A Short Course in Digital Photography

Navigating this on-line Book

To return to the top of the page, click any of the the pyramid-like icons.

To jump to a specific section in a chapter, click one of the topics listed in CONTENTS at the top of the page.

To move to another chapter, click the Previous Page or Next Page button on the navigation bar.

To display the book's table of contents, click the Book Contents button on the navigation bar.

To return to the site's home page to see other books, click the Home Page button on the navigation bar.

A Short Course in Digital Photography

Introduction

All great images, digital or otherwise, start by capturing a great photo and capturing great photos requires an understanding of your camera. It's these aspects of digital photography that this book is all about.

- To browse through chapters, click the **Previous Topic** or **Next Topic** button on the navigation bar.
- To jump between chapters openers, click the **Previous Chapter** or **Next Chapter** button on the navigation bar.
- To display the book's table of contents, click the **Book Contents** button on the navigation bar.
- To return to the site's home page to see other books, click the **Home Page** button on the navigation bar.

Digital cameras are only a few years old and are just now beginning to make serious inroads into photography. They have yet to be fully accepted by some photographers. However, despite some current limitations, digital cameras are the wave of the future and it's only a matter of time before most photographs are taken with these kinds of cameras rather than traditional film-based cameras.

Photographers who don't accept digital cameras generally base their arguments on the fact that the images are not as good as film-based cameras. Yet these same photographers most likely use 35 mm SLR cameras that are not as good as 8 x 10 view cameras. And if they do use 8 x 10 cameras, they don't use the even better mammoth glass plate view cameras used by Jackson and Muybridge after the Civil War. If they really wanted quality, they'd be using mules to carry their equipment. So much for their argument being based on the quality of the image.

The sad truth is that the quality of images has hardly improved at all since the first daguerreotypes of the 1840's and albumen and platinum prints of the late 1800s. What's happened is that both cameras and photographic processes have become easier and more convenient. Digital cameras are just another step along this path. Images captured with these cameras are admittedly different, but you'd be hard pressed to prove they are inferior. Many of the arguments you hear today about digital cameras are but echoes of the sentiments expressed when the 35mm Leica was introduced in 1925. Suddenly there was a camera that was easy to handle in the most difficult situations and with a long roll of motion picture film, capable of capturing one image after another. It may have used a much smaller negative, and hence been "inferior," but photographers who held onto their big, awkward box cameras were soon bypassed by history.

Another argument against digital cameras is that they are mainly of the point and shoot variety. That means they are fully automatic and don't have the controls that photographers have traditionally used to get great photos. This implies they are used for vacation pictures or photographs are taken as documents of family events. However, there is a certain elitism and snobbishness about this point of view. In general, the photographer brings more to a great photograph than the camera does. The history of photography is replete with stories about photographers who didn't know or care much about cameras. Jaques Henri Lartigue was getting great images before he was 10 years old--and with an old box camera to boot. It's said that Dorthea Lange (or was it Margaret Borke White) used the printed instructions that came with her film to set her camera's setting--"bright sun 1/125 at f/16, cloudy bright 1/125 at f/11, and so on."

But even if objections to image quality and lack of controls were true, these will change over time as more sophisticated, yet still affordable, cameras are introduced. Image quality already rivals or exceeds 35 mm film in high-end cameras. And these cameras also have the same controls as a professional 35 mm SLR. Their only drawback is their price, but prices are falling rapidly now that image sensors are solid state and Moore's Law is at work. In the meantime, you can get good pictures with point and shoot cameras, but to get great ones you still need to understand what the camera is doing for you automatically. If you understand the basic functions of your digital camera, you'll find it easier to expand and improve your photography. It's this understanding that gives you the creative control you need to record a scene realistically, just the way you saw it, or to instead capture the feeling or mood instead of the details making up the scene. Your understanding of a few basic principles makes it possible to take a photograph that best expresses what you want to convey.

The flowers in the foreground add both depth and interest to what might otherwise be a pretty dull picture.

Putting a dead steer in roughly the same position in this image as the flowers are in the previous one has quite a different effect.

Like artists in other mediums, as a photographer you have a set of "tools" that can make your photographs not only exciting and interesting to others but also unique to your own, very personal view of the world around you. The basic tools you have to work with are the way sharpness, tone, and color interact in the scene being photographed, the vantage point from which to take the picture, and the light under which it’s photographed.

You can choose to keep everything in a scene sharp for maximum detail or to blur it all for an impressionistic portrayal. You can keep some parts sharp and dramatic while letting others appear soft and undistracting. You can use black-and-white to emphasize tone, the innumerable shades of light and dark in every scene, or color to capture bright and powerful or soft and romantic colors. You can photograph the same subject at dawn, noon, dusk, or at night, in sun, rain, snow, or fog. Each of these variables will influence the image you get.

This ice-locked marina is in a lake in the Colorado Rockies. The melting ice takes on the look of surrealistic water.

All of this is possible by adjusting only three controls on your camera: focus, shutter speed, and aperture. These three controls, however, when combined with patience, experience, and your own personal view of the world, lend themselves to an infinite variety of possibilities, which makes photography a life-long interest and challenge for even the most experienced professionals.

With traditional photography, the final image varies very little from the original scene unless you have some serious darkroom skills.

With creative digital photography, the image can be just a starting point. Making photographs look like paintings has been frowned on in photography for the past 80 or so years. Maybe this form of pictoralism will make a comeback.

When learning and practicing photography, remember that there are no "rules," no "best" way to make a picture. Great photographs come from experimenting and trying new approaches even with old subjects.

Everything in a scene may not be equally important. When you look at the world your eye focuses sharply on only very small areas at any one time. You can select what is important from an almost infinite number of details. Photographers can use the same technique to isolate the most important part of a scene.

Sharpness in an image is one basic effect you can control in your photographs. In this photograph, the photographer chose to convey a feeling of speed and motion in the water rather than freeze it sharply.

Exposure choices can be used to portray any scene light or dark as you wish. More exposure to light makes a scene lighter, less exposure makes it darker. You can also adjust these tones as well as colors in a photo editing program.

A Short Course in Digital Photography

1. The World of Digital Photography

CONTENTS

Digital photography is really only a few years old, but it's already finding wide acceptance in many areas of photography. In this chapter, as we explore what kinds of photos people take, who's taking them, and how the images are used. As you read through this chapter, perhaps you'll find areas in which you might want to adopt digital photography.

What Kinds of Digital Photos are being Taken?

People like David Grenewetzki think nothing of strapping their new digital camera to a remote control airplane, or even a rocket, and launching it into the wild blue yonder to capture photos from a bird's-eye view. Until camera prices come way down, you might want to find other applications for your new camera.

What could be more fun than strapping your new camera onto a remote control airplane for pictures from hundreds of feet up! Check out David's site for lots more on this and rockets too. Image © 1997-1998 by David Grenewetzki.

Fine art photography is a broad category that has included everything from the amazing prints of Ansel Adams to fuzzy prints from a pinhole camera. It’s not at all surprising that digital cameras have become part of the hardware repertoire that artists work with. Long before Jerry Uelsmann was making montages, this form of photography was going on. Here is a 1905 image by Adelaide Hanscom that has many of the features we see in manipulated digital art.

Adelaide Hanscom did an entire series of manipulated images to illustrate a 1905 edition of the Rubiyat.

Photographs don't always have to be put to work. Most are really just for enjoyment. Capturing memories and strange sights are just a few such uses.

Peggy Curtin took this photo of a miniature St. Paul's Cathedral while leading a tour of Prince Edward Island in Canada.

There is a grand tradition of photographing on the street, capturing the fast action as it unfurls. This style of photography grew out of the freedom first offered by the 35 mm Leica, the first camera to truly allow high quality photography on the fly. Previously, cameras were tethered to tripods, or bulky and obvious. Bring up a one of those big, boxy Graflexs to take a picture and people ducked or fled the scene. Bring up a Leica and no one notices, not even when it makes its muffled "click." Some digital cameras are even smaller than the Leica and make no sound at all.

These mannequins in a London store window seemed quite willing to be photographed. Overcoming my usual shyness, I fired away.

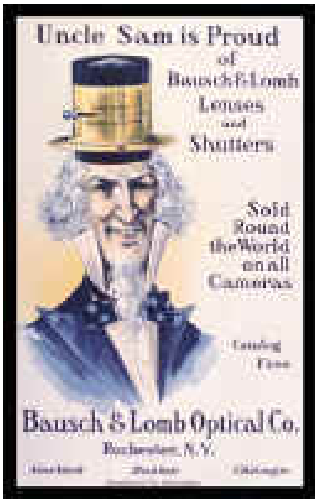
Nature photography is perhaps one of the most difficult kinds of photography. Subjects are elusive; one reason why so many "nature" photographs are taken in zoos and preserves where it's like shooting fish in a barrel. However, if you do it au natural, nature photography joyfully merges a love of the outdoors with a love of making images. If no good shots appear, you've still had a nice walk.

I stalked these big-horned sheep through the wilds of the London Zoo

One the first and most lasting applications of photography has been to bring distant worlds home to viewers. Digital photography now makes it possible to put all of your images on the Web and bore the entire world instead of just your friends and family. (I am probably the only photographer who fell asleep while showing his own slides.) One nice thing about digital cameras is that you can show your images on a TV set. You can even select only the best and copy them from you computer back onto the camera's storage device so you can give an edited slide show of just the best images. Some of the issues of digital travel photography are discussed in the section Travel Photography.

Stonehenge sits alone on England's Salisbury Plain looking much like it must have to those who built it thousands of years ago.

It's often necessary to make photographic copies of documents and objects. For example, a museum might want an illustrated inventory of everything in its possession. Digital cameras are ideal for this application.



Here an old advertisement for camera lenses has been copied.

Who's Taking Digital Photos?

Some of the early adopters of high-end digital cameras were photographers doing studio photographs for catalogs and other publications. They were able to quickly adopt these cameras for a variety of reasons. To begin with, objects such as birdhouses or dinner plates don’t move. This makes it possible to get the long exposures required by some high-resolution cameras that take three exposures to get a full color image. Another reason is that the images are usually reproduced small enough so their faults don't show. Finally, the production houses that prepare the catalogs prefer to receive digital images so they can avoid the time and cost of scanning them.

This studio image was taken with Sound Vision's CMOS-PRO—the first CMOS digital camera specifically designed for the graphic arts professional. Image courtesy of Sound Vision Inc.

Commercial photographers were amongst the first to adopt digital photography. Using expensive digital backs to large format cameras, these photographers are turning out images that rival those from film-based cameras.

Mike Berceanu shot this image on the Agfa StudioCam scanning digital camera. Courtesy of Mike Berceanu.

Reporters and news organizations such as the Associated Press have adopted digital cameras because the photos can be immediately transmitted from the site where they're taken over telephone lines or even a wireless connection. And once received, they are ready to use, no lab processing is required. A photo of the winning touchdown at a Super Bowl game can appear in a paper across the country within minutes. The low-resolution of digital cameras (compared to silver-based film) doesn't matter because newspaper printing is also low-resolution. Good sites on digital photojournalism are Rob Galbraith's and Dirck Halstead's.

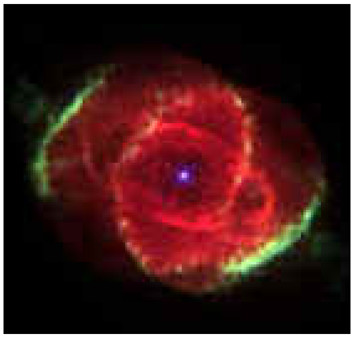
A rescue helicopter approaches the cliffs of Dover, England and rescues a man stranded by the incoming tide.

Weegee may not have put down his flash-bulb equipped Grapflex for a digital camera, but law enforcement agencies sure have. Like others, they are attracted to the speed of processing and the ability to easily enhance images and distribute them on-line.

Digital photography is ideal for many scientific applications. Here a special digital camera has captured the spectral reflectance properties of plants so their status can be determined. Using photographs such as these, farmers are better able to manage their crops.

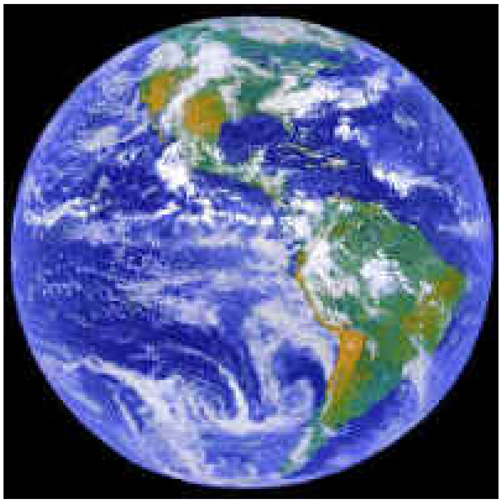
Digital cameras can also be used for special purposes. Here's an image taken with the Dycam ADC camera. And who ever said there wasn't art in science? I'd love to see what creative photographers could do with this camera. Courtesy of Dycam.

Digital image sensors have been used in astronomy for years. They are now widely used in place of film, even on the orbiting Hubble Space Telescope.



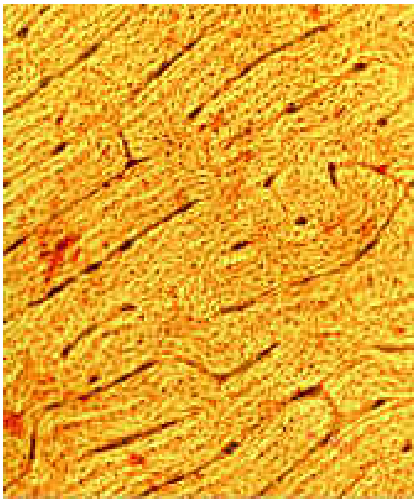
This NASA Hubble Space Telescope image shows one of the most complex planetary nebulae ever seen, NGC 6543, nicknamed the "Cat's Eye Nebula." Hubble reveals surprisingly intricate structures including concentric gas shells, jets of high-speed gas and unusual shock-induced knots of gas. Estimated to be 1,000 years old, the nebula is a visual "fossil record" of the dynamics and late evolution of a dying star. This image was created with support to Space Telescope Science Institute, operated by the Association of Universities for Research in Astronomy, Inc., from NASA contract NAS5-26555 and is reproduced with permission from AURA/STScI.

When you fly a camera through space or land it on another planet, getting film back to Earth is a big problem. The solution, of course, is to use a digital camera and send the image back digitally by radio transmission. That's exactly what was done on the Mars Rover mission where a small vehicle crawled across the surface of the planet sending back images—some of them in stereo.



Full view of the Earth, taken by GOES-8 (Geostationary Operational Environmental Satellite) on 2 September 1994 at 18:00 UT. Courtesy of Public Use of Remote Data.

It's common practice to take videos or photographs of what's revealed by a microscope. One of the masters of this was Roman Vishniac who was a true scientific artists. Digital cameras are ideal for this situation because the images can be immediately displayed.



Normal human bone captured through a Nikon microscope with SoundVision's CMOS-PRO. Image courtesy of Sound Vision, Inc.

Kids are getting into digital photography in a big way. With the recent development of low-cost image sensors that are used in cameras, companies are developing more products that include vision. Cameras can now go into products in which they were previously too expensive or bulky.

Mattel and Intel have jointly created the Intel Play X3™ Microscope.

