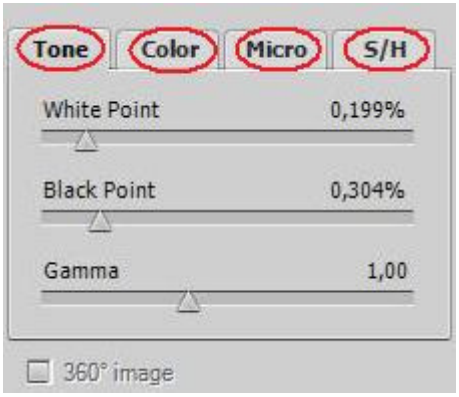


Image 18

There are four areas that are treated next (circled in image 18), tone (more brightness and contrast controls), color (fine control over color only), micro (small scale contrast) and shadow/highlight (adjustments to the extremes of tonal scale). With tone there are three sliders: white point, black point and gamma. White point sets the point beyond which outlying pixels will be clipped to pure white for the purpose of getting more photographic feel to the image. It also brightens the image. The default is set to 0,25% on the scale from 0 to 10%. White point was set to 0,199% for this case study through trial of different settings and evaluating the affect they had on the image. Black point works in the same way than white point with the exception of setting the point beyond which outlying pixels will be clipped to pure black. This affects also the overall contrast of the image and gives better photographic feel to the image by ensuring that black colors are truly black. The default is 0 from 10% and for this study it was set to 0,304%. Gamma correction sliders works in a way that it darkens or brightens the image without clipping highlights or shadows. Moving the slider to the left slightly compresses the shadows and expands the highlights giving an overall darker look to the image. Moving the slider to the right slightly expands the shadows and compresses the highlights making the image look brighter. The range of the gamma correction is 2,00 on the left (darkest) to 0,35 on the right (brightest) and the default is 1. The default setting was the best setting for the image in this study. (Freeman 2008, 78.)

The next sub-menu in order is the color. This allows adjusting the colours separated from brightness and contrast. It is possible to control temperature, saturation highlights and saturation shadows with this menu.

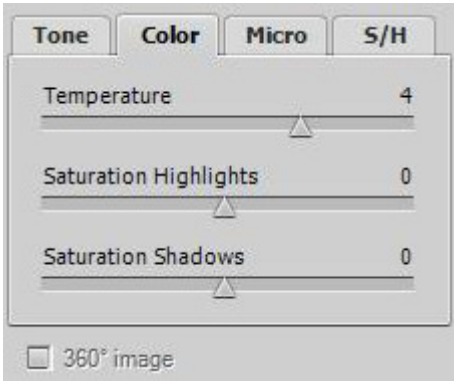


Image 19

Image 19 shows the settings made for the colours in the case study. There aren't any really radical changes as it was best suitable for the image in question. Temperature adjusts the overall color temperature from cold bluish (slider left) to warmer reddish (slider right) look. It ranges from -10 to +10 and it was set to 4 in this case. Saturation highlights works in a same

way as the color saturation slider, but it affects only to the brighter pixels. Slider to the left weakens the saturation on the pixels and slider to the right strengthens it. Scale is from -10 to +10. Saturation shadows works the same way as saturation highlights but is restricted to darker pixels only. In this case study they were both left to default values.

Micro sub-menu opens settings that affect on the image in smaller scale, on a level of few pixels only.

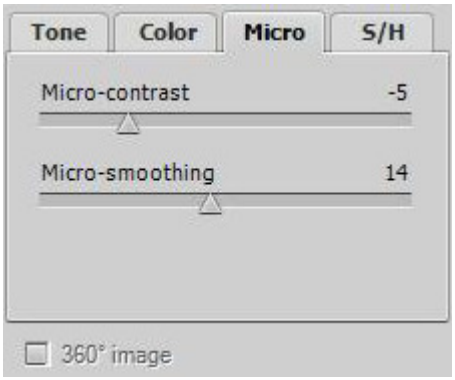


Image 20

There are two setting that can be adjusted in the micro sub-menu (image 20). Micro-contrast controls the emphasizing of contrast on a scale of a few pixels. Moving the slider to the left reduces small scale contrast and brightens the image, moving the slider left increases small scale contrast and darkens the image. The scale of micro-contrast ranges from -10 to +10 and for the case study image it was set to -5. Micro-smoothing works in a combination with the micro-contrast, smoothing out the enhancement of details in small scale. It can give cleaner appearance to the image by reducing possible noise for example. The range varies from 0 (far left) to +30 (far right) and it was set to 14 for the case study image. Default is 2. (Freeman 2008, 79.)

