Analog and Digital Data

Film-based photography is **analog** in nature, while computerized images are **digital** in nature. **Figures 2-7a** and **2-7b** show the data that makes up a digital photograph. This data is readily manipulated. Our relationships to analog and to digital data are quite different.

◆ **2-7a** *To our eye, digital photographs can look smooth and full of continuous tones.*

◆ **2-7b** *When a digital photograph is enlarged, we see the individual elements that actually comprise it.*

The analog world is full of long-playing records and clocks with smoothly moving hands that are reminiscent of the path of the sun and moon through the sky. We ourselves live in an analog world, with time flowing smoothly past, as day fades to night, as we gradually age.

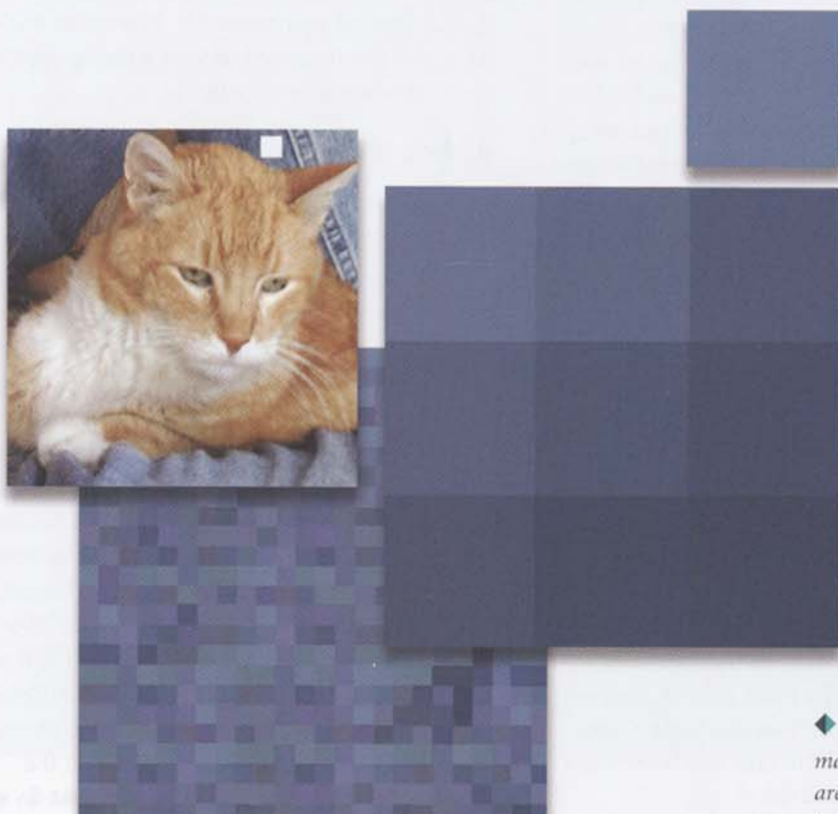
The digital world, however, is full of discrete units of information, like music recorded on CDs and digital clocks. Each piece of music or unit of time is a separate, distinct entity that can be accessed and manipulated. A quarter to seven on sweeping hands feels like a very different kind of time than 6:45 glowing at us in the morning from our digital alarm. **Figure 2-8** is a gracious old analog clock.

What is the difference between an analog and a digital photograph? When black-and-white film is chemically developed and printed into a photograph, it is analog. When we examine such a photograph under a magnifier, all we can see is a close-up of continually changing gray values.

◆ **2-8** *Robert Bryson.* Longcase clock. *Edinburgh, 1835. Shown in its traditional case.*
Courtesy George Bryson's daughter.

A digital photograph is captured with a digital camera or scanned. When a digitized photograph is examined close up on a monitor, we see indivisible picture elements or **pixels** that give only the illusion of a continuous gray or color tones. The more pixels, the smoother and more complete the image will be. In **Figure 2-9** the cat's image has been enlarged, showing discrete bits of visual data located in the tiny white square above its head. The top right shape represents a single pixel. The square beneath it represents 3 × 3 pixels in a three-inch square. The bottom represents 24 × 24 pixels in the same size square. The original image shows 300 pixels per inch, which in a three-inch square means you're looking at 900 pixels across. There are many kinds of digital data besides visual data. Consider audio CDs. Digital sound data also exists in accessible units of information that allow for editing.