Mattel Media has the Barbie Digital Camera that's inexpensive and, surprise—it's PINK. It holds only 6 images at 240 x 320 resolution but costs $64. It comes with software that lets kids use their photographs to create cards and place their photos into Barbie scenes. Mattel is also exploring digital cameras for boys (camouflage maybe?).

The Barbie Photo Designer Digital Camera brings low-cost digital imaging to kids. Courtesy of Mattel media.

How are Digital Photos Used?

Most of us take lots of photos and then chuck them in a drawer. If we care enough about some, we may even put them in an album. The problem is, we rarely share them with others and after awhile forget a lot about the circumstances under which we took them. Digital images change all of that. They are easy to insert into documents or Web pages along with captions or text. This makes it easy to create journals for personal memories or to share with others. You can post them on the Web for anyone to see, or print copies and give them to people who shared the experiences with you. Everyone can now be a publisher.

Lots of us have old family photographs that have been tossed in drawers and not well cared for over the years. As our families grow and spread out, it's harder and harder to organize and share these images that recall so much. However having them scanned, or even just photographing them with a digital camera, makes them easy to insert into documents or e-mail. You can even give someone a digital picture frame and feed photos to it over the Internet from anywhere in the world.

The Digi-Frame™ Model DF-560 comes complete with three interchangeable decorator frames - change them to match your decor, or your mood.

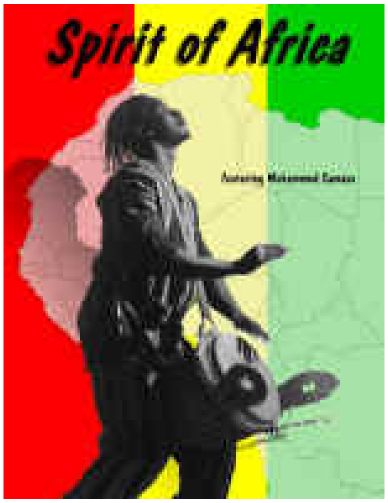
In the old days of film photography, you had to physically deliver photos to people you wanted to share them with. Today, that's not necessary. You can quickly send photos as e-mail attachments, post them on a Web site, or upload them to one of the many free photo sharing sites such as ofoto. Once your images are uploaded, you can even order prints, or lots of other products with your photos on them.

Who needs a gallery show when you can put your own photos on mugs?

Once images are in digital form, you can start to take pieces from various images and paste them into other images. These composite images can be tame or wild. In fact, compositing is done so often on television and in print advertisement that we're growing used to it.

Here the moon has been cut out of one image and pasted into another. You can't even tell the image has been altered.

Posters, books, magazines, journals, reports, and other kinds of other documents are illustrated with photographs and other images. Since these publications are increasingly desktop published, digital photos are just another part of the stew.



Rick Ashley took a digital photograph of the drummer Mohammed Camara and merged it with some clip art to create a stunning poster used to announce classes and performances. Image courtesy of [Rick Ashley](#).

Some big users of digital images are multimedia developers. Since multimedia is always displayed on a computer screen, or projected from it, digital images are a necessary ingredient. Whether originally taken with a digital camera or with a film camera and then scanned, the final image has to be in a digital format.

The PACE program was produced by Kim Foley to accompany a college computer text written by herself, Kunal Sen, Cathy Morin and myself. The text and program are published by Irwin/McGraw-Hill.

Anyone who is taking photographs for the Web prefers digital cameras because the images are ready to post as soon as they are taken. The images don’t have to be first processed and then scanned as film has to be. This saves both time and money. Since most screens display only low-resolution images, the low-resolution of some cameras is no drawback. In fact, higher resolution images would be too big to post on most Web sites and would have to be reduced anyway.

The author of this site has a number of Web sites all well illustrated with digital images. The site shown here is one for kids on bulldozers and other construction equipment. If you click the link to check it out, please come back.

Once images are in a digital format, you can include them in desktop published documents created with programs such as Microsoft Word, PageMaker, or QuarkXPress.

Images have been placed in a PageMaker document to prepare them for publishing.

Once the almost exclusive domain of Polaroid instant cameras, photos for IDs are increasingly taken in digital form. Once captured, they can be immediately printed right on the ID cards, making counterfeiting more difficult.You can also use the images to create buttons or illustrated business cards.

Fargo printers are used to make full-color ID cards complete with photographs. Courtesy of Fargo.

Newsletters from companies and organizations are often full of images. Employees and members are honored when promoted, retired, or when they reach some milestone, and events are documented. As the publishing process has become digital and moved to the desktop, so have the photographs used to illustrate these newsletters.

Realtors are big consumers of photography. Exterior shots are taken for newspaper ads and interior shots for brochures and Web sites. The ease and immediacy of digital cameras makes them widely used in this field.

A typical interior view such as those taken for real estate brochures.

If your house or office burns down, or blows or floats away, how do you prove you lost that velvet painting of Elvis? The best way is to photograph your belongings and store the image files on a disk. Then, hope you'll be able to open the images a decade from now when you need them and file formats and devices have changed (remember the 5 1/4-inch floppy?) To be on the safe side, display the images on the TV and tape them then store the tape in a safe place.

If you don't have some items insured, you may have to make do if anything goes wrong. It helps if you have photos that show the "before." The insurance company will photograph the "after."

If you are like millions of other people, you may have things around the house you want to sell. It's easier than ever now with on-line auction such as e-bay. It's been proven over and over again that items accompanied by a good photo bring much higher prices.

A clear crisp digital image can make all of the difference when selling an item in and on-line auction.

A Short Course in Digital Photography

2. Image Sensors—Capturing the Photograph

CONTENTS

Unlike traditional cameras that use film to capture and store an image, digital cameras use a solid-state device called an **image sensor**. These fingernail-sized silicon chips contain millions of photosensitive diodes called **photosites**. In the brief flickering instant that the shutter is open, each photosite records the intensity or brightness of the light that falls on it by accumulating a charge; the more light, the higher the charge. The brightness recorded by each photosite is then stored as a set of numbers that can then be used to set the color and brightness of dots on the screen or ink on the printed page to reconstruct the image. In this chapter, we'll look closely at this process because it's the foundation of everything that follows.

The Development of the CCD

Based on a press release by Patrick Regan; Lucent Technologies, Murray Hill

George Smith and Willard Boyle invented the charge-coupled device (CCD) at Bell Labs. They were attempting to create a new kind of semiconductor memory for computers. A secondary consideration was the need to develop solid-state cameras for use in video telephone service. In the space of an hour on October 17, 1969, they sketched out the CCD's basic structure, defined its principles of operation, and outlined applications including imaging as well as memory.

Willard Boyle (left) and George Smith (right). Courtesy of Lucent Technologies.

By 1970, the Bell Labs researchers had built the CCD into the world's first solid-state video camera. In 1975, they demonstrated the first CCD camera with image quality sharp enough for broadcast television.

Today, CCD technology is pervasive not only in broadcasting but also in video applications that range from security monitoring to high-definition television, and from endoscopy to desktop videoconferencing. Facsimile machines, copying machines, image scanners, digital still cameras, and bar code readers also have employed CCDs to turn patterns of light into useful information.

Since 1983, when telescopes were first outfitted with solid-state cameras, CCDs have enabled astronomers to study objects thousands of times fainter than what the most sensitive photographic plates could capture, and to image in seconds what would have taken hours before. Today all optical observatories, including the Hubble Space Telescope, rely on digital information systems built around "mosaics" of ultrasensitive CCD chips. Researchers in other fields have put CCDs to work in applications as diverse as observing chemical reactions in the lab and studying the feeble light emitted by hot water gushing out of vents in the ocean floor. CCD cameras also are used in satellite observation of the earth for environmental monitoring, surveying, and surveillance.

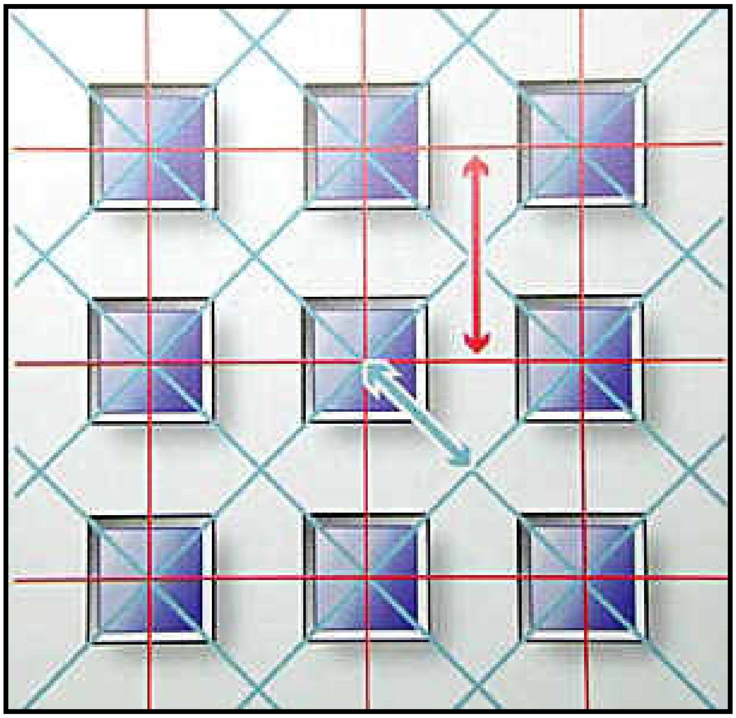
Image Sensors and Pixels

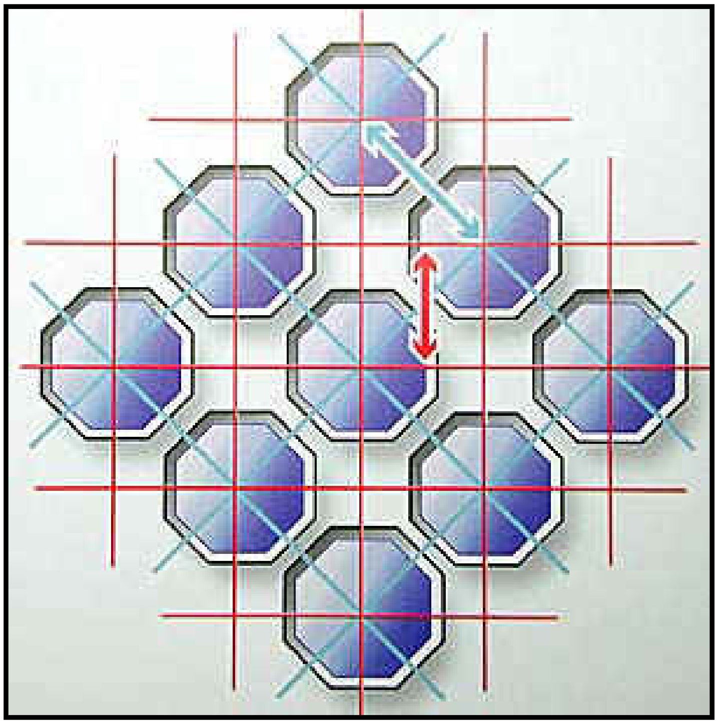
Digital photographs are made up of hundreds of thousands or millions of tiny squares called picture elements, or just **pixels**. Each of these pixels is captured by a single photosite on the image sensor when you take the photo. Like the impressionists who painted wonderful scenes with small dabs of paint, your computer and printer can use these tiny pixels to display or print photographs. To do so, the computer divides the screen or printed page into a grid of pixels, much like the image sensor is divided. It then uses the values stored in the digital photograph to specify the brightness and color of each pixel in this grid—a form of painting by number. Controlling, or addressing a grid of individual pixels in this way is called bit mapping and digital images are called **bit-maps**.

Here you see a reproduction of the famous painting "The Spirit of '76" done in jelly beans. Think of each jelly bean as a pixel and it's easy to see how dots can form images. Jelly Bean Spirit of '76 courtesy of Herman Goelitz Candy Company Inc. Makers of Jelly Belly jelly beans.

The makeup of a pixel varies depending on whether it's in the camera, on the screen, or on a printout.

On an image sensor, each photosite captures the brightness of a single pixel. The layout of the photosites can take the form of a grid or honeycomb depending on who designed it.





A typical image sensor has square photosites arranged in rows and columns.

The Super CCD from Fuji uses octagonal pixels arranged in a honeycomb pattern.

Image size

The quality of a digital image, whether printed or displayed on a screen, depends in part on the number of pixels used to create the image (sometimes referred to as *resolution*). The maximum number that you can capture depends on how many photo sites there are on the image sensor used to capture the image. (However, some cameras add additional pixels to artificially inflate the size of the image. You can do the same thing in an image-editing program. In most cases this upsizing only makes the image larger without making it better.)

Image Sizes—Optical and Interpolated

Beware of claims about image sizes (often referred to as *resolution*) for cameras and scanners because there are two kinds; optical and interpolated. The **optical resolution** of a camera or scanner is an absolute number because an image sensor's photosites are physical devices that can be counted. To improve resolution in certain limited respects, the resolution can be increased using software. This process, called **interpolated resolution**, adds pixels to the image. To do so, software evaluates those pixels surrounding each new pixel to determine what its colors should be. For example, if all of the pixels around a newly inserted pixel are red, the new pixel will be made red. What's important to keep in mind is that interpolated resolution doesn't add any new information to the image—it just adds pixels and makes the file larger. This same thing can be done in a photo editing program such as Photoshop by resizing the image. Beware of companies that promote or emphasize their device's interpolated (or enhanced) resolution. You're getting less than you think you are. Always check for the device's optical resolution. If this isn't provided, flee the product—you're dealing with marketing people who don't have your best interests at heart.

More pixels add detail and sharpen edges. If you enlarge any digital image enough, the pixels will begin to show-an effect called pixelization. This is not unlike traditional silver-based prints where grain begins to show when prints are enlarged past a certain point. The more pixels there are in an image, the more it can be enlarged before pixelization occurs.

The photo of the face (right) looks normal, but when the eye is enlarged too much (left) the pixels begin to show. Each pixel is a small square made up of a single color.

This table lists some standards of comparison. The numbers from various sources differ. One great thing about the Web is that you can talk back to an author and correct him. Click here to send a message setting me straight.

Element	**Resolution**	**Total Pixels**
Color TV (NTSC)	320 x 525	168,000
Human eye	11,000 x 11,000	120 million
35-mm slide		The "Economist" magazine says it has 20 million or more. CMOS Imaging News says 5 to 10 million depending on the film. Another source says about 80 million pixels. Robert Caspe at SoundVision states that color negative film has 1000 pixels per inch while color positive film has 2000 pixels per inch.
1982 Kodak Disc camera film		3 million pixels—each about 0.0003 inch in diameter

The size of a photograph is specified in one of two ways-by its dimensions in pixels or by the total number of pixels it contains. For example, the same image can be said to have 1800 x 1600 pixels (where "x" is pronounced "by" as in "1800 by 1600"), or to contain 2.88-million pixels (1800 multiplied by 1600).

This digital image of a Monarch butterfly chrysalis is 1800 pixels wide and 1600 pixels tall. It's said to be 1800x1600.

Camera Resolutions

As you have seen, image sensors contain a grid of photosites—each representing one pixel in the final image. The sensor's resolution is determined by how many photosites there are on its surface. This resolution is usually specified in one of two ways—by the sensor's dimension in pixels or by its total number of pixels. For example, the same camera may specify its resolution as 1200 x 800 pixels (where "x" is pronounced "by" as in "1200 by 800"), or 960-thousand pixels (1200 multiplied by 800). Very high end cameras often refer to file sizes instead of resolution. For example, someone may say a camera creates 30-Megabyte files. This is just a form of shorthand.

