Beginning Digital Image Processing

Using Free Tools for Photographers

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To my lovely Sarah.

Contents at a Glance

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About the Author

■ **Sebastian Montabone** is a computer engineer with a Master of Science degree in computer vision. After publishing his thesis on human detection in unconstrained environments, he has worked in different areas such as intelligent IP cameras for automated surveillance, data mining, game development, and embedded devices. Currently he is a software consultant and entrepreneur.

About the Technical Reviewer

Roger Wickes has been involved with software for over 30 years, having had the privilege of participating in the monumental convergences that have shaped computing in all of its dimensions. He started his career learning leadership at Admiral Farragut and the USCG Academy, and fell in love with computerized simulation. His first commercial job was working for CSC at the Naval Underwater Systems Center on big secret underwater things. He then learned how to consult and worked in an entrepreneurial environment for Technology Applications and Development Company in Newport, RI. Tired of the snow, he joined the Fortune 100 company EDS (now HP) in Georgia, where he learned structured techniques for software development, the financials of running a large business, global consulting, and all the leadership skills needed to operate the Atlanta Service Center of 120 professionals developing software on all the major platforms. Sensing the opportunity of the Internet and Web, he was a founding partner in ITG, filling all roles from Consultant, Account Manager, and CFO. At ITG, he was promoted to CIO, where he enabled and led the development of the first Internet-based payroll and staff exchange systems. He fell in love with visual imagery and Blender a decade ago, is a Blender Certified Instructor, consultant, and author of *Blender Essentials* by Lynda.com and *Foundation Blender Compositing* by Apress. He has been the animator for TV commercials, games, and film. He enjoys scuba diving, skiing, travel, and enabling the next gen. His web site is rogerwickes.com.

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First of all, many thanks to the developers of GIMP for creating excellent software for general image editing. The developers of ImageMagick deserve a big thank you for their incredible work making the most powerful command-line image-processing program. The people behind the Hugin project deserve great thanks for making the creation of panoramas a joy. I would also like to express my gratitude to the developers of Qtpfsgui for making HDR imaging easy. Thanks to all of those behind the UFRaw project for allowing us to read many RAW formats as well as to the developers of Avidemux for creating a simple and useful video editor. Special thanks to Dr. Paul Harrison, the developer of the excellent Resynthesizer GIMP plug-in and Phil Harvey, for creating the best tool for dealing with metadata: ExifTool. This book could not exist without all of your amazing work.

Last but not least, I would very much like to thank the staff at Apress for assisting in editing this book. It has been a lot of work and their input has been invaluable in enhancing the content of this book.

Introduction

Digital image post-processing and open-source software are exciting topics; this book is the fusion of both. How cool is that? After you read this book, you will be able to edit your images for free.

This book starts with some background information about photography and digital images to give the reader a common base. Then, several image post-processing techniques are presented with ascending difficulty, from simple resizing or cropping to more advanced subjects such as high dynamic range (HDR) imaging, distortion correction, or panoramas. Armed with these techniques, using the best open-source tools available, you will be ready to start editing your images for free. In each case, I will show you the best free tools for the job. Finally, as an added bonus, the last two chapters cover extra stuff: video processing for creating your own movies from single video clips and CHDK to enhance your camera features.

The first chapter of the book introduces general photography concepts. You will learn common concepts used in photography so that you can control your camera to take the shots that you want. Understanding these concepts is the key to shooting a good photo, which in turn is the starting point for image editing.

The second chapter describes all the details of digital images. Because you are going to work with digital images, in-depth knowledge is beneficial before you start editing.

The third chapter covers the simplest and most common post-processing techniques. Every photographer often needs to resize or crop their images so that they fit in the specific medium they want to present. All these operations and more are presented in this chapter.

The fourth chapter explains how to control color in your images. Everything that you need to know is here. The fifth chapter covers the most commonly used filters in digital photography, such as noise reduction, blur, or the unsharp mask. The sixth chapter covers the photo retouching techniques that photographers use to fix images with small problems such as skin blemishes, removing small objects, and so forth.