Each separate pixel or other unit of digital data can be manipulated. Pixels can be accessed and changed by adjusting value, hue, and luminosity. Each unit viewed on the monitor represents a separate location in memory. This can give the artist/designer, photographer, or filmmaker total control over the image. It can also leave audience members unsure that what they are seeing exists in reality or only in the digital, fabricated world.



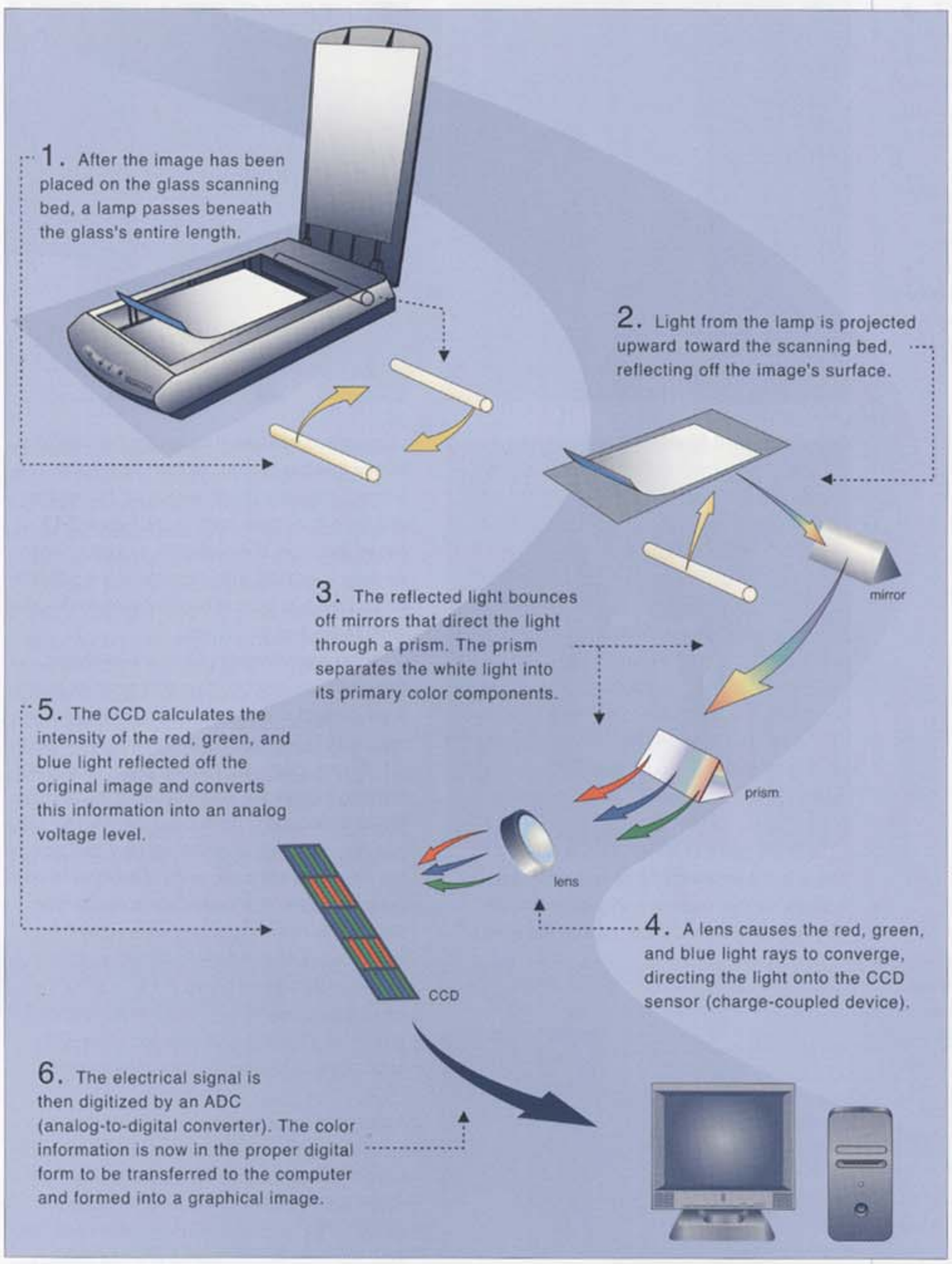
◆ **2-9** *The pixels that make up a digital image are represented in three increasing enlargements.*