Low-end cameras currently have resolutions around 640 x 480 pixels, although this number constantly improves. Better cameras, those with 1 million or more pixels are called **megapixel cameras** and those with over 2-million are called **multi-megapixel cameras**. Even the most expensive professional digital cameras give you only about 6-million pixels. As you might expect, all other things being equal, costs rise with the camera's resolution.

Size isn't everything!

The large an image's size in pixels, the larger the image file needed to store it. For this reason, some cameras allow you to specify more than one size when you take a picture. Although you are likely to get better results with a larger image, it isn't always needed—especially when the image is going to be displayed on the Web or printed very small. In these cases smaller images will suffice and because they have smaller file sizes, you'll be able to squeeze more into the camera's memory.

Resolution of Digital Devices

Although more photosites often means better images, adding more isn't easy and creates other problems. For example:

- It adds significantly more photosites to the chip so the chip must be larger and each photosite smaller. Larger chips with more photosites increase difficulties (and costs) of manufacturing. Smaller photosites must be more sensitive to capture the same amount of light.
- More photosites create larger image files, creating storage problems.

Monitor Resolutions

The resolution of a display monitor is almost always given as a pair of numbers that indicate the screen's width and height in pixels. For example, a monitor may be specified as being 640 x 480, 800 x 600, 1024 x 768, and so on.

- The first number in the pair is the number of pixels across the screen.
- The second number is the number of rows of pixels down the screen.

monitorres with labels.JPG (57808 bytes)

This is a 640 x 480 display. That means there are 640 pixels on each row and there are 480 rows.

Images displayed on the monitor are very low-resolution. As you can see from the table below, the actual number of pixels per inch depends on both the resolution and the size of the monitor. Generally, images that are to be displayed on the screen are converted to 72 pixels per inch (ppi), a resolution held over from an early era in Apple's history. (The red numbers in the table are the pixels per inch for each combination of screen size and resolution.) As you can see from the table, this isn't an exact number for any resolution on any screen, but it tends to be a good compromise. If an image is 800 pixels wide, the pixels per inch are different on a 10-inch wide monitor that on a 20-inch. The same number of pixels have to be spread over a larger screen so the pixels per inch falls.

Resolution	Monitor Size				
	14	15	17	19	21
640 x 480	60	57	51	44	41
800 x 600	74	71	64	56	51
1024 x 768	95	91	82	71	65

Printer and Scanner Resolutions

Printer and scanner resolutions are usually specified by the number of **dots per inch** (dpi) that they print or scan. (Generally **pixels per inch** refer to the image and display screen and **dots per inch** refer to the printer and printed image. Sometimes I think terminology shifts like this are done just to confuse us. In this book we use them interchangeably) For comparison purposes, monitors use an average of 72 ppi to display text and images, ink-jet printers range up to 1700 dpi or so, and commercial typesetting machines range between 1,000 and 2,400 dpi.

Image Sensors

Just as in a traditional camera, light enters a digital camera through a lens controlled by a shutter. Digital cameras have one of three types of electronic shutters that control the exposure:

- **Electronically shuttered sensors** use the image sensor itself to set the exposure time. A timing circuit tells it when to start and stop the exposure
- **Electromechanical shutters** are mechanical devices that are controlled electronically.
- **Electro-optical shutters** are electronically driven devices in front of the image sensor which change the optical path transmittence.

From Light Beams to Images

When the shutter opens, rather than exposing film, the digital camera collects light on an image sensor—a solid state electronic device. As you've seen, the image sensor contains a grid of tiny photosites. As the lens focuses the scene on the sensor, some photosites record highlights, some shadows, and others record all of the levels of brightness in between.

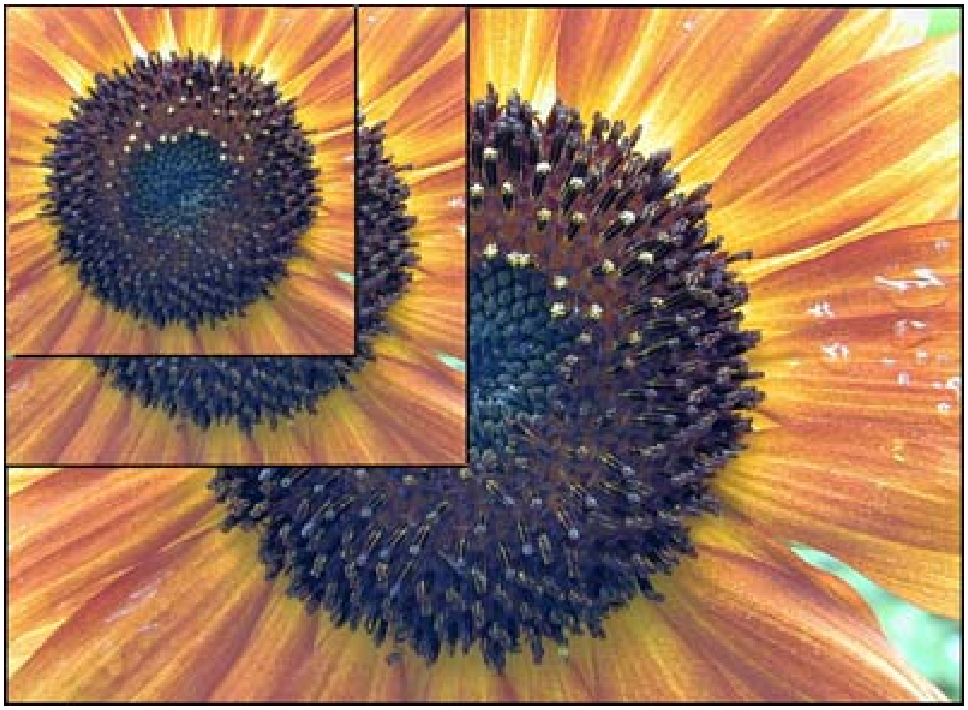


Image sensors are often tiny devices. Here you can see how much smaller the common 1/2" and 2/3" sensors are compared to a 35mm slide or negative.

Each site converts the light falling on it into an electrical charge. The brighter the light, the higher the charge. When the shutter closes and the exposure is complete, the sensor "remembers" the pattern it recorded. The various levels of charge are then converted to digital numbers that can be used to recreate the image.

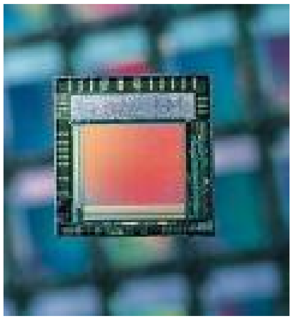
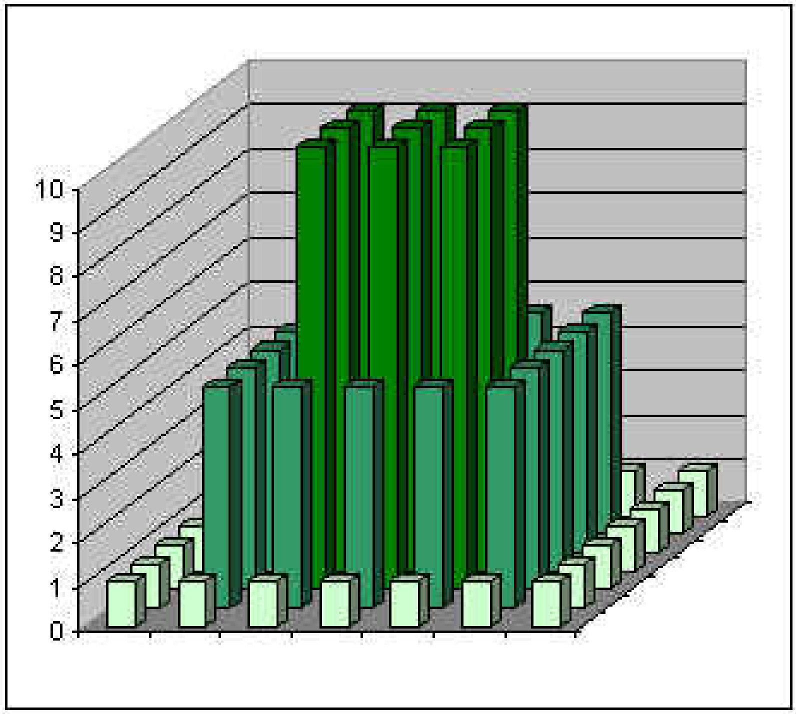


Image sensors contain a grid of photosites that convert light shining on them to electrical charges. These charges can then be measured and converted into digital numbers that indicate how much light hit each site. Courtesy of VISION.

These two illustrations show how image sensors capture images.

1	1	1	1	1	1	1	1	1
1	1	5	5	5	5	5	1	1
1	1	5	10	10	10	5	1	1
1	1	5	10	10	10	5	1	1
1	1	5	10	10	10	5	1	1
1	1	5	10	10	10	5	1	1
1	1	5	10	10	10	5	1	1
1	1	5	5	5	5	5	1	1
1	1	1	1	1	1	1	1	1

When an image is focused through the camera (or scanner) lens, it falls on the image sensor. Varying amounts of light hit each photosite and knock loose electrons that are then captured and stored. The number of electrons knocked loose from any photosite is directly proportional to the amount of light hitting it.



*When the exposure is completed, the sensor is like a checkerboard, with different numbers of checkers (electrons) piled on each square (photosite). When the image is read off the sensor, the stored electrons are converted to a series of analog charges which are then converted to digital values by an **Analog-to-Digital (A to D) converter**.*

Interlaced vs. Progressive Scan

Once the sensor has captured an image, it must be read, converted to digital, and then stored. The charges stored on the sensor are not read all at once but a row at a time. There are two ways to do this—using interlaced or progressive scans.

- On an **interlaced scan** sensor, the image is first processed by the odd lines, and then by the even lines. These kinds of sensors are frequently used in video cameras because television broadcasts are interlaced.

- On a **progressive scan** sensor, the rows are processed one after another in sequence.

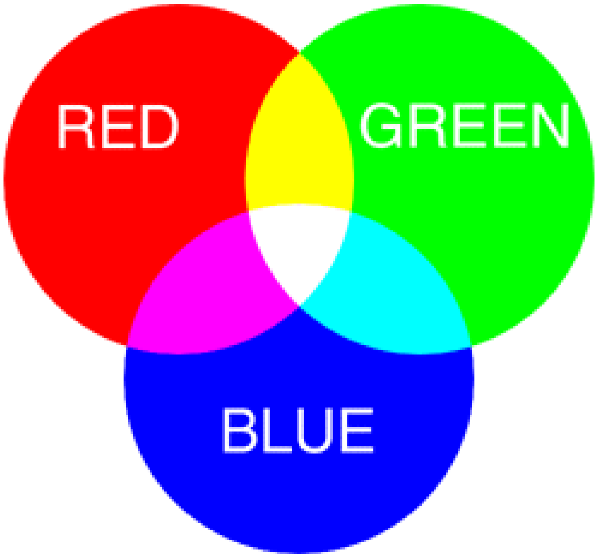
On an interlaced scan sensor, the image is first read off every other row, top to bottom. The image is then filled in as each alternate row is read.

Image Sensors and Colors

When photography was first invented, it could only record black & white images. The search for color was a long and arduous process, and a lot of hand coloring went on in the interim (causing one author to comment "so you have to know how to paint after all!"). One major breakthrough was James Clerk Maxwell's 1860 discovery that color photographs could be formed using red, blue, and green filters. He had the photographer, Thomas Sutton, photograph a tartan ribbon three times, each time with a different one of the color filters over the lens. The three images were developed and then projected onto a screen with three different projectors, each equipped with the same color filter used to take its image. When brought into register, the three images formed a full color image. Over a century later, image sensors work much the same way.

Additive Colors

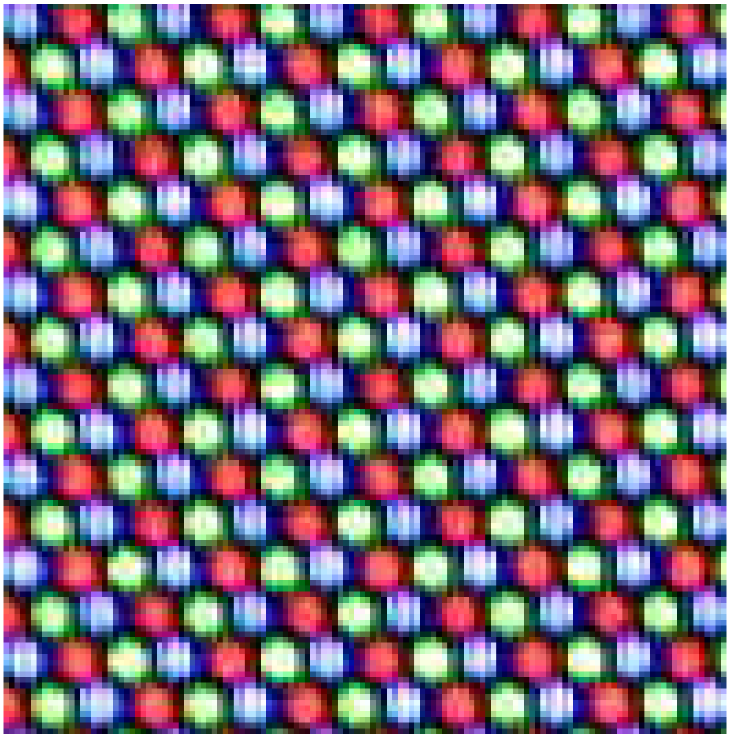
Colors in a photographic image are usually based on the three primary colors red, green, and blue (RGB). This is called the **additive color system** because when the three colors are combined in equal quantities, they form white. This system is used whenever light is projected to form colors as it is on the display monitor (or in your eye). The first commercially successful use of this system to capture color images was invented by the Lumerie brothers in 1903 and became know as the Autochrome process. They dyed grains of starch red, green, and blue and used them to create color images on glass plates.



RGB uses additive colors. When all three are mixed in equal amounts they form white. When red and green overlap they form yellow, and so on.

For more on color, visit The ColorCube Web site.

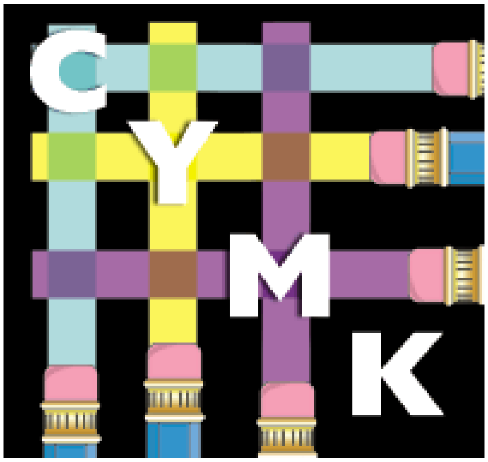
On the monitor, each pixel is formed from a group of three dots, one each for red, green, and blue.



On the screen, each pixel is a single color formed by mixing triads of red, green, and blue dots or LCDs.