Chapter 7 covers a more advanced technique, HDR. You will learn how to create those images from ordinary pictures. Chapter 8 covers distortion correction. It shows you how to correct the distortion produced by perspective and lenses. In Chapter 9, you will understand how to take the images needed for making panoramas as well as how to create them.

The last two chapters cover bonus material. Chapter 10 teaches you how to create movies from your video clips, and Chapter 11 describes how to use CHDK to enhance your camera's features.

I hope you enjoy this journey into open-source digital-image post-processing!

CHAPTER 1

Digital Photography

Have you ever wanted to make panoramic photos like the one shown in Figure 1-1?

Figure 1-1. *You can take panoramas like this.*

How about fix the perspective distortion when you shoot a building, as in Figure 1-2?

Figure 1-2. *Or perspective shots.*

Or simply remove a complete object from your photograph, as in Figure 1-3?

Figure 1-3. *Or do some magic.*

In this book, I will explain how to do these things and more with the help of free software—you don't have to buy expensive software to achieve these results. After you finish reading this book, you will be able to convert your images into great-looking photos using the software and techniques I describe.

But let's go one step at a time. There are some things you have to understand first so that you can get the best results for your photos. Let's start with what digital photography actually is.

In its most general sense, photography is the process of generating a two-dimensional view of a three-dimensional space using light. In simpler terms, photography is the art of drawing with light.

Light and Photography

Light comes from many different sources. Some of these are natural, such as the sun, lightning, fire, or even glowworms. Other sources are not commonly found in nature, such as halogen lamps, incandescent light bulbs, neon lights, or light-emitting diodes.

As light travels through the air, or any other substance such as water or even vacuum, it usually runs into objects. When this happens, some part of the light gets absorbed by the object and some of it gets reflected. This reflection allows us to see objects that do not emit their own light, which are the most common ones in our world.

Humans are able to see objects because of our extraordinary visual system, which is composed of the eyes and some parts of the brain. The eyes gather light from the current field of view, forming an image in the retina. This information is processed by the brain, producing the visual perception of the world that we know. By changing the position of our eyes, we can select the field of view that we want to look at.

In photography, the light from the current field of view of the camera is projected on a photographic film or an electronic sensor, producing an image. This idea is based on the camera obscura (Latin for dark chamber) and it is where the name *camera* comes from.

The camera obscura is an old invention that consists in a closed room (or box) that has only one small hole or aperture on the exterior of one of the sides. Because light generally travels in straight lines, the light from the exterior passes through the aperture and gets projected upside-down into the opposite side, preserving its color and perspective. Figure 1-4 shows how this works.