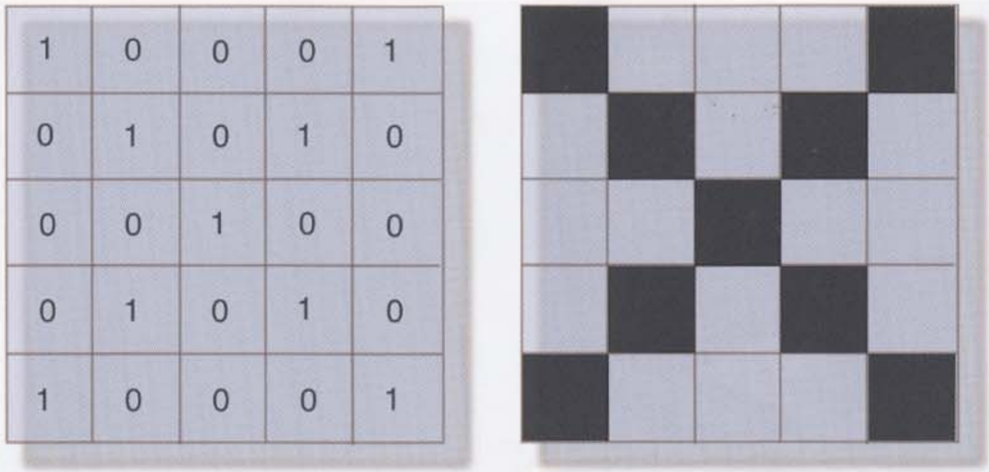
The Digital Image

Why do we see what we see on the monitor? How is the computer graphic display created from a scanned or drawn image? The answers lie in a combination of **hardware** and **software**. Hardware is the physical component that you work with, be it a PC or a Mac or one of the other excellent systems. These systems will have memory in **megabytes** or **gigabytes** (or more) installed. The printers, scanners, and various input devices are also part of the hardware. The software, however, constitutes the programs installed on your computer. Much of this book is devoted to mastering the software on your computer. In order to master it, you will first need to have a background in the structure of digital data.

Analog to Digital Conversions

Now that we know about the difference between analog and digital data, how is digital data created? In a scanner or a digital camera, analog to digital converters (ADCs) transform analog voltage signals to digital red, green, and blue (RGB) values. In a flatbed scanner, for example, a page is placed face down on the scanner and a scan head moves along the page, illuminating it. The light reflected from the page strikes a series of mirrors that redirect it to a lens. This lens focuses the beam of light into a prism that splits the beam into red, green, and blue components. The red, green, and blue light beams strike rows of photosensitive cells where they are converted into an analog voltage level. Finally, the analog to digital converter changes these voltage levels to digital information, storing the RGB levels for all the individual pixels in the image that are seen on the screen. **Figure 2-10** shows how this all works.

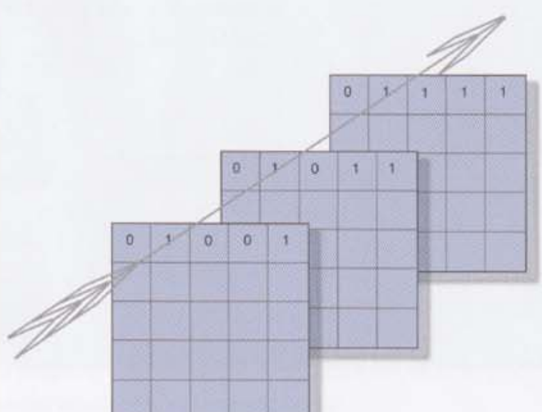




◆ **2-11** *Binary data consists of two commands. This diagram shows how a binary "on or off" command translates to a pixel that is either colored in black or not.*

Bits, Bytes, and Binary It is interesting to understand how digital data is stored, and fascinating to realize that complex, beautiful images of computer graphics are reliant on very basic numbers and mathematics for their creation. All digital design comes down to an "on" or "off" command at the hardware level. This is known as **binary data** because there are only two choices—"0" or "1." **Figure 2-11** shows a simple diagram of "on" and "off" binary code that translates to a pixel colored black or left uncolored. The word *binary* means "compounded or consisting of two things or parts." No matter how elaborate the artwork, this is its structural underpinning.