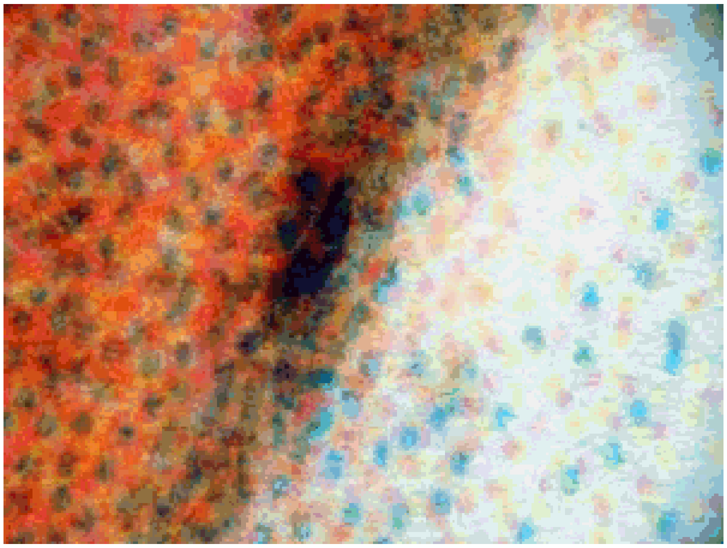
Subtractive Colors

Although most cameras use the additive RGB color system, a few high-end cameras and all printers use the CMYK system. This system, called **subtractive colors**, uses the three primary colors Cyan, Magenta, and Yellow (hence the CMY in the name—the K stands for an extra black). When these three colors are combined in equal quantities, the result is a reflected black because all of the colors are subtracted. The CMYK system is widely used in the printing industry, but if you plan on displaying CMYK images on the screen, they have to be converted to RGB and you lose some color accuracy in the conversion.



When you combine cyan, magenta, and yellow inks or pigments, you create subtractive colors.

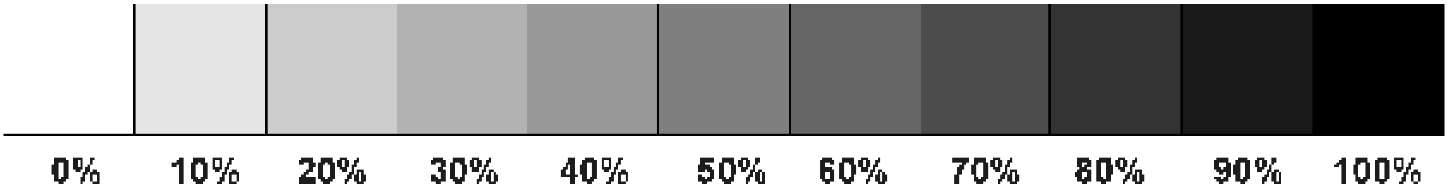
On a printout, each pixel is formed from smaller dots of cyan, magenta, yellow, and black ink. Where these dots overlap, various colors are formed.



This brief animation zooms in on a part of an inkjet print to show you increasing levels of detail. Courtesy of Trevor Anderson.

It's All Black and White After All

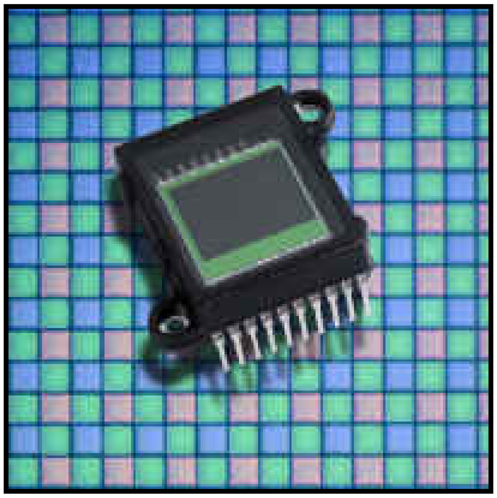
Image sensors record only the **gray scale**—a series of 256 increasingly darker tones ranging from pure white to pure black. Basically, they only capture brightness.



The gray scale contains a range of tones from pure white to pure black.

How then, do sensors capture colors when all they can do is record grays? The trick is to use red, green, and blue filters to separate out the red, green and blue components of the light reflected by an object. (Likewise, the filters in a CMYK sensor will be either cyan, magenta, or yellow.) There are a number of ways to do this, including the following:

- Three separate image sensors can be used, each with its own filter. This way each image sensor captures the image in a single color.
- Three separate exposures can be made, changing the filter for each one. In this way, the three colors are "painted" onto the sensor, one at a time.
- Filters can be placed over individual photosites so each can capture only one of the three colors. In this way, one-third of the photo is captured in red light, one-third in blue, and one-third in green.



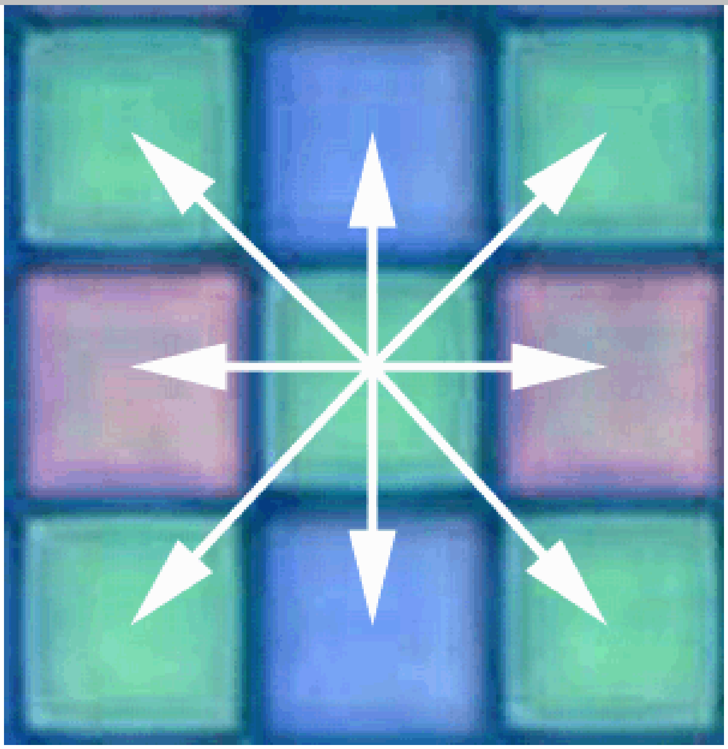
Each pixel on the image sensor has red, green, and blue filters intermingled across the photosites in patterns designed to yield sharper images and truer colors. The patterns vary from company to company but the most popular is the Bayer mosaic pattern shown here behind the image sensor. Courtesy of IBM.

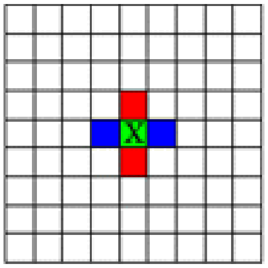
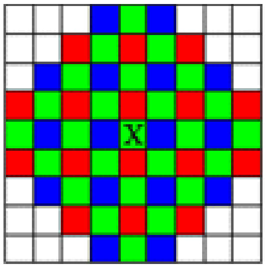
From Black and White to Color

When three separate exposures are made through different filters, each pixel on the sensor records each color in the image and the three files are merged to form the full-color image. However, when three separate sensors are used, or when small filters are placed directly over individual photosites on the sensor, the optical resolution of the sensor is reduced by one-third. This is because each of the available photosites records only one of the three colors. For example, on some sensors with 1.2 million photosites, 300-thousand have red filters, 300-thousand have blue, and 600-thousand have green. Does this mean the resolution is still 1.2 million, or is it now 300-thousand? Or 600-thousand? Let's see.

Each site stores its captured color (as seen through the filter) as an 8-, 10-, or 12-bit value. To create a 24-, 30-, or 36-bit full-color image, interpolation is used. This form of interpolation uses the colors of neighboring pixels to calculate the two colors a photosite didn't record. By combining these two interpolated colors with the color measured by the site directly, the original color of every pixel is calculated. ("I'm bright red and the green and blue pixels around me are also bright so that must mean I'm really a white pixel.") This step is computer intensive since comparisons with as many as eight neighboring pixels is required to perform this process properly; it also results in increased data per image so files get larger.

Here the full-color of the center green pixel is about to be interpolated from the colors of the eight surrounding pixels.



 Traditional interpolation uses only nearest neighbors of the unknown colors.  HP's demosaicing uses all measured pixels for estimating all 3 color values, over a region as large as 9x9.	*HP has introduced a process called demosaicing that interpolates colors using a much wider range of adjacent pixels. Courtesy of HP.*

Color Channels

Each of the colors in an image can be controlled independently and is called a **color channel**. If a channel of 8-bit color is used for each color in a pixel—red, green, and blue—the three channels can be combined to give 24-bit color.

When an image is open in Photoshop, a dialog box shows the red, green, and blue channels so you can select the one you want to work on. The top image in the dialog box is the combined 24-bit RGB.

Color Aliasing

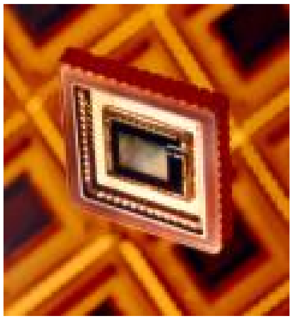
When interpolation is used, there has to be enough information in surrounding pixels to contribute color information. This isn't always the case. Low-resolution image sensors have a problem called **color aliasing** that occurs when a spot of light in the original scene is only big enough to be read by one or two pixels. Surrounding pixels don't contain any accurate color information about the pixel so the color of that spot may show up as a dot of color disconnected from the surrounding image. Another form of color aliasing shows up as out of place color fringes surrounding otherwise sharply defined objects.

Area Array and Linear Sensors

Hand a group of camera or scanner designers a theory and a box of components and you'll see fireworks. They will explore every possible combination to see which works best. The market determines the eventual winners in this "throw them against the wall and see what sticks" approach. At the moment, designers have two types of components to play with: area array and linear sensors.

Area-array Sensors

Most cameras use **area-array sensors** with photosites arranged in a grid because they can cover the entire image area and capture an entire image all at once.



Area array image sensors have their photosites (pixels) arranged in a grid so they can instantly capture a full image. Courtesy of VISION.

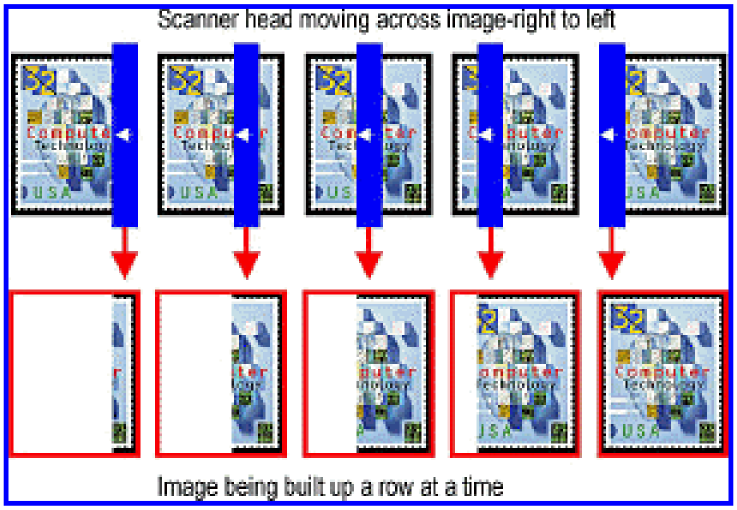
These area array sensors can be incorporated into a camera in a variety of ways.

- **One-chip, one-shot cameras** use different color filters over each photosite to capture all three colors with a single exposure. This is the most common form of image sensor used in consumer-level digital cameras.

- **One chip, three shot cameras** take three separate exposures: one each for red, green, and blue. A different colored filter is placed in front of the image sensor for each of the colors. These cameras cannot photograph moving objects in color (although they can in black & white) and are usually used for studio photography.
- **Two-chip cameras** capture chromonance using one sensor (usually equipped with filters for red light and blue light) and luminance with a second sensor (usually the one capturing green light). Two-chip cameras require less interpolation to render true colors.
- **Three-chip cameras**, such as one from MegaVision, use three full frame image sensors; each coated with a filter to make it red-, green- or blue-sensitive. A beam splitter inside the camera divides incoming images into three copies; one aimed at each of the sensors. This design delivers high-resolution images with excellent color rendering. However, three-chip cameras tend to be both costly and bulky.

Linear Sensors

Scanners, and a few professional cameras, use image sensors with photosites arranged in either one row or three. Because these sensors don't cover the entire image area, the image must be scanned across the sensor as it builds up the image from the captured rows of pixels. Cameras with these sensors are useful only for motionless subjects and studio photography. However, these sensors are widely used in scanners.



As a linear sensor scans an image a line at a time it gradually builds up a full image.

- **Linear image sensors** put a different color filter over the device for three separate exposures—one each to capture red, blue or green.
- **Tri-linear sensors** use three rows of photosites—each with a red, green, or blue filter. Since each pixel has it's own sensor, colors are captured very accurately in a single exposure.

CCD And CMOS Image Sensors

Until recently, CCDs were the only image sensors used in digital cameras. They have been well developed through their use in astronomical telescopes, scanners, and video camcorders. However, there is a new challenger on the horizon, the CMOS image sensor that promises to eventually become the image sensor of choice in a large segment of the market.

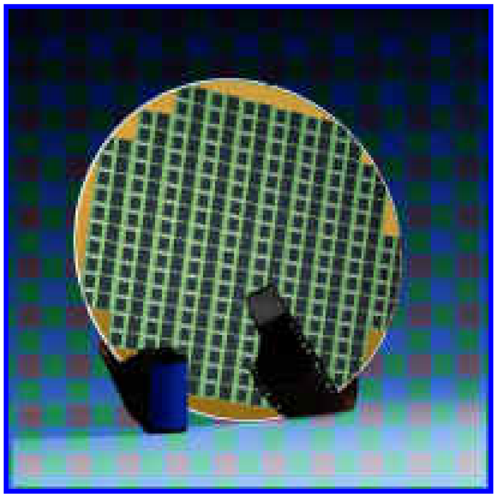
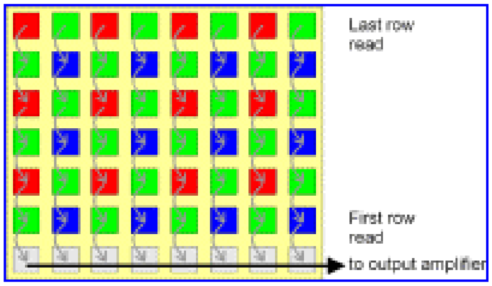


Image sensors are formed on silicon wafers and then cut apart. Courtesy of IBM.

CCD Image Sensors

Charge-coupled devices (CCDs) capture light on the small photosites on their surface and get their name from the way that charge is read after an exposure. To begin, the charges on the first row are transferred to a **read out register**. From there, the signals are then fed to an amplifier and then on to an analog-to-digital converter. Once the row has been read, its charges on the read-out register row are deleted, the next row enter the read-out register, and all of the rows above march down one row. The charges on each row are "coupled" to those on the row above so when one moves down, the next moves down to fill its old space. In this way, each row can be read—one row at a time.