Shadows/highlight sub-menu opens controls for adjustments in tonal scale. These are usually the last adjustments done before processing all the settings and creating the tonemapped HDR image. There are three sliders in the last sub-menu that can be adjusted: highlight smoothing, shadows smoothing and shadows clipping (image 21).

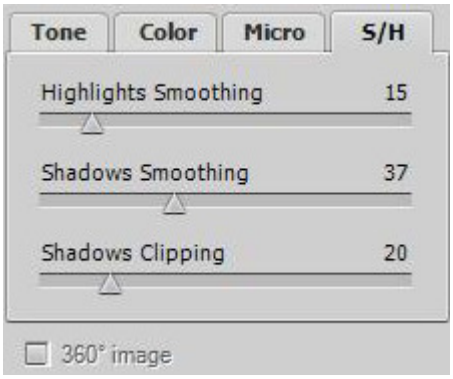


Image 21

Highlight smoothing makes it possible to brighten the highlights only. It can be used to improve overall contrast and to reduce any unwanted halos. It ranges from 0 to +100 and the default value is 0. Highlight smoothing was set to 15 in this case. Shadows smoothing brightens just the shadows with the effect of reducing overall contrast. In some cases this might be needed. It ranges also from 0 to +100 and the default value is 0. Value 37 was set for the case study image. Shadows clipping clips the shadows to black. It is used in combination with shadows smoothing slider as without it the effect can be unnatural. Purpose of shadows clipping is once again to increase contrast and give more photographic look. It can be used also for removing noise in the darkest tones. It ranges from 0 to +100 and the default is 0. Value of 20 was best for the case study image. (Freeman 2008, 79.)

The whole tonemapping phase and all the settings that are done during it depend entirely on the source image and on the creativity of the user. There is no right or wrong way to go through it. It has to be done usually with testing different settings on the image and finding the most suitable setting for the specific image. One set of settings might work with one image and be totally wrong for another. The process of trial and error is best way to find the correct settings.

After the tonemapping settings are done, the "process" button is pressed in the tonemapping settings window. Photomatix now processes the image and applies all the adjustments to the final image. This takes usually several seconds depending on the amount of adjustments that have to be processed. After this is done, the tonemapped HDR image opens to the screen. The newly created image can be saved either in JPEG format or TIFF format (Tagged Image File Format). If the image needs some post-processing work, it is best to save in TIFF format as it stays uncompressed and preserves most of the information. After this the image is ready for post-processing.

## 7.5 Post-processing the created HDR image

After the tonemapping phase the new image might be finished already. But in most cases there might be some small adjustments that could be done to finalize the image. This relies also in the creativity of the user and some other software is usually used for this. For the image in this case study Photoshop CS 2 was used. There were only minor adjustments that were applied for the image. First thing was straightening the horizon of the image. The image was tilted one stop clockwise to get the horizon vertical and the crop tool was used to get rid of the unwanted parts of the image for improving the overall composition. After that only small adjustments were done for the overall contrast and saturation.

## 7.6 End result: the final HDR image

Image 22

After the post-processing the HDR image is basically finished. The final image (image 22) shows the advantages of HDR technique when thinking back to the problems that occurred with the single exposure image of the same scene. The sky displays the correct color tone that matched the sky of the real scene. It can be seen that the sun is going down and also there are details on the clouds. The middle area of the image shows the trees and bushes with more color and detail. Even though there is some halo effect on the edges of the trees, it's quite suitable for this image. Also all the branches of the trees can be seen now. The leaves on the foreground show also more color and detail now. Details under the leaves are visible now despite of the shadows casted from the edges of the leaves. With the improved details on the leaves and on the trees there is almost a three-dimensional effect on the image. The surface that covers most of the image shows also more detail and the reddish color that can be seen on it comes from a light post nearby.

It could be stated that the image lacks naturalness as compared to the single exposure image, but this is usually because of the way we have gotten used to how a photograph usually looks like. This HDR image nevertheless shows the dynamic range of the scene in much more broader way and shows the scene closer to the way human eye would see it.