A single piece of information is called a **bit**, and it is the smallest unit of computer memory. A single bit can represent a black or a white pixel on the monitor. Each pixel on the screen represents a location in computer memory on a **bitmap** that has an "on" or "off" command. This bitmap is usually stored several bit planes (layers) deep to achieve complexity. **Figure 2-12** shows that more complex color can occur when we have a location with multiple bits of information. Three bits exist at each location in this diagram of stacked bit planes.



◆ **2-12** *Stacked bits of binary data make more complex color possible. The information at each pixel is no longer "0" or "1," but any of several combinations of those commands.*

When several layers of bits are combined, these bits can display grays and complex colors. A grouping of eight bits is called a **byte** and can represent 256 different grays or colors per pixel. A full-color image will take up much more memory than a grayscale image because it uses more bits of information. Three bytes (twenty-four bits) give the capability of rendering 16.7 million colors. These are the basic units of memory in computer hardware. It is incredible to realize that the visually rich images we create come from such humble origins based on "on" and "off" and multiplication. **Figures 2-13a–c** show the same image created with one bitmap, eight bit planes, and a full twenty-four bits. This is the basic physical structure of computer memory.

Memory There are two kinds of memory in a computer. An integrated circuit chip on the computer's motherboard has a permanent memory called **ROM** (Read-Only Memory). It holds the computer's essential operating instructions. The **RAM** (Random-Access Memory) is the memory used to actively create files. When you launch an application or open a document, it is loaded

(a)

(b)

(c)

◆ **2-13 [a–c]** *These three versions of the same image are created with one bitmap, eight bit planes, and a full twenty-four-bit depth.*

into RAM and stored there while you work. Enough RAM is needed to hold both the software and the data you generate. Every year that passes, artists and designers seem to need more RAM to drive their increasingly sophisticated software.

Internal hard drives, small removable mini-drives, DVDs, CDs, and Zip disks have storage space measured in megabytes and gigabytes. There are 1,024 bits in a byte, 1,024 bytes in a kilobyte, 1,024 kilobytes in a megabyte, and 1,024 megabytes in a gigabyte. A deluge of stored data surrounds most people working with computer graphics. When you have been at it more than a few years, a great many of your files are archived on outmoded storage devices. This means you need to continually update the storage of

Focus On Concept

What is the similarity between the prehistoric cave paintings and the marks we make today? Food is a need of all civilizations and is reflected in their communication. Can you think of another need shared across time and across geographic boundaries? How is it expressed and communicated? As you consider these questions, think about both the communications function and the potential for personal expression we find in our writing and imagery.

Our contemporary "New Media" store, retrieve, share, and manipulate data very differently than in the past. What kind of digital data do you encounter every day? What analog data does it replace? Consider the old analog clock in Figure 2-8 or think about various kinds of music storage. How do such technologies make your world different from that of your parents? How might your grandchildren's world differ from your own?

What do you think the next new communication invention will be? Will it bring any significant changes? Can you think of any science fiction inventions that may come true?

important files by transferring them to a new, larger storage device.

Accessing Memory Data storage has a conceptual dimension as well as a physical one. In addition to the physical storage of data, it is interesting to consider the impact such data storage has on us as individuals and as a society. As digital information grows and our access to it increases, how do we sort out the meaningful things? From books to photographs to computer disks to the Web, our personal and cultural storage capacity has increased. How to identify meaningful data is a practical as well as a philosophical question. Remember the student whose grandmother saved decades of images in her attic? Is a different personal value associated with dusty, print pages compared to crisp, digital recordings? What about a painting compared to a digital image? There is a difference between the physical nature of pigment on a surface and a digital file or print.

Next we will look more closely at the physical structure of the data that we are storing.