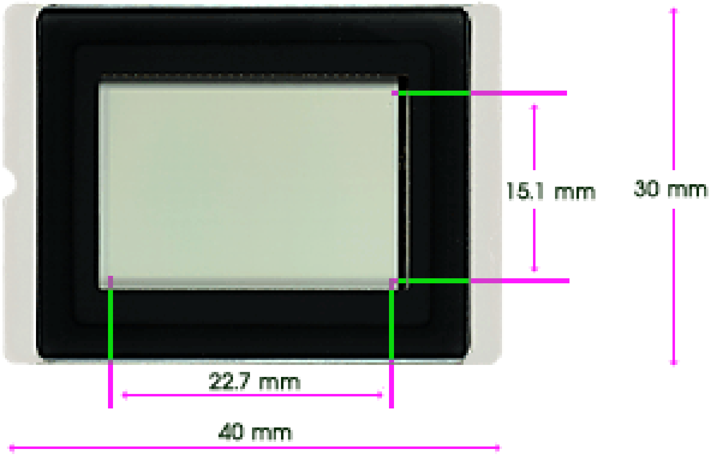


The CCD shifts one whole row at a time into the readout register. The readout register then shifts one pixel at a time to the output amplifier.

It is technically feasible but not economic to use the CCD manufacturing process to integrate other camera functions, such as the clock drivers, timing logic, and signal processing on the same chip as the photosites. These are normally put on separate chips so CCD cameras contain several chips, often as many as 8, and not fewer than 3.

CMOS Image Sensors

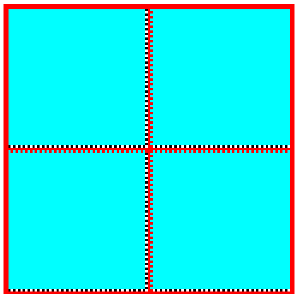
Image sensors are manufactured in wafer foundries or fabs. Here the tiny circuits and devices are etched onto silicon chips. The biggest problem with CCDs is that there isn't enough economy of scale. They are created in foundries using specialized and expensive processes that can only be used to make CCDs. Meanwhile, more and larger foundries across the street are using a different process called **Complementary Metal Oxide Semiconductor** (CMOS) to make millions of chips for computer processors and memory. This is by far the most common and highest yielding process in the world. The latest CMOS processors, such as the Pentium III, contain almost 10 million active elements. Using this same process and the same equipment to manufacturer **CMOS image sensors** cuts costs dramatically because the fixed costs of the plant are spread over a much larger number of devices. (**CMOS** refers to how a sensor is manufactured, and not to a specific sensor technology.) As a result of this economy of scale, the cost of fabricating a CMOS wafer is one-third the cost of fabricating a similar wafer using a specialized CCD process.



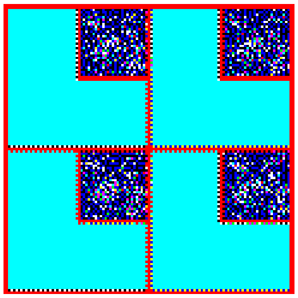
The CCD imaging elements used in most digital cameras are costly and consume high levels of energy. Increasing the size of these imaging elements to include more pixels would require much larger power supplies as well as make them even more expensive. In developing the EOS D30, Canon concentrated on using a CMOS sensor instead of a CCD. The CMOS technology has attracted attention for its lower power requirements, as well as its ability to integrate with image-processing circuits. However, several engineering obstacles remained–including problems with the precision of internal transistors that led to variable image precision–and few products were developed using this technology. However, Canon has now overcome these obstacles, and has succeeded in developing a large CMOS sensor. Courtesy of Canon.

Here are some things you might like to know about CMOS image sensors:

- CMOS image quality is now matching CCD quality in the low- and mid-range, leaving only the high-end image sensors still unchallenged.
- CMOS image sensors can incorporate other circuits on the same chip, eliminating the many separate chips required for a CCD. This also allows additional on-chip features to be added at little extra cost. These features include anti-jitter (image stabilization) and image compression. Not only does this make the camera smaller, lighter, and cheaper; it also requires less power so batteries last longer.
- CMOS image sensors can switch modes on the fly between still photography and video. However, video generates huge files so initially these cameras will have to be tethered to the mothership (the PC) when used in this mode for all but a few seconds of video. However, this mode works well for video conferencing although the cameras can't capture the 20 frames a second needed for full-motion video.
- While CMOS sensors excel in the capture of outdoor pictures on sunny days, they suffer in low light conditions. Their sensitivity to light is decreased because part of each photosite is covered with circuitry that filters out noise and performs other functions. The percentage of a pixel devoted to collecting light is called the pixel’s **fill factor**. CCDs have a 100% fill factor but CMOS cameras have much less. The lower the fill factor, the less sensitive the sensor is and the longer exposure times must be. Too low a fill factor makes indoor photography without a flash virtually impossible. To compensate for lower fill-factors, micro-lenses can be added to each pixel to gather light from the insensitive portions of the pixel and "focus" it down to the photosite. In addition, the circuitry can be reduced so it doesn't cover as large an area.



100% Fill factor



75% Fill factor

Fill factor refers to the percentage of a photosite that is sensitive to light. If circuits cover 25% of each photosite, the sensor is said to have a fill factor of 75%. The higher the fill factor, the more sensitive the sensor.

- CMOS sensors have a higher noise level than CCDs so the processing time between pictures is higher as these sensors use digital signal processing (DSP) to reduce or eliminate the noise. The DSP is one early camera (the Svmini), executes 600,000,000 instructions per picture.

A Short Course in Digital Photography

3. So you Have to Know Arithmetic After All

CONTENTS

Let's start with one surprising fact: A pixel has no size or shape. At the time it's born, it's simply an electrical charge much like the static electricity that builds up on your body as you shuffle across a carpet on a dry day. A pixel is only given size and shape by the device you use to display or print it. Understanding how pixels and image sizes relate to one another takes a little effort but you need to bring nothing more to the process than your curiosity and elementary school arithmetic skills.

The calculations described in the following sections are nothing more than subtraction, addition, multiplication, and division. However, to make it easier to explore the various relationships being discussed, you can download an Excel worksheet "Image Size Calculator" that will help you better follow the discussion and explore the concepts we discuss. The worksheet has been saved in Excel 5 format so that version and all later versions can read it.

- To download the unzipped version (20 Kilobytes), click here.
- To download the zipped version (xxxx bytes), click here.

The Arithmetic of Image Sizes

A pixel begins its life on the camera's image sensor during that flickering moment when the shutter is open. The size of each photosite on the image sensor can be measured, but the pixels themselves are just electrical charges converted into digital numbers. These numbers, just like any other numbers that run through your head, have no physical size.

Although the captured pixels have no physical dimensions, a sensor's size is specified like those in a digital photo, except the count is the number of photosites that it has on its surface. This size is usually specified in one of two ways—by the sensor's dimension in pixels, or by its total number of pixels. For example, the same image can be said to have 1800 x 1600 pixels (where "x" is pronounced "by" as in "1800 by 1600"), or to contain 2.88-million pixels (1800 multiplied by 1600).

This digital image of a Monarch butterfly chrysalis is 1800 pixels wide and 1600 pixels tall. It's said to be 1800x1600.

Since pixels stored in an image file have no physical size or shape, it’s not surprising that the number of photosites doesn't by itself indicate a captured image’s sharpness or size. This is because the size of each captured pixel, and the image of which it’s a part, is determined by the output device. The device can spread the available pixels over a small or large area on the screen or printout.

- If the pixels in an image are squeezed into a smaller area, perceived sharpness increases (from the same viewing distance). Images on high-resolution screens and printouts look sharper only because the available pixels are grouped into a small area—not because there are more pixels.
- As pixels are enlarged so the image is spread over a larger area, the image’s perceived sharpness falls (from the same viewing distance). If enlarged past a certain point, the square pixels will begin to show—the image becomes pixilated.

To visualize this concept, imagine two tile mosaics, one with small tiles and one with large. The one with small tiles will have sharper curves and more detail. However, if you have the same number of large and small tiles, the area covered by the small tiles will be much less. Sharpness and detail is also related to viewing distance. If you stand close to the small mosaic it will appear almost identical to the larger one viewed from farther away.

SMALL MOSAIC IMAGE NEEDED LARGE MOSAIC IMAGE NEEDED

To make an image larger or smaller for a given output device, it must be resized (resampled) in the camera, in a photo-editing program, or by the application you're printing it with. Resizing is performed by interpolation, and sometimes this is done without your even being aware of it. When an image is made larger, extra pixels are added and the color of each new pixel is determined by the colors of its neighbors. When an image is made smaller, some pixels are deleted.

Exploring Image Sizes

This figure and Part 1 on the Excel worksheet "Image Size Calculator" calculate the total number of pixels in an image when you enter the image's width and height in pixels.

1. Image Sizes			
1	**Width of image**	1,600	pixels
2	**Height of Image**	1,200	pixels
3	**Total pixels in image**	1,920,000	pixels

1. Enter the width of the image in pixels on this line.

2. Enter the height of the image in pixels on this line.

3. A formula on this line calculates the total number of pixels in the image by multiplying the image's width by its height.

Exercise

Enter the width and height of your own images and see what the total number of pixels is. You can find image sizes in your camera's user guide. There may be more than one resolution, and if so, try them all.

The FinePix 4700 ZOOM records JPEG images at three compression image sizes. How many pixels are there in each image size?

- 2,400 x 1,800
- 1280 x 960
- 640 x 480

The Arithmetic of Displaying Images

When a digital image is displayed on the computer screen, its size is determined by three factors—the screen's resolution, the screen's size, and the number of pixels in the image.

The Screen's Resolution

The size of each pixel on the screen is determined by the resolution of the screen. The resolution is almost always given as a pair of numbers that indicate the screen's width and height in pixels. For example, a monitor may be specified as being a low-resolution 640 x 480, a medium resolution of 800 x 600, or a high-resolution of 1024 x 768 or more. (The first number in the pair is the number of pixels across the screen. The second number is the number of rows of pixels down the screen.)

This is a 640 x 480 display. That means there are 640 pixels on each row and there are 480 rows.

Another way to think about the size of each pixel is in terms of how many pixels are displayed per inch on the screen. The larger the pixels, the fewer fit per inch. As you can see from the illustration below, the actual number of pixels per inch (the numbers in red) depends on both the resolution and the size of the monitor. (Screen measurements are based on a diagonal, and these measurements are horizontal measurements across the screen so they don't relate exactly to screen sizes.)

	Monitor Size				
Resolution	14	15	17	19	21
640 x 480	60	57	51	44	41
800 x 600	74	71	64	56	51
1024 x 768	95	91	82	71	65

The red numbers in the illustration are the pixels per inch for each combination of monitor size and resolution. To simplify the calculations, images that are to be displayed on the screen are generally considered to be displayed at 72 pixels per inch (ppi). As you can see from the table, 72ppi isn't an exact number for any resolution on any screen, but it tends to be a good compromise. (The 72 dpi is held over from an early era in Apple's history.)

Screen Resolution and Image Size

On any given monitor, changing screen resolution changes the size of displayed objects such as icons, text, buttons, and images. As the resolution increases, object sizes decrease but they do appear sharper. Take a look here at the same image displayed at three different resolutions: 640 x 480, 600 x 800, and 1024 x 768.

640 x 480. At this resolution, an image in Photoshop fills the screen.

800 x 600. When the screen resolution is increased, the image gets smaller.

1024 x 768. When the resolution is increased again, the image gets even smaller.

When displaying images on the screen, it's important that the viewer be able to see the entire image without having to scroll it. To ensure this, Web designers often assume that the lowest common denominator display is a 640 x 480 screen. For this reason, most images to be sent by e-mail or posted on a screen are sized so they are no larger than 600 pixels wide (for landscape images) or 400 pixels high (for portrait images).

TIP: Checking Your System

To see what resolution your Windows system is set to, display Window's Start menu, point to Settings to cascade the menu, and then click Control Panel. When the Control panel opens, double-click the Display icon or command to display the Display Properties dialog box, then click the Settings tab on the dialog box and check the Screen Area setting.

Screen Size and Image Size

Just as the screen's resolution can affect the size of an image, so can the size of the display. If you have a 14" monitor and 21" both set to 800 x 600 pixels, the pixels per inch are different. The same 800 pixels are spread across a larger screen on the larger monitor so the pixels per inch falls. Imagine the image printed on a balloon. As you inflate it, the image gets larger.

Exploring Display Sizes

This figure and Part 2 on the Excel worksheet "Image Size Calculator" calculate the size of an image displayed on the screen.

2. Displaying Images			
1	Width of digital image	800	pixels
2	Height of digital image	480	pixels
3	Measured width of screen	14	inches
4	Screen's horizontal resolution	800	pixels
5	Screen's ppi	57	ppi
6	Width of image on screen	14	inches
7	Height of image on screen	8	inches
8	Will image fit on screen?	YES	

1. Enter the width of the image in pixels on this line.

2. Enter the height of the image in pixels on this line.

3. Measure the width of the screen display and enter it on this line.

4. Enter the horizontal resolution your screen is set to on this line. (For example, if it's set to 800 x 600, enter 800.)

5. A formula on this line calculates you screen's actual dots-per-inch by dividing it's horizontal resolution in pixels by its width in inches. In the illustration above it divides 800 by 14 for a ppi of 57.

6. A formula on this line calculates the width of the image on the screen in inches by dividing the width in pixels by the screen's ppi. In the illustration above it divides 800 by 57 for an image width of 14 inches.

7. A formula on this line calculates the height of the image in inches by dividing the height in pixels by the screen's ppi.

8. A formula on this line compares the width of the image in pixels, with the screen's horizontal resolution. If the image is smaller than the screen (in pixels), it will fit, otherwise it won't.

Exercises

1. If your image is 1600 x 1200, how large will it be when displayed on a 72ppi screen? Will it fit on a 14" screen?

2. If your image is 1200 x 8, how large will it be when displayed on a 72ppi screen? Will it fit on a 10" screen?

The Arithmetic of Printing Images

Printer resolutions are usually specified by the number of dots per inch (dpi) that they print. (Generally ppi—pixels per inch—refer to the image and display screen and dpi—dots per inch—refer to the printer and printed image. In this course we sometimes use them interchangeably)

For comparison purposes, monitors use an average of 72 ppi to display text and images, ink-jet printers range up to 1700 dpi or so, and commercial typesetting machines range between 1,000 and 2,400 dpi.