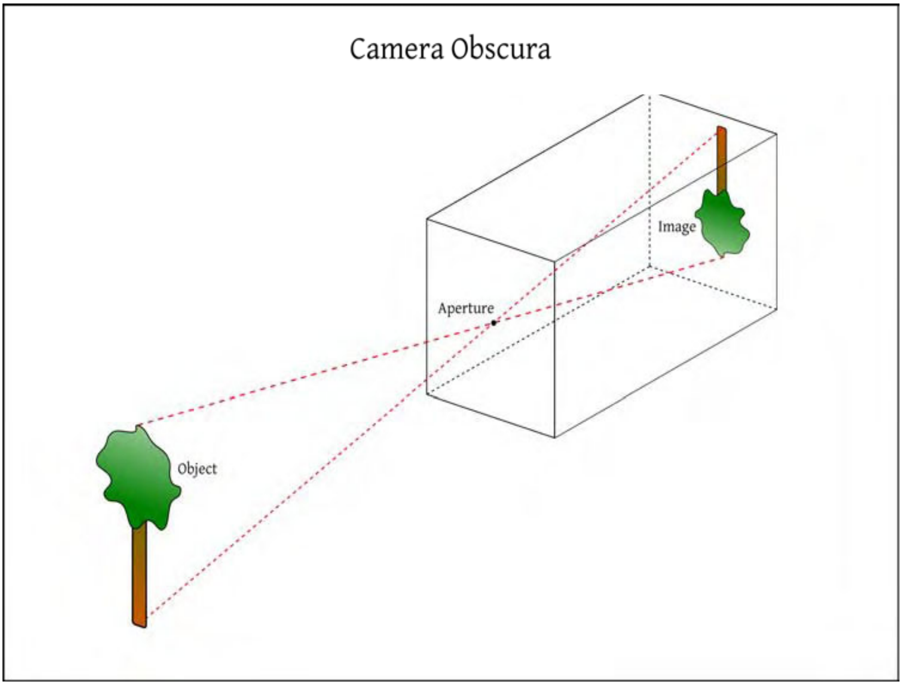

Figure 1-4. *How the camera obscura works. Light from the exterior of the room passes through the small aperture and gets projected into the opposite wall, inverted.*

Some of the users of the camera obscura were astronomers and artists. Astronomers could see the movement of the sun without damaging their eyes, and artists could place a translucent screen and trace the outlines obtaining realistic paintings. This was the start of rotoscoping as a technique used in film and media.

The field of view that gets projected into the screen depends on the distance from the screen to the aperture. In photography, this distance is similar to the concept of focal length. Because the screen remains the same size, an image created by a large field of view presents smaller objects than an image produced by a small field of view (see Figure 1-5). This is similar in the human eye. The field of view that you see is given by the distance from your pupil to the retina. It also depends on other things; for example, you have a larger field of view when viewing with your two eyes instead of just one because of the processing done in the brain.

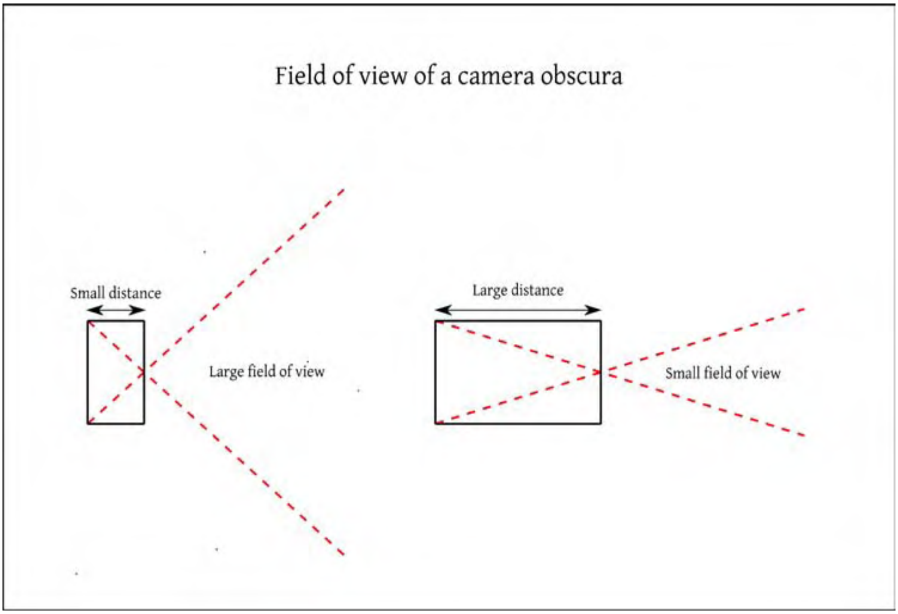

Figure 1-5. *The relationship between the distance of the sides of a camera obscura and its field of view. Larger distances produce narrower fields of view (think of zoomed in). Smaller distances produce larger fields of view (think of zoomed out).*

The main problem with the camera obscura is that the resulting image is very dim because of the small amount of light that passes through the aperture. To solve the problem, Giambattista Della Porta started using converging lenses. The result of this is that the rays of light are projected into a smaller image; therefore, more brightness is achieved, obtaining better projections.