Pixels and Resolution What is the relationship between image, data storage, and memory? Each of the smallest visual units on the screen (called pixels) represents a location in memory. A digital image is broken down into pixels, each of which can be assigned an individual color. This is similar to the painting technique used in **Figures 2-14a–b** by the Neo-Impressionist and Pointillist Georges Seurat (1859–1891). In this detail from *A Sunday on La Grande Jatte—1884*, you can see that each of his paint strokes is a pigment placed on the canvas without blending. The viewer optically mixes the result.

Resolution refers to the fineness or sharpness of a screen display or computer-generated printed piece. The more memory available and thus the more pixels in the digital image, the higher the resolution is, and the clearer the image will be. The resolution of an individual file depends on what the artist/designer designates when the file is created, as in the Photoshop window **(Fig. 2-15)** where resolution for a new file is set. The number of individual pixels will determine the resolution of the image. **Figure 2-16** shows a high-resolution and low-resolution version of a graphic with straight lines. Note the jagged edges on the image on the right. These "jaggies" are especially noticeable in typography or graphics with straight lines. For print graphics, a final file resolution of 150 to 300 dpi (dots per inch) or more is mandatory.

The resolution of a screen, however, is independent from the image file you view on it. Screen resolution is set by the hardware. It is approximately 72 dpi, varying a little depending upon which computer you're using. Because the screen cannot show the full resolution of an image, it is wise to do **proof prints** of an image, which means printing out the file to paper so it can be seen in a higher resolution than the screen allows. Keep in mind that monitor viewing is in low resolution, and don't plan on evaluating a digital design that is intended for print by viewing the monitor.

◆ **2-15** *Photoshop window in which resolution and size for a new file are set.*

◆ **2-16** *Low resolution results in the jagged quality of the graphic on the right.*

◆ **2-14 [a]** *Georges Seurat.* A Sunday on La Grande Jatte. *1884. Oil.*

Helen Birch Bartlett Memorial Collection, The Art Institute of Chicago.

◆ **2-14 [b]** *Detail.*

Drawing and Painting

There are two kinds of image files in computer graphics: **vector graphics** and **raster graphics**. These are also known as **object-oriented** and **bitmapped** graphics for reasons that are discussed shortly. Both are capable of creating dynamic images, depending upon the skill of the artist/designer. Vector graphics are like a cross-stitch embroidery pattern in which the yarn stays as separate interwoven strands. Raster graphics, on the other hand, are like a woven fabric in which the color pattern is dyed into the cloth. The vector color "strands" can be separated and moved independently, but raster "fabric" cannot.

Vector graphics involve creating shapes that are clean edged and are defined as geometric objects. The vector object, whether a shape or a drawn line, can be easily selected and edited, repositioned and transformed. Vector graphics are resolution independent, which means they retain crisp edges when enlarged. This is a powerful concept. However large or small you transform a vector file, it remains perfectly sharp. This is especially important with files that need to be output in varying sizes. A company or product logo design is a good example of such a file. **Figure 3-1** shows the logo for Sandhill Studio at varying sizes.

3-1 *Figures created in vector programs can be enlarged without losing detail.*

Vector graphics are used in typography, which needs to be perfectly crisp and clear. They are also used in illustration, in the creation of GIF files for the web, for animation, and in engineering diagrams. Increasingly, very interesting and varied lines can be achieved with vectors. InDesign, Quark, Illustrator, and Freehand are samples of programs that use vectors. **Figure 3-2** with its soft clouds and crisp train details was created in Illustrator.

Raster graphics are a painterly approach that involves changing the color attributes of pixels. Photoshop and Painter are examples of software programs that create raster files. As you know, pixels are individual picture elements that are the basic structure of raster files. Each individual pixel can be manipulated separately. They form a "map" of your image. The colors in raster graphics can appear to have gradual transitions and softened edges. Each brush stroke appears to blend with the next, and although there is no easy way to separate a stroke from its layer and reposition it, the overall result can be very painterly as you learned in Chapter 2.

Raster graphics are used in anything involving the creation and manipulation of photo-based imagery. They are used in illustration and fine art. They are an important part of web JPEG graphics. **Figures 3-3a–d** compare raster and vector art using the same pair of scanned scissors. The scan in Figure 3-3a is drawn over to create the vector art shown in Figure 3-3b. It has hard line edges and can be scaled up or down without loss of detail. The last two figures show possible variations of a raster file, with its capability for soft edges and image manipulation.