Since image sizes are described in pixels and photographic prints in inches, you have to convert from pixels to inches. To do so, you divide the image's dimension in pixels by the resolution of the device in pixels per inch (ppi). For example, to convert the dimensions for a 1500 x 1200 image being printed at 300 ppi you divide as follows:

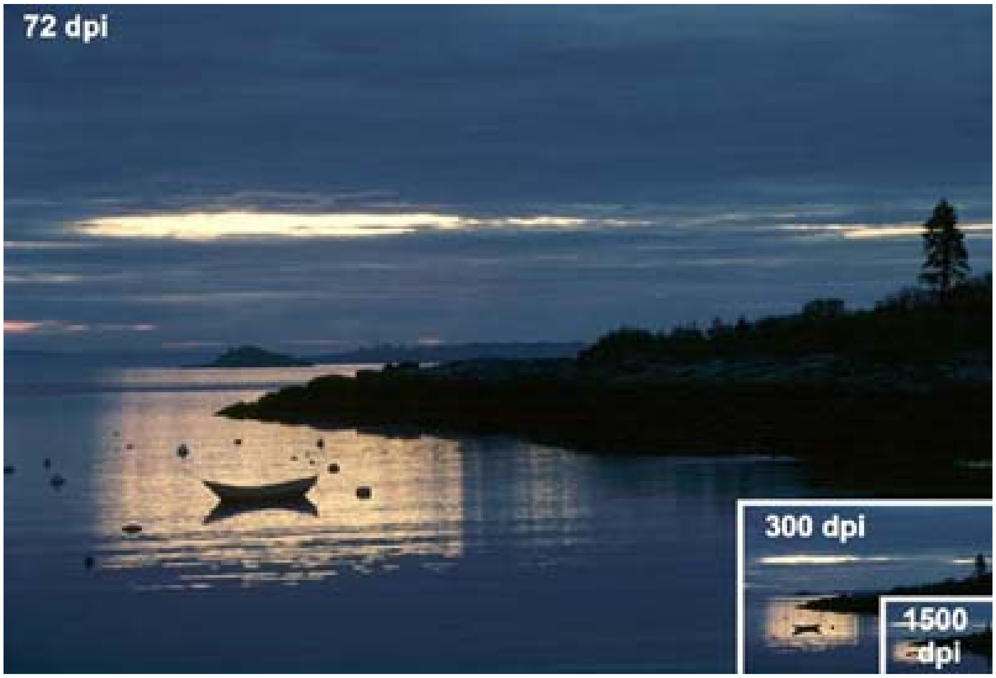
Width: 1500 pixels ÷ 300 ppi = 5"

Height: 1200 pixels ÷ 300 ppi = 4"

The result is a 5" x 4" print. However, if the output device prints 600 ppi, the result changes to a 2.5" x 2" print as follows:

Width: 1500 pixels ÷ 600 ppi = 2.5"

Height: 1200 pixels ÷ 600 ppi = 2"



This graphic shows how a 640 x 480 image displays or prints on devices with different dots per inch. At 72 ppi it's 8.9" x 6.7", at 300 ppi it's 2.1" by 1.6", and at 1500 ppi, it's only 0.43" x 0.32"—smaller than a stamp.

Exploring Print Sizes

This figure and Part 3a on the Excel worksheet "Image Size Calculator" calculate the size of print you can expect from a given file size and printer resolution.

3a. Printing Images-Print Sizes			
1	Width of digital image	1,600	pixels
2	Height of digital image	1,200	pixels
3	Printer's resolution	300	dpi
4	Width of print	5.33	inches
5	Height of print	4.00	inches

1. Enter the width of the digital image in pixels on this line.

2. Enter the height of the digital image in pixels on this line.

3. Enter the number of dots per inch (dpi) printed by your printer on this line.

4. A formula on this line calculates the horizontal size (width) of the image in inches by dividing the image's width in pixels by the printer's dpi.

5. A formula on this line calculates the vertical size (height) of the image in inches by dividing the image's height in pixels by the printer's dpi.

Exercises

1. If your image is 1600 x 1200 and your printer's resolution is 600 dpi, how big will the print be?

2. If your image is 800 x 600 and your printer’s resolution is 300 dpi, how big will the print be?

3. If your printer prints 300 dpi, how wide will an image have to be in pixels, to get a 6-inch wide print?

4. Using the widths and heights listed in the "Original" column and the specified printer dpi’s, calculate the width and height of the prints you’d get.

Original 800 x 600, printed at 300 dpi is ____ x ____

Original 800 x 600, printed at 600 dpi is ____ x ____

Original 1600 x 1200, printed at 300 dpi is ____ x ____

Original 1600 x 1200, printed at 600 dpi is ____ x ____

Original 1800 x 1600, printed at 300 dpi is ____ x ____

Original 1800 x 1600, printed at 600 dpi is ____ x ____

Understanding Pixels Per Inch

Normally you don’t have to change the number of pixel’s in an image to change the size of a printout. That task is handled by the software program you use to print the image. For example, if you place an image in a program such as QuarkXpress or PageMaker, its printed at the size you specify in those programs.

One thing to keep in mind is that if you enlarge a print too much, it won’t be as sharp as you may desire. That’s because a certain minimal number of dots per inch, usually about 300, are needed to get a good print. Pixels begin to show when the print is enlarged to a point where the pixels get get so big that the pixels per inch (ppi) fall too low. If your printer can print a sharp image only at 300 or more pixels per inch, you need to determine if the size of the image you plan on printing will fall below this level. Let's say you have a scanned image and want to print it at a certain size. When you enlarge or reduce an image like this, the ppi change. To find out what the pixels (or dots) per inch becomes, you convert from the image's original size in pixels to its pixels per inch. For example, if you print an image that’s 1600 pixels wide so the print is 10" wide, there are only 160 dots per inch (unless its resampled) (1600 pixels ÷ 10 inches = 160 pixels per inch). When you know the width of the image in pixels, you can divide that number by the printer’s dpi to determine the largest possible print size in inches.

Exploring Print DPI

This figure and Part 3b on the Excel worksheet "Image Size Calculator" calculates the dpi of a print when you use a program that automatically resizes a file for printing.

	3b. Printing Images-DPI		
1	Width of digital image	1,600	pixels
2	Height of digital image	1,200	pixels
3	Desired width of print	6	inches
4	Height of print	4.5	inches
5	DPI	267	dpi

1. Enter the width of the digital image in pixels on this line.

2. Enter the height of the digital image in pixels on this line.

3. Enter with desired width of your printout on this line.

4. A formula on this line calculates the height of the print so it has the same aspect ratio as the digital image.

5. A formula on this line calculates the dpi used to make the print by dividing it's width in pixels by its width in inches.

Exercises

1. To come

The Arithmetic of Color Depth

Resolution isn't the only factor governing the quality of your images. Equally important is the number of colors in the image. When you view a natural scene, or a well done photographic color print, you are able to differentiate millions of colors. Digital images can approximate this color realism, but whether they do so on your system depends on its capabilities and its settings. How many colors there are in an image, or how many a system can display is referred to as color depth, pixel-depth, or bit depth. Older PCs are stuck with displays that show only 16 or 256 colors. However, almost all newer systems include a video card and a monitor that can display what's called 24-bit True Color. It's called true color because these systems display 16 million colors, about the number the human eye can discern.

TIP: Checking Your System

You may have to set your system to full-color, it doesn't happen automatically. To see if your Windows system supports True Color (not all do), display Window's Start menu, point to Settings to cascade the menu, and then click Control Panel. When the Control panel opens, double-click the Display icon or command to display the Display Properties dialog box, then click the Settings tab on the dialog box and check the Color palette setting.

How do bits and colors relate to one another? It's simple arithmetic. To calculate how many different colors can be captured or displayed, simply raise the number 2 to the power of the number of bits used to record or display the image. For example, 8-bits gives you 256 colors because $2^8=256$. Here's a table to show you some other possibilities.

Name	Bits per pixel	Formula	Number of colors
Black and white	1	2^1	2
Windows display	4	2^4	16
Gray scale	8	2^8	256
256 color	8	2^8	256
High color	16	2^{16}	65 thousand
True color	24	2^{24}	16 million

Black and white images require only 2-bits to indicate which pixels are white and which are black. Gray scale images need 8 bits to display 256 different shades of gray. Color images are displayed using 4 bits (16 colors), 8 bits (256 colors), 16 bits (65 thousand colors) called high color, and 24 bits (16 million colors) called true color. Some cameras and scanners will use 30 or 36 bits per pixel. These extra bits are used to improve the color in the image as it is processed down to its 24-bit final form. (**Ed note**: Are there any 30/36 bit monitors or printers?)

Review: Bits and Bytes

When reading about digital systems, you frequently encounter the terms bit and byte.

The bit is the smallest digital unit. It's basically a single element in the computer that like a light bulb has only two possible states, on (indicating 1) or off (indicating 0). The term bit is a contraction of the more descriptive phrase binary digit.

Bytes are groups of 8-bits linked together for processing. Since each of the eight bits has two states (on or off), the total amount of information that can be conveyed is 2^8 (2 raised to the 8th power), or 256 possible combinations.

Exploring Color Depth

This figure and Part 4 on the Excel worksheet "Image Size Calculator" calculate the total number of pixels in an image when you enter the images width and height in pixels.

4. Color Depth and File Sizes

1	**Bits per pixel**	24	
2	**Number of possible colors**	16,777,216	
3	**Image width**	1,600	pixels
4	**Image height**	1,200	pixels
5	**Total number of pixels**	1,920,000	pixels
6	**File size (uncompressed)**	46,080,000	bits
		5,760,000	bytes
		5,760.00	kilobytes
		5.76	megabytes
7	**Table of color depths**		

Name	Bits per pixel
Black and white	1
Windows display	4
Gray scale or 256 colors	8
High color	16
True color	24
Oversampled	30

1. Enter any bits per pixel from the table of color depths (on line 7 and following) on this line.

2. A formula on this line calculates the number of possible colors by raising the number 2 to number of bits per pixel.

3. Enter the width of the digital image in pixels on this line.

4. Enter the height of the digital image in pixels on this line.

5. A formula on this line calculates the total number of pixels in the image by multiplying the image’s width by its height.

6. A formula on this line calculates the size of the uncompressed file that would be needed to store the image of the size and color depth you’ve entered. File sizes are shown in bytes, kilobytes, and megabytes.

Exercises

1. To come

A Short Course in Digital Photography

4. Scanning Film and Prints

CONTENTS

Even if you don’t use a digital camera, you can still work with digital images. All you need to do is have your slides, negatives, or prints scanned. You can do this yourself if you have a scanner, or you can have them scanned onto a CD disc or floppy at your local photofinisher or lab. The resolution of these images is much higher than you get from all but the most expensive cameras, so if quality is an issue this is really the best route to take.

Most scanning services are available when you have your film developed. The problem with this is that you pay to scan the good, the bad, and the ugly. It’s much better to have your images developed normally and then select out the best for scanning later.

Scanning Basics

Color scanners work by creating separate red, green, and blue versions of the image, and then merging them together to create the final digital image. Some scan all of the colors in one pass while others take three passes, a slower but higher quality method. Which method is used depends on the scanner's image sensor. Most scanners use linear CCDs arranged in a row. Those that require three passes use a single row of photosites and pass different filters (red, green, or blue) in front of the sensor for each pass or use three different light sources. Others have 3 rows of photosites, each row with its own filter so they can capture all three colors on a single pass.

As the image is scanned, a light source travels down the photo (some print and document scanners instead move the document past the light source). The light source reflects off a print or passes through a transparency and is focused onto the image sensor by a mirror and lens system. Because of this mirror and lens system, the sensor does not have to be as wide as the area being scanned.

The horizontal optical resolution of the scanner is determined by the number of photosites on its sensor. However, the vertical resolution is determined by the distance the paper or light source advances between scans. For example, a scanner with a resolution of 600 x 1200 has 600 photosites on its sensor and moves 1/1200 of an inch between each scan.

Reflective or Transparency

Some scanners are designed to scan photos and other documents, called **reflective copy**. Others are designed to scan slides and larger transparencies.

Size of Originals

Most reflective scanners can scan 8½ by 11 originals but some can go much larger. Transparency scanners scan 35mm slides and negatives and some go much larger. As the size increases, so does the cost.

Resolution and Resolving Power

As you saw in Chapter 2, there are two types of resolution. **Optical resolution** is the "native" resolution of your scanner as determined by the optics in your scanner hardware. **Interpolated resolution** is resolution enhanced through software, and is useful for certain tasks such as scanning line art or enlarging small originals. However, in photography interpolation adds no new detail to the image yet makes the file size a lot larger. For these reasons, you should never scan a photograph at a setting higher than the scanners optical resolution.

The true resolution of the scanned image depends on more than the scanner's resolution. It's ability to capture details is known as its resolving power. This resolving power is determined not just by resolution but also by the quality and alignment of it's lenses, mirrors, and other optical elements and the accuracy with which it moves along the image when scanning. It's possible for a very well designed scanner with a lower resolution to outperform a cheaper one with a higher resolution.

Dynamic Range

Scenes in the real world are full of bright light and deep shadows. The extremes are referred to as the **dynamic range**. Film doesn't have anywhere near the dynamic range of nature, so it's always a struggle to accurately capture a scene on film. It's like trying to squeeze one of those coiled snakes back into the can after you've taken the lid off to let it pop out. Ansel Adams Zone System was developed to make this easier with black and white film, but color film can't be manipulated in the same way. When film is turned into prints, they have even less dynamic range so something is always lost. This is one of the reasons that it's better to scan slides or negatives then prints. Display screens have a dynamic range closer to slides than to prints. That means that when you scan images for the Web, you need to be sure you capture the full dynamic range.

How much dynamic range you can capture depends on its ability of the scanner's ability to register tonal values ranging from pure white to pure black. It must also be able to accurately map the tones on the original to tones on the digital image. If the scanner doesn't have enough tonal range, details will be lost in shadow areas, highlights, or both.

A scanner's dynamic range can be measured and given a numeric value between 0.0 (white) to 4.0 (black) that indicates its ability to capture all values within the full dynamic range. Common flatbed scanners typically register values from about 0.0 to 2.4. New 30- or 36-bit scanners claim a dynamic range up to around 3.0, making them more adept at pulling detail out of shadow areas within images.

Although image density ranges from pure white to pure black, no detail can be seen in those areas. As you progress from pure white into slightly darker areas, detail emerges. The point at which a scanner can detect this detail is called **DMin** (minimum density). The same is true at the other end of the spectrum. The point at which detail can be detected before the image goes to pure black is called **DMax** (maximum density). The dynamic range is calculated by subtracting DMin from DMax. For example, if a scanner has a d-min of 0.2 and a d-max of 3.2, its dynamic range is 3.0.

Color depth

As you saw in Chapter 2, color depth refers to how many bits are assigned to each pixel in an image. The best scanners use 36 bits (12 for each color red, green, and blue) to produce 6.8 trillion colors. When these files are processed down to 24-bit files, they contain images with more subtle gradations of color and more color accuracy.

The quality of the colors in a scanned image depend not just on depth but on their **registration**. Since the colors are being captured by different sensors or at slightly different times, they may not overlap perfectly. If they don't color fringes will appear around details in the image.

TWAIN—Don't Leave the Store Without It

There's an old expression "never the twain shall meet." When scanners were first connected to PCs, that's pretty much the way it was. Everyone had their own proprietary set of protocols that made scanning possible with their hardware or software and a few other products that they choose to support. The problem with this approach was that scanners from different manufacturers were incompatible with many application programs. Before buying a scanner, you had to check if your applications worked with it. If you had a scanner, you had to be sure applications would work with it before you bought them. They all spoke different "languages." To solve this problem a set of standards called **TWAIN** were developed. The name "TWAIN" stands for nothing, although many people like to believe it stands for "Tool Without An Interesting Name." Hardware and software that uses TWAIN standards can communicate with one another. These standards are embedded in a device driver that is installed on your system. It is this

TWAIN driver that makes it possible to directly acquire images from external sources while working within an application such as Photoshop.

When purchasing digital imaging software and hardware, be sure they are TWAIN compliant. This standard has been so widely adopted, you'll find that most are.

Film Scanners

The highest quality scans are from slides or negatives because they have a much higher dynamic range than prints. Special **film scanners** (also called slide or transparency scanners) have been designed to scan film and the results are outstanding. By using the included filmstrip holder, strips up to 6 frames in length can be scanned, one frame at a time. In fact, Photo CDs are created on high resolution film scanners such as these.

Because slides and negatives are so small and must be enlarged so much, these units must have very high resolutions to be really useful. Even at 2700 dpi, a print on a 1500 dpi printer would be less than 2 inches wide.