Advances in chemistry allowed storing the projected images permanently. At first, photographic plates were used, but later they were replaced by photographic film, which has evolved into what is being used in modern film cameras. The standard photographic film format is the 135 film, which is commonly known as 35mm because of its width. When digital cameras refer to having a full-frame sensor, it means that its size is the same as the 35mm film frame, which is 24x36mm (see Figure 1-6).

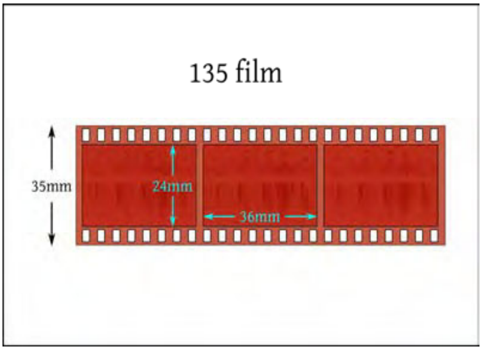

Figure 1-6. *The dimensions of the commonly used 135 film. The standard size of each frame is 24mm x 36mm. The perforations on the sides are used to move the film. Each frame contains exactly eight perforations on each side so that the camera can move the film correctly to the next frame.*

The introduction of a medium to store light gave birth to photography. Image quality of the photographs started to improve year after year, adding more details and color. The process of developing photographs was also improved. All of these made taking photographs much easier, making it very popular among the public.

For many years, film cameras were the standard. Usually, a person would take up to 36 photographs (depending on the length of the film) with their camera and then send the film to a lab for developing. Expert photographers would develop their own photographs, having total control on the final image. This development is a chemical process done in a dark room that transfers the information from the film onto photographic paper. How this developing process is done, which specific photographic paper is used, and other factors influence in how the resulting photograph will look.

Advances in electronics resulted in the invention of the charged coupled device (CCD), which in conjunction with other technologes led to the origin of digital photography.

Digital photography uses electronic components to capture and store light instead of film. Digital cameras started to be produced and consumed by many people. Although at the beginning, the image quality was very poor, today's digital cameras produce images comparable to film cameras.

The main components of a digital camera are the lens, the viewfinder or LCD screen, the CCD, the image storing device, and the shutter button, along with the different controls available in the camera.

You should select your camera components based on what you are planning to photograph. The perfect camera for taking pictures of your friends at a party may be very different from the perfect camera for taking pictures of landscapes. Because the selection of your camera components is very important, let's examine these components in more detail.

Digital Camera

You probably grew up with cameras in the house, and the basic principles are simple enough that even a child can understand them: point and shoot. Digital cameras are a different animal than the film cameras you probably had as a kid, and they're evolving rapidly. Some parts are still easily recognizable from film cameras, such as the lens and shutter control, but other parts are unique to digital cameras, such as the LCD screen and the sensor. Knowing your camera is an important first step to taking good photos, so I'm going to go over the components in this section. Although each brand and model of camera has small differences, there are enough similarities that you should be able to apply this discussion to your specific camera.

Lens

The lens is the surface of entry of the light into the camera. It is responsible for directing the light from outside the camera to the sensor, where the image is created. Assuming that the camera is always in the same physical position, the specific field of view that the camera is looking at, which is what will be shown in the picture, is defined by the focal length of the lens. The *focal length* is the distance from the lens to the point where all the incoming rays of light converge due to the optics of the lens. Similar to the camera obscura, a lens with a small focal length produces an image with a large angle of view, while on the other hand a lens with a large focal length produces an image with a small angle of view.

Some lenses have the ability to change the focal length in a specific range, like the one in Figure 1-7. This is commonly known as *optical zoom*. When the photographer zooms in, he sees that the objects appear larger. This is because he is increasing the focal length of the lens. When zooming out, he is decreasing the focal length of the lens, causing the objects to appear smaller.