# 8 Conclusion and recommendations

After gone through the whole process of HDR imaging from start to finish one thing is certain, it is not for everybody. It is quite technical process that requires understanding of the theory of many different aspects of photography, but also the theory on the many variables that have to be taken into account when producing HDR images. It is possible to generate HDR images with quite little knowledge on the matter because after the shooting phase the processing phase is automated for many parts. But understanding how the dynamic range of a scene can and should be captured and understanding which settings should be applied to which image makes the whole image generation much more complex but also more advantageous. When there are sufficient amount of correctly shot exposures and the processing phase is gone through properly, the results can be quite impressive. When thinking about the whole concept of HDR imaging, the word "potential" comes to mind. HDR imaging can have a big influence on the product development in the future and the use of the technique will most probably grow more and more.

If thinking from the point of photography, HDR imaging was developed in many parts as a solution for many of the common problematic issues of photography. The exposure issues of problematic scenes and the inability of capturing the true dynamic range of a scene were both resolved with HDR technique. The technique is really one of the latest big trends with photography but also with image editing. It has also expanded the possibility of creativity of photographers. So it has a lot of potential, but it also demands for technical development to evolve. As it was made clear, HDR images cannot be viewed directly with normal displays or print-outs without the tonemapping phase. Here lies potential for the manufacturers of computer displays. At the moment of writing this there is only one display in the market that is capable displaying the dynamic range of HDR image without tonemapping. The Brightside DR37-P HDR display has a significantly lower level of black color than any other displays, which makes the displaying of HDR images possible. With the popularity of HDR technique growing, it is quite probable that LCD displays will continue to evolve to the direction of the Brightside display. Same thing goes for the digital cameras in the market. The overall popularity of photography is growing at this moment. One big reason for this is the big changes in DSLR camera prizes. The growing of the popularity has also affected to the timeframe in which new camera models are being released. All the major manufacturers release several new models for all prize and consumer categories several times a year. And with new models come new and improved functions and features. This is also an opening for the HDR technique. At this moment there is only one camera in the market that is capable of capturing a truly high dynamic range in one shot. The SphereoCamHDR is a German-made panoramic camera that scans the scene as it rotates and captures much higher dynamic range that normal camera with one shot. This kind of technique is probably still quite far from normal consumer cameras and today still the only way to capture wider dynamic range is with several exposures. This process however is coming easier with the auto exposure bracketing feature that is included in many of the compact digital cameras also. Most of the digital SLR cameras have the AEB function with three possible exposures, but many of the new Nikon cameras for example have the possibility of seven exposures already. So there is clear development happening on that area also. Once again because of the growing popularity of HDR technique, it is very probable that these features will evolve for the future camera models.

When thinking of the bigger picture of commercial potentiality, HDR technique is already becoming a permanent tool for the movie industry, gaming industry and designers in general. The movie industry has used HDR imaging as a part of movie special effects for a long time already with many of the highest grossing movies in history. The gaming industry is also a good indicator of the big leap in development of graphics. The games today with all the full

high definition graphics are light years ahead of the games from couple years back. HDR imaging plays also a big part in this industry and most likely will be a more significant part of it in the future. All of this also supports the development of displays as they are highly used in the making process as in the viewing of the final product.

Despite of the potential, it is quite obvious that HDR technique is not for everyone. Even though the HDR software have evolved a lot, they are quite cheap and they have the generation and processing phases automated for many parts, the use of the technique still requires studying and patience. During the case study it was quite clear that HDR technique was not suitable for all kinds of scenes, not even close. Because of the several exposures, it is very probable that over bright areas will be clipped and that is something that is difficult to mend even during tonemapping. So for example very bright and sunny scenes are more difficult to process into HDR image than for example evening sun scenes. It is also important to take the direction of the light into account. Shooting directly opposite to the light makes the tonemapping very difficult and it's hard to get good results. So it is important to understand which kinds of scenes are suitable for HDR imaging and also what has to be considered when doing to capturing phase. When doing the tonemapping, it has to be first decided what kind of tonemapping operator is used. This depends on the software in use and also on the wanted results. The tonemapping operator used in the case study is the more complex of them two, but did produce better and more detailed results. Usually all the HDR software are informative and they guide the user step by step along the way, but it still is important to know which setting affects which area and the creativity of the user plays an important role. HDR imaging requires patience, knowledge on the basics of photography, knowhow of software and on the use of computers and creativity. But when these are combined, there is potential for stunning images.

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**Gallery of HDR images:** (All images are photographed, generated and processed by Jussi Kääriä. )