Konica's Q-Scan scans 35mm and APS film at 24-bit depth and a resolution adjustable from 200 to 1,200 dpi in 70 seconds or less per frame. Courtesy of Konica.

Some of the best film scanners use a software program called Digital ICE from Applied Science Fiction to eliminate dust and scratches on the surface of the scanned film.

Flatbed Scanners

Flatbed scanners are reflective scanners useful for scanning both black and white and color prints. Flatbeds are excellent for scanning old photographs for restoration purposes. (The print should be removed from any frame to make flat contact with the scanner glass. Make sure the glass on the flatbed is clean.)

One advantage of flatbed scanners is that they do double-duty. They are ideal for copying documents of all kinds and many even come with OCR (optical character recognition) software that converts printed text to an editable digital form.

The Epson Expression 636 color scanner delivers 36 bit scanning at 600 dpi. It has an optional transparency adapter so you can scan slides and negatives. Courtesy of Epson.

Many flatbed scanners come with optional **transparency units** that allow you to scan slides. A transparency adapter is a scanner cover that diffuses light evenly through the transparent media. It sits in place of the copyboard cover that is included with the scanner. Generally, the resolution of these units is below those of units designed to scan transparencies. Paper materials can still be scanned with the transparency adapter in place.

A transparency adapter allows you to scan slides and film. Courtesy of MicroTek.

When first encountering a copy machine, many people have tried copying money, photographs, and other objects. Some even go so far as to press their nose or other parts of their anatomy against the glass to capture an image. Basically, they are using the copier as a **lensless camera**. You can do the same with a flatbed scanner and the results can be interesting. One trick is to try different background materials laid on top of the objects to be scanned. These can range from other image to black velvet.

By laying some coins on the scanner glass and then placing a hand over them, it looks like a handful of change.

Print Scanners

Print or photo scanners are specifically designed to scan snapshot-sized photos. They're ideal for digitizing the photographs you've collected over the years. The quality you get from scanning prints isn't as great as from scanning slides or negatives. However, some of these small scanners also allow you to scan negatives, slides, and prints.

The Epson PhotoPlus color photo scanner will scan a photo in less than 60 seconds. Courtesy of Epson.

Drum Scanners

When price is no object and quality is paramount, you need to have prints or transparencies scanned on a drum scanner. On these scanners the transparency or print is affixed to a glass drum. As the drum spins, the image is read a line at a time by a **photomultiplier tube** instead of a CCD. A bright pinpoint of light is focused on the image and its reflection (prints) or transmission (transparencies) is measured by the tube. These tubes provide the highest quality RGB and CMYK scans with greatly improved highlight and shadow detail. Their dynamic range is so high they can capture detail in both deep shadows and bright highlights and they also capture subtle differences in shading. Resolutions range up to 12,500 dpi and higher and these scanners have very large scanning areas.

These expensive scanners are available at service bureaus where you pay by the scan. The cost of the scanner, computer time, and labor involved with a drum scan demands a higher charge.

Drum scan resolutions are sometimes identified with the term RES. For example "RES 30" denotes 30 pixels per millimeter which could be compared to 762 ppi (pixels per inch). The higher resolution scans create very large files that would prove difficult to work with even with a high-end workstation.

Kodak Picture Makers

If you don't have a scanner and want to make prints, all you have to do is locate a dealer with a Kodak Picture Maker. To operate these self-serve machines, you point to items on a touch-sensitive screen.

- For input, these systems scan prints, negatives and slides. Some models even accept Photo CD disks and flash memory cards from cameras.
- Once scanned, you can process the image a little to reduce red-eye, zoom, crop, and add mattes and borders.
- For output, they can print images up to 8" x 12" and place a number of smaller images on the same sheet of paper. You can also print on transparency material and even output to floppy disks in the JPEG and FlashPix formats (see Chapter 7). The printer in these units is a dye-sublimation printer. You'll see in Chapter 10 that this is the finest type of printer available for photographs.

The Kodak Picture Maker scans prints, slides, and negatives so you can make prints using a touch screen. You can even save the scanned image onto a disk. Courtesy of Kodak.

Getting Images Scanned

When you want high image quality, you can have your slides or negatives scanned onto FlashPix or Photo CDs at your local camera store or any service bureau that offers this service. The advantage of doing this is that you then have an archival set of images that's easy to store and access. Each CD comes with a series of thumbnail images that let you quickly locate any image you want.

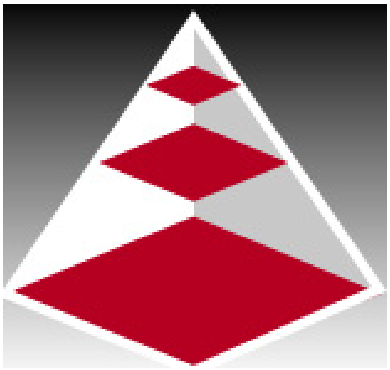
The quality of these scanned images is much higher than what you get from the most expensive digital cameras. Prices vary, but range between $1 and $2 per image depending on the level of service and the number of images scanned at any one time.

Photo CD

Kodak's **Photo CD** is a Compact Disc (CD) containing image files stored as Image Pacs. Once scanned onto the disc, the images can be displayed on a TV using a Photo CD player or copied into your computer from any CD drive that supports the Photo CD format (almost all now do). Photo CD's are covered in detail in Chapter 7.

FlashPix CDs

The **FlashPix** format stores images in a number of resolutions and each resolution is subdivided into square tiles. FlashPix aware applications work with the resolution that works best for a given application. This can greatly speed things up for you. For example, you can edit a low resolution version and then apply those changes to a higher resolution version when ready to print. Also, since the images are broken into tiles, only the section of the image you are using needs to be updated on the screen as you work on the image. This reduces the time you sit around waiting for the screen to update.



A FlashPix file contains the same image at a number of different resolutions. You can view the image at one resolution on your computer screen and download a different resolution for printing. This greatly speeds up your viewing time and outputs high-quality images. Courtesy of LivePicture

The FlashPix logo identifies the format on the Web.

Your photofinisher can arrange to have your slides or negatives scanned onto a Kodak FlashPix CD, or a Picture Disk Plus floppy disk. The PictureWorks FlashPix Format Viewer is included on every Kodak FlashPix CD so you can view the pictures and make minor picture enhancements.

To view FlashPix images on the Web, you need a FlashPix viewer. To edit and save FlashPix images with Photoshop you need the FlashPix plug-in. Both are available in The Digital Photographer's Toolbox. The FlashPix format is covered in detail in Chapter 7. FlashPix is an image technology developed jointly by Kodak, LivePicture, HP, and Microsoft.

At the low end of the scanning market are floppy disk scans. Although generally limited to low resolutions, these services are both cheap and convenient. There is hardly a system anywhere that can't read a floppy disk.

PhotoNet dealers can scan your images onto a floppy disk or even posted on the Web. Image courtesy of PictureVision.

- **Kodak Picture Disks** are floppy disks with up to 28 digitized images. The images are 400 x 600 pixels with 24-bit color. You can have these images scanned at your photo dealer when you have your film processed, or at any later time. Kodak Picture Disk Viewer software included on each disk allows you to view the images. It also allows you to organize your images into albums, and crop, rotate, and print them.
- **Kodak Picture Disk Plus**. Picture Disk Plus images are scanned in either JPEG or FlashPix format and less compression is used for higher quality. The result is large file sizes that are better for high-quality prints. You can have prints, negatives, or slides scanned onto these disks at stores that have a Kodak Image Magic Print Station or Enhancement Station.
- **PictureVision Floppy Shots**. PictureVision's Floppy Shots™ are images scanned onto a floppy disk at a local photofinisher or dealer. The images are usually 600 X 400 pixels with 24-bit color. The number of images that can fit on a disk varies between 40 and 100, depending on how well each compresses. The disk contains a program that displays your images singly as in a slide show, or as a multi-image contact sheet. You can also rotate and zoom the images or enter up to 32,000 characters of text for each picture.
- **PhotoNet Disk**. PictureVision's PhotoNet service scans your film or slides and posts them on the Web where you can view them. (see Chapter 10). In addition, you get the scanned images on a 3 ½" diskette along with an index print showing thumbnails. Software is included so you can view the images.

Scanning Images Yourself

When you first start scanning and printing images, it seems like there is a black art involved. Actually, it's not that at all, you just have to understand some relationships between pixels and inches. Here we'll try and explain those relationships so they're understandable. To follow these discussions better, and to calculate your own scanning and print sizes, download the Scan Calculator by clicking the link below. It was created with Excel 97.

Download Excel Scan Calculator

Scanning and File Sizes

When scanning, your goal is to get a digital image file that contains all of the detail you need without the file being too large to work with. If you scan at too low a resolution, you'll lose detail. If you scan too high, you're file will be too large. When you scan an original image—either a slide or a print—the file size depends on a number of factors including the area being scanned, the resolution of the scanner, and the color depth, or number of bits assigned to each pixel. Let's take a look at this step-by-step as you'd calculate file sizes using the downloadable scanning calculator—Part 1.

1. Scanning and Files Sizes				
1	**Size of Original**	Horizontal	10.00	inches
2	(in inches)	Vertical	8.00	inches
3	**Scanner's Resolution**		1,200	dpi
4	**Scanned Pixels**	Horizontal	12,000	pixels
5		Vertical	9,600	pixels
6		Total	115,200,000	pixels
7	**Color depth**		24	bits
8	**File Size**	Bits	2,764,800,000	bits
9		Bytes	345,600,000	bytes
10		Kilobytes	345,600	kilobytes
11		Megabytes	345.60	megabytes

1. Enter the width in inches of the art to be scanned.
2. Enter the depth or height of the art to be scanned.
3. Enter the scanner's optical resolution or the resolution to intend to scan at.
4. The scanned pixels horizontally are calculated by multiplying the scanner's resolution (line 3) times the horizontal size of the original (line 1).
5. The scanned pixels vertically are calculated by multiplying the scanner's resolution (line 3) times the vertical size of the original (line 2).
6. The total scanned pixels is calculate by multiplying the horizontal scanned pixels (line 4) times the vertical scanned pixels (line 5).
7. The color depth is where you enter the number of bits assigned to each pixel. This would usually be 1 if the image is black & while, 8 if it's grayscale (like a black and white photography), or 24 if it's color.
8. The file size in bits is calculated by multiplying the number of pixels in the image (line 6) time the color depth (line 7).
9. The file size in bytes is calculated by dividing the file size in bits (line 8) by 8.
10. The file size in kilobytes is calculated by dividing the file size in bytes (line 9) by 1,000.
11. The file size in megabytes is calculated by dividing the file size in kilobytes (line 10) by 1,000.

Printing a Digital File of Known Size

Most of the time, you have an image of known size, perhaps directly from a camera, and want to print it out. In these case, you want to know the size of the print you'll get at various printer resolutions.

2. Printing a Digital File of a Known Size				
1	**Size of Original**	Horizontal	3,072	pixels
2	(in pixels)	Vertical	2,048	pixels
3	**Output Resolution (dpi)**		361	dpi
4	**Size of output**	Horizontal	8.51	inches
5	(in inches)	Vertical	5.67	inches

1. Enter the width in pixels of the digital file.
2. Enter the depth in pixels of the digital file.
3. Enter the printer's output resolution in dots per inch (dpi).
4. Horizontal size of output is calculated by dividing the number of pixels horizontally in the original (line 1) by the output resolution.
5. Vertical size of output is calculated by dividing the number of pixels vertically in the original (line 2) by the output resolution.

Scanning an Image for Printing at a Specified Size

There are times when you know what size you want a print to be and need to calculate backwards to what size the image file should be. For most purposes, you can expect to get photorealistic quality with a print having about 300 dpi. This means, a 4 x 6 print needs an image file of 1200 x 1800, and an 8 x 10 print needs one 2400 x 3000.

You can stretch or shrink images you've imported into programs such as PageMaker and QuarkXPress. Because the number of pixels in the image don't change, the dots per inch have to. For example, let's say you placed an 800x600 image on a page and it was 2-inches wide. If you print it out at that size, it will print at 400 dpi (800 divided by 2"). If you now stretch the image to be 4 inches wide, the dpi drops to 200 (800 divided by 4"). If you want the image 4" wide AND 400 dpi, best scan it so it's 1600 pixels wide before you import it. However, if it's to be printed on a printing press, the rules change and become more complex. You should scan the image so its sots per inch are twice the lines per inch (lpi) at which it will be printed.

3. Scanning an Image for Printing at a Specified Size				
1	**Size of Output**	Horizontal	12.00	inches
2	(in inches)	Vertical	8.00	inches
3	**Output Resolution (inches)**		300	dpi

4	**Size of Original**	Horizontal	3,600	pixels
5		Vertical	2,400	pixels
6	**Color Depth**		24	bits
7	**File Size**	Bits	207,360,000	bits
8		Bytes	25,920,000	bytes
9		Kilobytes	25,920	kilobytes
10		Megabytes	25.92	megabytes

1. Enter the width in inches of the art to be scanned.
2. Enter the depth or height of the art to be scanned.
3. Enter one of the the printer's output resolution in dots per inch (dpi).
4. The horizontal size of the original is calculated by multiplying the desired horizontal size of the output (line 1) by the desired output resolution (line 3).
5. The vertical size of the original is calculated by multiplying the desired vertical size of the output (line 2) by the desired output resolution (line 3).
6. Enter the color depth of the image. This would usually be 1 if the image is black & while, 8 if it's grayscale (like a black and white photography), or 24 if it's color.
7. The file size in bits is calculated by multiplying the horizontal by the vertical size of the original (lines 4 and 5) to calculate the total number of pixels in the image and then multiplying those by the color depth (line 6).
8. The file size in bytes is calculated by dividing the file size in bits (line 7) by 8.
9. The file size in kilobytes is calculated by dividing the file size in bytes (line 8) by 1,000.
10. The file size in megabytes is calculated by dividing the file size in kilobytes (line 9) by 1,000.

Scanning an Image for Screen Display

Scanning an image for the screen is the same as scanning one for printing except the output is usually specified in pixels, not inches. Although the actual number of pixels per inch on a monitor vary depending on its size and resolution, images are generally scanned at 72 ppi for screen display (although they are sometimes scanned up to 96 ppi). Making them any larger doesn't add any information to the image and just makes the files larger.

4. Scanning an Image for Screen Display				
1	**Image Being Scanned**	Horizontal	1.00	inches
2	(in inches)	Vertical	1.50	inches
3	**Screen's Resolution**		72	dpi
4	**Desired Image Width**		400	pixels
5	**Desired Image Height**		600	pixels
6	**Color Depth**		24	bits

7	**File Size**	Bits	5,760,000 bits
8		Bytes	720,000 bytes
9		Kilobytes	720 kilobytes
10		Megabytes	0.72 megabytes

1. Enter the width in inches of the image to be scanned.
2. Enter the depth or height of the image be scanned.
3. Enter the screen's resolution in dots per inch (dpi). This is normally 72 dpi on average.
4. Enter the desired width of the image in pixels.
5. The vertical size of the image is calculated by dividing it's width on line 4 by the ratio of the original's width to height calculate by dividing line 1 by line 2.
6. Enter the color depth of the image. This would usually be 1 if the image is black & while, 8 if it's grayscale (like a black and white photography), or 24 if it's color.
7. The file size in bits is calculated by multiplying the horizontal by the vertical size of the original (lines 4 and 5) to calculate the total number of pixels in the image and then multiplying those by the color depth (line 6).
8. The file size in bytes is calculated by dividing the file size in bits (line 7) by 8.
9. The file size in kilobytes is calculated by dividing the file size in bytes (line 8) by 1,000.
10. The file size in megabytes is calculated by dividing the file size in kilobytes (line 9) by 1,000.