Figure 1-7. *This image shows a digital single lens reflex camera with a lens mounted. This particular lens allows changing the focal length from 18 to 55 mm. The currently selected focal length is 35 mm.*

Note that optical zoom is different than *digital zoom*. Optical zoom means that the optics of the camera are changed so a different field of view will be captured. Digital zoom is a quick resize and crop operation done inside the camera on the original field of view. Due to the limited processing power and time available in the camera, the result is not always acceptable. You can always achieve the same or better results afterwards in the post processing stage so I strongly recommend that you don't use the digital zoom feature on the camera itself.

Newer models of camera lenses offer a very useful feature called Image Stabilization (IS) or Vibration Reduction (VR). This feature compensates the camera shakes made by the hand of the photographer, allowing you to take sharper photographs without a tripod. It is a complex system that reads information from sensors, accelerometers, and gyroscopes, and moves the lens elements accordingly to compensate the movement of the camera in real time. If you are planning to buy a new lens, I highly recommend you buy one that has this feature; it will make your photographs look much sharper.

Viewfinder or LCD Screen

The viewfinder is the part of the camera that allows you to observe the scene that is going to be photographed. Some cameras offer an LCD screen to observe the scene as well, but there is a difference between them depending on the camera type and model.

In digital single lens reflex cameras (DSLR), like the one shown in Figure 1-8, the viewfinder is connected directly to the light coming from the lens using reflection of an internal mirror. When the photograph is taken, the internal mirror moves to direct the light into the sensor instead of into the viewfinder. This movement is the cause of the typical noise of the DSLRs when taking a photograph. Also, because of this design, the LCD screen in most old DSLRs cannot show the so-called live preview because the light is always being directed only to the viewfinder. Newer models of DSLR have solved this problem by adding a second sensor dedicated only to the live preview and complex mirroring systems.

Figure 1-8. *The back of a DSLR. You can see both the viewfinder (above) and the LCD screen (below) from this view.*

In point-and-shoot digital cameras, there is a separate small lens located in a specific position, usually above the main lens, for directing the light to the viewfinder. This provides a rough estimate of the scene, but should not be used for serious photographs. Because the location of the small lens is different than the main lens, the actual photograph will have a different field of view than the image seen in the viewfinder. The LCD screen, on the other hand, is always showing the image represented by the light coming from the main lens to the sensor. When using point-and-shoot digital cameras, I recommend that you mostly use the LCD screen for composing the photograph and only use the viewfinder in bright sunlight. Actually, some camera manufacturing companies have opted for not including the viewfinder in new, smaller models.

If you own a camera with a viewfinder and an LCD screen, and both read the information from the main lens, it is a matter of taste as to which one to use, as both of them present advantages and disadvantages. For example, the LCD screen can be useless in a very bright location. When you use the viewfinder, your head needs to be physically close to the camera, which in some cases may be impossible or uncomfortable. On the other hand, LCD screens can be useful for displaying extra information, such as marking over or underexposed areas so that you can make sure your photo will be properly exposed when you take it. Finally, viewfinders show exactly the same light that will be used to generate the photograph, without any processing of the sensor, therefore showing more accurate information.

Sensor

The camera sensor is where the light is converted into an electric signal. The input to the sensor is light and the output is an array of voltages, one for each pixel location. Further processing is needed to generate the image from this array of voltages, which can be done in the camera itself or later in a computer.

To generate the array of voltages, the sensor has a fixed number of many small light sensors, one for each pixel, that sense the light when the photograph is taken. During the exposure, all these small light sensors start receiving light and when the exposure is finished, they stop receiving light and store the amount of voltage generated. More light received means more voltage measured by these small light sensors.

To create the image, the voltage stored on each small light sensor is compared to their possible range of voltage, which is called *dynamic range*. If there were no light coming in, the output for that specific position of the image would be considered black, and if the amount of received light produces more or the same voltage than the defined maximum of the small light sensor, the output for that specific position of the image would be considered white.