Object-Oriented and Bitmapped Graphics

Let's summarize the differences between these two kinds of graphic data files. Vector graphics programs are object-oriented and create images with clean, sharp lines based on **Cartesian coordinates** (see next section). These images can always be selected and moved independently of other objects in the file. They can be changed in size with no loss in clarity.

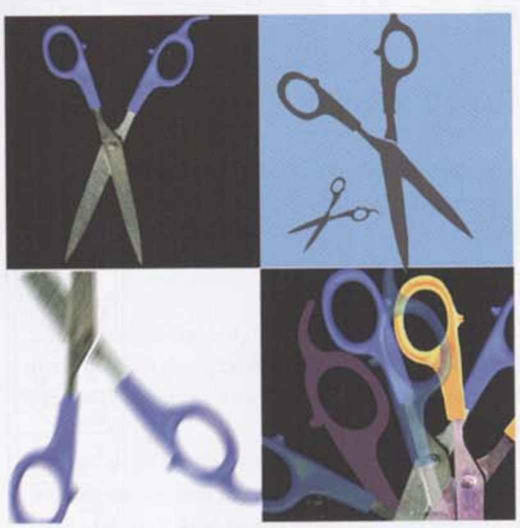
Bitmapped graphics are raster graphics comprised of pixels. Each pixel is individually manipulated through color and size to make a bitmapped file based on on-and-off commands. Bitmapped images lose data when changed in size but allow for a very painterly effect. Applications that have tools like paint cans and erasers are usually bitmapped graphics.

Now we will take a closer look at vector graphics and introduce the fundamental skills required to work with them. After this section, we will examine raster graphics. If you choose to follow the raster track and learn Photoshop first, skip to the Visual Language section now and return later to learn vector software.

Vector Graphics

In vector graphics we see the historical integration of philosophy, math, and drawing. The 17th-century philosopher René Descartes contributed to the field of human thought by considering fundamental questions of existence. He asked how we prove that we exist in *fact* and are more than a figment of imagination. When you think about trying to prove that, it's difficult. His most famous words were based upon his conclusion, "I think, therefore I am." He was also a fine mathematician and probably the first person to contribute to the development of computer graphics. His logic has informed us in philosophy, art, math, and science.

3-2 *This image was created by Jessica Davis for her student portfolio, using Illustrator software. It references her father's photograph of a local train station.*



3-3 [a–d] *The first scan of a pair of scissors is next shown as a vector drawing. The final two stages are raster image variations.*

Figure 3-15 shows a self-portrait paper cutting by contemporary artist and design educator Xiao Zang. An ancient Chinese technique, paper cutting often creates a relationship between figure and ground that is very dynamic. Zang works both with this time-honored technique and with the most current multimedia programs.

Ambiguous

Font animals are an enjoyable way to create an image that incorporates several kinds of typography into a final animal. This task asks you to utilize Illustrator's resizing and image transform functions as well as your imagination. Choose a single typestyle to work with and experiment with its italic, condensed, bold, and other versions to get the result you are looking for. You may want to convert the type to outline to have full control over its visual attributes. **Figures 3-16a–b** show animals created with typography in response to this final vector assignment. In the next section you will learn more about raster graphics and apply those graphics to an In The Studio assignment that also utilizes figure/ground relationships.

Raster Graphics

Now let's learn more about raster graphics. Some of this will review material presented previously. If you are choosing to do only vector software and save the raster for later, skip to the Summary Critique.

Rasters are very different from vectors. Raster graphics are created with individual picture elements called pixels, as discussed in Chapter 2. Think of the entire file as composed of tiny rectangles filled with color. Each pixel can be individually accessed and manipulated for a vast array of effects. Photoshop is a powerful raster graphics program. It has a flexible, intuitive feeling, much like painting with pigments. **Figure 3-17** shows the variety of lines that can be created in Photoshop.

As you know, because each pixel represents a location in memory that is a location on a bitmap, this kind of file is also called bitmapped graphics. When these files are enlarged, they lose resolution. The fewer the pixels, the coarser the image. More pixels create a finer image. Raster images should be created at the size they will be finally viewed or larger than their final size.

◆ **3-15** *Xiao Zang.* Pregnancy. *2002. Cut paper. 40 inches × 100 inches.*