Voltage values inside the range of every small light sensor would produce different grayscale values in the image. Therefore, sensors with a larger dynamic range can sense a larger range of different light intensities in the same shot. In other words, there would be less overexposed or underexposed areas in a sensor with a larger dynamic range than in one with a small dynamic range given the same light as input.

The previous method explains how to capture the intensity of the incoming light, producing grayscale images. In order to produce a color image, a little more needs to be done.

All the visible colors can be decomposed as functions of three primary colors: red, green, and blue. For example, if you mix red and green in equal proportions, yellow is generated. Therefore, to produce color images, one can use three of these arrays of small light sensors with a filter for each of the red, green, and blue and then combine their results.

This design is expensive, though, and almost every digital camera uses a different approach: The Bayer filter. This approach uses only one array but every small light sensor has a filter so it can only sense one specific color: red, green, or blue. The camera, or the computer, can then process this **RAW** (or unprocessed) data to form the final image.

The megapixel (MP) count of a sensor tells you the number of small sensors it has, and also the number of pixels of the image it produces. A higher MP count gives you better-quality images, but it also means that your images file sizes will be larger, which means that you will have room for less pictures on your memory card.

Storage

The storage component allows you to save the images in a permanent way; you can access them later from a computer or any other device. Normally a memory card is used for storage in most digital cameras.

There are different types of memory cards: Multi Media Cards (MMC), Secure Digital (SD), xD Picture Cards (xD), Compact Flash (CF), and Sony Memory Sticks (MS). All of them have similar performance, but each camera can only use the memory card it was designed to use (some cameras can read more than one format). Currently, the most widely used type is the SD memory card shown in Figure 1-9, so if you have to make a choice, it would be better to buy a camera that can support this technology, as it is turning into the standard.

Figure 1-9. *This picture shows three SD cards with different storage sizes and brand names.*

The main features that you should look for when buying a new memory card are the storage capacity and the writing speed. I would recommend that you buy a memory card with at least 1 or 2 GB of storage capacity, which will give you plenty of space for storing your images. As prices are constantly going down, I recommend that you buy the memory card with the largest capacity available for the specific camera that you own. Remember that an image with a higher megapixel (MP) count will end up using more space in the card, and that RAW data consumes much more space than the processed JPEG image.

About writing speed, it is better to buy a fast card because it will minimize the time between two shots. This is especially useful when taking photographs in continuous mode or when making videos where continuous writing to the card is made. Look for memory cards with 150x or faster writing speed to get the best results.

Controls

The controls of the camera allow you to define how and when the photograph is going to be taken. All digital cameras provide you with a shutter button, which is the responsible for initiating the process of creating the photograph. Before taking the photograph, you can adjust the specific settings for the shot.

Some point-and-shoot digital cameras only offer automatic settings, which means that the photographer only can access the shutter button and all the settings are calculated by the camera itself. Other models offer a mixture between fully automatic and manual mode, which means the photographer can specify different settings.

In DSLRs, the photographer can define all of the settings. The main difference in controls between DSLR models is that smaller cameras do not have physical knobs for changing the settings; therefore, the photographer needs to rely on the LCD screen to adjust them. On larger cameras, the photographer can change the controls using physical knobs, making it easier for her to change the settings while taking a photograph.

As always, there is a compromise with every added feature; therefore, selecting which camera is better for you will depend on how you plan to use it. The larger the camera, the better controls and quality it will have, but at the cost of being heavier, less portable, and more expensive.

Creating a Photograph

The entire process of taking a photograph involves three steps, shown in Figure 1-10. The first step is to define the specific view of the real world that is going to be photographed, which is called *composition*. This is obtained by changing the focal length of the lens, commonly known as zoom, or by changing the positioning or orientation of the camera itself until the desired scene is presented in the viewfinder.

The second step is to gather just enough light from the selected field of view to capture the desired photograph. The total amount of light gathered in the process of taking the photograph is called *exposure*. If not enough light is gathered, the image is said to be *underexposed* and it will look too dark or black. On the other hand, if there is more than just the needed light, the image is said to be *overexposed* and it will look too bright or white. The correct exposure is achieved using a combination of three controls: shutter speed, aperture, and sensitivity, which are described later.

The third and final step is called *post-processing*. In film, this step is done in a dark room and only professionals can do it, so most of us need to send the photos to a lab and wait for the final images. In digital photography, the post-production is done on the computer. This means that you don't need to send your photos to another person; you can process your own images yourself. In this step, the photographer produces the final image, correcting mistakes done in the previous two steps, adjusting the colors, applying filters, and in general making all the necessary changes needed for producing a great-looking photograph using image processing tools.

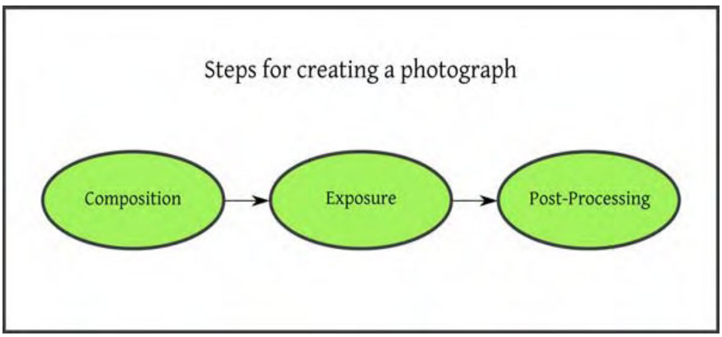

Figure 1-10. *Three steps to create a photograph.*

Composition

Composition relates to selecting the right field of view at the right time to create a good-looking picture. Creating great compositions is more of an art than a science. A good composition is made of an interesting subject with the correct lightning and presented in a good background and perspective. There are many books that you can read about these topics, but I will give you some basic guidelines that can be useful when taking pictures.

Field of View

The field of view defines exactly which objects are going to be present in the photograph and the perspective. You can change the field of view by changing the focal length of the lens and also by moving or rotating the camera. Changing the focal length of the lens does not change the perspective in the photograph; it only enlarges the central area of the image, maintaining the relative sizes of the objects. On the other hand, changing the position of the camera changes the perspective. This means that closer objects will look larger than objects that are farther away.

To make these concepts clear, I will show you the effect of each of them in a real-world example. Figure 1-11 shows an idea of the layout of the real-world objects used in this example. The larger cone will be the foreground object, the small cone will be in the background in the left side of the image, and the trees will appear far behind in the background.

Figure 1-11. *The layout of the objects in the real-world example*

First, I will show you the effect of changing the focal length of the lens without moving the camera. Figures 1-12 through 1-14 show that larger focal lengths produce narrower fields of view and smaller focal lengths produce deeper fields of view (the same concept as in the camera obscura). The effect is that the center area of the image gets enlarged, but the perspective remains the same. The size of the objects in the foreground is changed in the same proportion as the size of the objects in the background. Note how the cones and the trees maintain the distance between them, changing their image size on each picture.

Figure 1-12. *This picture was taken with a focal length of 6mm. Note how far apart the cones and trees look at this focal length; you can see a large field of view.*

Figure 1-13. *This picture was taken with a focal length of 10mm. Note how increasing the focal length reduces the field of view. If you compare this image to the previous one, the center of the image got enlarged and the objects at the borders are no longer present.*

Figure 1-14. *This picture was taken with a focal length of 35mm.Note how close the cones look now and how reduced the field of view is. Also, the perspective and relative sizes of the objects remained constant in all these images.*

The second point I want to show you is how the field of view changes when moving the camera while maintaining the focal length of the lens constant. When moving the camera to another location, a change in perspective is achieved. Figures 1-15 through 1-17 show the same scene viewed from different locations, keeping the focal length constant. Note how now the distance between the objects as well as their size change from picture to picture.