Scanning Black Magic

Scanning on one level is simple, plop a print on the copyboard and click the Scan button. However, to get the best results, there are lot's of little things that need tweaking. Here are some of them.

- Two terms are used interchangeably when scanning and printing: dots per inch (dpi) and pixels per inch (ppi). This has been done to add a little confusion to all discussions.
- Image quality improves as resolution increases. However, there is a point of diminishing returns at which the image file just gets larger without any noticeable effects on the image.
- The quality of a scanner is determined in part by how much detail it can extract from dark areas in an image. CCDs are not really good at this. but photo multiplier tubes uses in drum scanners are better.
- Scanned images almost always need sharpening. When the image is scanned, pixels in the image often overlap or are blurry because the scanning process isn't perfect. Sharpening cleans up the boundaries between colors to make things appear sharper. Most photo editing programs have a filter called an unsharp mask that allows you to sharpen just parts of the image based on their radius and threshold. Sharpening, and even oversharpening, is especially important when you are dramatically enlarging a file. Philip Greenspun recommends using Photoshop's Unsharp Mask filter by setting the **Amount** to 100 and the **Threshold** to 2. The **Radius** setting then varies depending on the size of the image file—doubling as the width doubles. Using Photo CD resolutions as example, he suggest 0.25 for 128x192 images. 0.5 for 256x384 images, 1.0 for 512x768 images, 2.0 for 1024x1536 images, and 4.0 for 2000x3000 images.
- The number of pixels you need to get photorealistic results depends a lot on the printer your using.

For dye-sub printers (see Chapter 9) a resolution that gives you 300 dpi or even less will work if the print is to be viewed at a normal viewing distance of 10 inches or so. On any printer that uses dithering, such as an ink-jet, you need 3 to 4 times as much—perhaps 800 dpi.

- If you scan illustrations from catalogs, magazines, or other printed materials, these images are already made up of tiny dots. Scanning them often creates interference patterns called **moiré patterns**. To reduce these, use a Gaussian blur filter in your photo-editing program.
- Postscript printers and printing presses use a measurement of resolution called **lines per inch**. This is based on the screen they used to break a halftone image such as a photography into small dots (what we computer people now call pixels). Historically, these screens (halftone line screens) had straight lines that varied in width. Although the screens changed at the turn of the century (1900) to grids that break the image into dots, the old label of lines per inch has stuck. Screen printers for PostScript printers range between 85 and 180 lpi. The lower figure is used for newspaper printing and the higher one for quality books and catalogs. When scanning photographs for later screening, you should scan so the image has twice the dots per inch as the lines per inch it will be printed at. For example, if the image will be printed with a 133 line screen, scan it so it has 266 dots (or pixels) per inch.

A Short Course in Digital Photography

5. Image Files and Compression

CONTENTS

Digital photographs are stored as bitmaps—a series of individually addressable pixels. Over the years, a number of different bitmap image formats have been developed. Each has it's own unique characteristics which determine when and where you might choose it over the others. However, most of these have fallen into disuse or are encountered only in special circumstances. As new demands arise, such as displaying images on the Web, new formats emerge. Some, such as Photo CD, gain wide acceptance. Others generate a lot of excitement and then disappear because they are found to have flaws or just don't get critical mass. In this section we explore those formats you are most likely to use or encounter. However, whatever format you choose, there are programs that will convert it to any of the other formats.

Bit-Map Vs Vector Images

All of the still images that you see on the Web, or in multimedia programs, and many that you see in print, have been created or manipulated on a computer in a digital format. There are two basic forms of computer graphics: bit-maps and vector graphics. The kind you use determines the tools you choose. Bitmap formats are the ones used for digital photographs. Vector formats are used only for line drawings.

Bit-mapped images

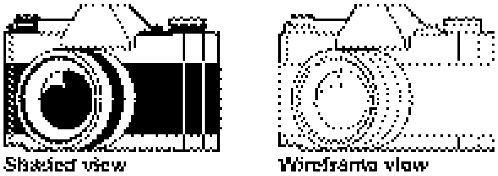
Bit-map images are formed from pixels—a matrix of dots with different colors. Bitmap images are defined by their dimension in pixels as well as by the number of colors they represent. For example, a 640 x 480 image contains 640 pixels and 480 pixels in horizontal and vertical direction respectively. If you enlarge a small area of a bit-mapped image, you can clearly see the pixels that are used to create it. When viewed normally, the small pixels merge into continuous tones much as the dots used to create newspaper photographs do. Each of the small pixels can be a shade of gray or a color. Using 24-bit color, each pixel can be set to any one of 16 million colors. All digital photographs and paintings are bitmapped, and any other kind of image can be saved or exported into a bitmap format. In fact, when you print any kind of image on a laser or ink-jet printer, it is first converted (**rasterized**) by either the computer or printer into a bitmap form so it can be printed with the dots the printer uses. To edit or modify these bitmapped images you use a paint program. Bitmap images are widely used but they suffer from a few unavoidable problems. They must be printed or displayed at a size determined by the number of pixels in the image. Printing or displaying one at any other size can create unwanted patterns in the image. Bitmap images also have large file sizes that are determined by the image's dimensions in pixels and its color depth. To reduce this problem, some graphic formats such as GIF and JPEG are used to store images in compressed format.

Vector graphics

Vector graphics are really just a list of graphical objects such as lines, rectangles, ellipses, arcs, or curves—called **primitives**. **Draw programs**, also called **vector graphics programs**, are used to create and edit these vector graphics. These programs store the primitives as a set of numerical coordinates and mathematical formulas that specify their shape and position in the image. This format is widely used by computer-aided design programs to create detailed engineering and design drawings. It has also become popular in multimedia when 3D animation is desired. Draw programs have a number of advantages over paint-type programs. These include:

- Precise control over lines and colors.
- Ability to skew and rotate objects to see them from different angles or add perspective.
- Ability to scale objects to any size to fit the available space. Vector graphics always print at the best resolution of the printer you use, no matter what size you make them.
- Color blends and shadings can be easily changed.
- Text can be wrapped around objects.

When working with a draw program, you can display the image in two views: wire frame view or shaded. In wire frame view, you see just the underlying lines—a skeletal view of the image. The image is displayed this way because it can be manipulated on the screen a lot faster. To see what the finished model looks like, you can apply colors to the wire frame and display it with the wire frame covered by these shaded surfaces.



The camera is shown in shaded view (left) and wireframe view (right). The ability to shift between these two views is characteristic of vector (draw) programs.

Native and Transfer Image Formats

Since bit-mapped images are the ones that most concern photographers, those are the ones we'll concentrate on in this section. Bitmap file formats fall into two subclasses; native and transfer or exchange formats.

Native Formats

As new programs are introduced, developers have a tendency to create proprietary, or **native formats** that can be read only by their programs. Part of this desire is to have a competitive advantage. But there is also a need sometimes to design a new format to accommodate new procedures or possibilities. However, native formats present serious problems for users who want to transfer image files among programs and share them with others. They are often not readable by other programs.

Transfer Formats

Because native formats are so limiting, **transfer formats** have been designed to allow images to be moved between application programs and even between operating systems. Some of these formats started out as native formats but were so widely adopted by others that they became transfer formats. Almost all graphics applications can open and save these transfer formats as well as their own native formats.

Digital Camera Formats

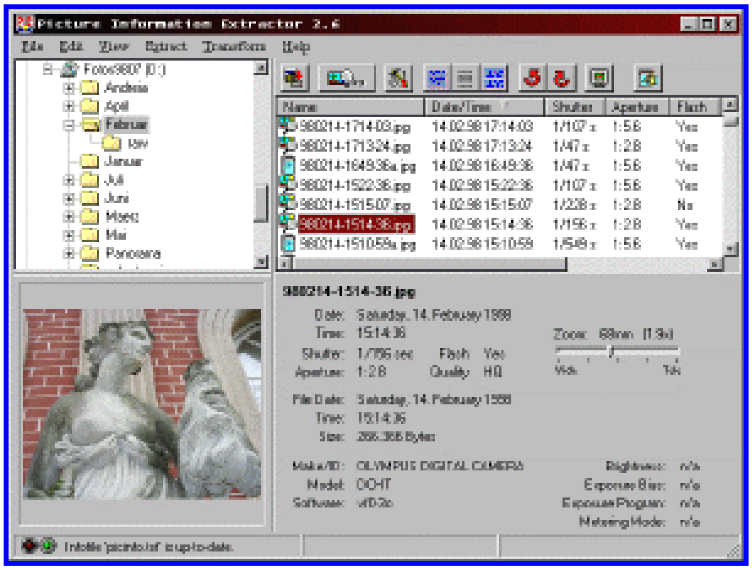
Almost all cameras store images in a format known as JPEG. A few let you save higher quality images in a format known as TIFF. A select few let you save all of the originally captured data in a file format known as RAW. Lets take a look at these three formats.

JPEG

The **JPEG** (Joint Photographic Experts Group) format, pronounced "jay-peg," is by far the most popular format for display of photographic images on the Web. The term "JPEG" is often used to describe the JFIF file format (JPEG File Interchange Format). JFIF is the actual file format that contains an image compressed with the JPEG method. These newer JFIF files originally used the JPG extension, however, the latest standard calls for using a JIF extension instead. The format is optimized for the display of photographs and doesn't work as well as GIF for type or line drawings (GIF is optimized for those). JPEG images have two distinctive features:

- JPEG uses a lossy compression scheme but you can vary the amount of compression and hence trade off file size for image quality, even making extremely small files with poor quality.
- JPEG supports 24-bit color. GIF, the other format widely used on the Web supports only 8-bits.

Compression is performed on blocks of pixels eight on a side. You can see these blocks when you use the highest levels of compression or greatly enlarge the image. JPEG is a two pass compression and de-compression algorithm. This means it take longer to load and display than a gif file. You can save images in a progressive JPEG format that works somewhat like an interlaced GIF. While a standard JPEG loads from top to bottom, a progressive JPEG displays the entire image starting with the largest blocks. This allows the image to be displayed first in low-resolution and then filled in as more data arrives. When you save an image in this format, you can specify the number of progressive scans. Don't use JPEG to save original images you expect to modify later. Every time you open one of these files, and then save it again, the image is compressed. As you go through a series of saves, the image become more and more degraded. Be sure to save your originals is a loss-free format such as TIFF or BMP at maximum color depth. Also, when you save an image as a JPEG, the image on the screen won't reflect the compression unless you load the saved version.



When you take a photo with a digital camera, exposure information such as shutter speed and aperture is saved in a header to the image file. PIE is a file utility that extracts the camera information from the raw .jpg and renames the PIC000XX.JPG filename to a more computer friendly name keyed to the date and time as well as other photo information. Courtesy of juworld.

JPEG 2000

The JPEG image format has been around since before digital photography took off. Its age is showing and many feel it's time for improvements. That's what's driving the development of JPEG 2000 by the Digital Imaging Group (DIG). (Don't be surprised if the name is changed now that "2000" sounds old.) This is not a minor revision, it's as if they jacked up the JPEG name and rolled an entire new file format under it. Here's how it differs from your fathers JPEG:

- Uses wavelet compression instead of the old DCT (Discrete Cosine Transformation) to give a higher compression (20% better) and better image quality with fewer artifacts (image flaws).
- Wavelet technology allows an image to be "streamed." A low resolution image appears quickly and then is gradually "filled in" with more detail. As a user, you can decide when you have enough resolution for your purposes. This is referred to as "level of interest access."
- You can save the image in a lossless JPEG format without having to save it in a lossless format such as TIFF.
- The old JPEG had no provision for a default color space so images looked different on different systems. JPEG 2000 makes sRGB the default color space but you can also specify another color space such as ICC to override sRGB. Either way image colors are rendered more accurately.
- Improved image information capabilities let you store a lot more information about the image including details about the image such as the color space used and the camera used to take it.

TIFF

TIFF (Tag Image File Format), pronounced "tiff," was originally developed by Aldus Corporation to save images created by scanners, frame grabbers, and photo editing programs. This format has been widely accepted and widely supported as an image transfer format not tied to specific scanners, printers, or computer display hardware. TIFF is also a popular format for desktop publishing applications. There are several variations of the format, called **extensions**, so you may have occasional problems opening one from another source. Some versions are compressed using the LZW or other lossless methods. TIFF files support up to 24-bit colors.

CCD RAW

When an image sensor captures data for an image, some cameras allow you to save the raw, unprocessed data in a format called CCD RAW (.CRW). This data contains everything captured by the camera. Instead of being processed in the camera, where computing power and work space is limited, the raw data can be processed into a final image on a powerful desktop computer. The increased power and work space can make a significant difference in the results. In addition, you can save the raw data and process it with other software or in different ways. When the raw data is processed in the computer into a JPEG or other image, it's a "one size fits all" form of processing and the RAW data is discarded. In the final file, not only has some of the original data been changed, some has also been deleted.

Here's what Chuck Westfall, Manager/Technical Information Dept.at Camera Division/Canon U.S.A., Inc. has to say about the RAW format. "Some of the main benefits of CCD RAW files are their smaller file size written by the camera (approximately 60% smaller than an uncompressed RGB TIFF file of equal resolution), a potentially shorter interval between exposures, and optimum image quality due to superior image processing algorithms made possible by an external PC. Of course, one of the main reasons for shooting CCD RAW in the first place is to eliminate the clarity-robbing "artifacts" created by lossy JPEG compression. As you know, Canon was among the first manufacturers to offer an uncompressed file format as far back as 1996 with the PowerShot 600; it's only very recently that other camera makers have begun to offer uncompressed file formats as well. Some makers still don't.

In addition to the digitized raw sensor data, which results in 1 byte per pixel, the .CRW format also records white balance data, contrast mapping, etc. This information is applied during signal processing to enhance color accuracy and other aspects of image quality.

It should also be noted that current PowerShot cameras initially capture image data at 10 bits per channel in 4 channels (C-M-Y-G). Whereas current signal-processing algorithms reduce this to 24-bit RGB output (8-bits per channel), it's conceivable that, with .CRW files at least, a revised algorithm could preserve the 10-bit input data intact with no increase in initial file size. In fact, future cameras could increase the digital capture gradation from 10-bit to 12-bit or even higher, resulting in even further improvements in color quality.

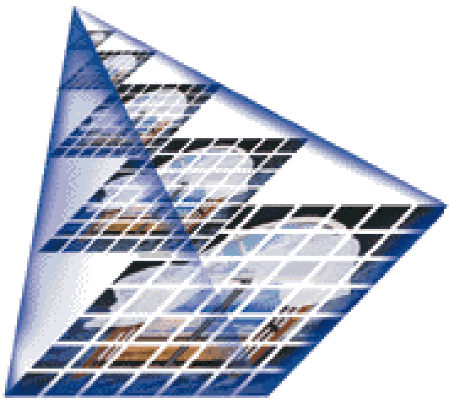
To summarize, the .CRW format already offers many advantages compared to other file formats. There's also a lot of room for further improvements over time."

Web Formats

Many digital photos end up on the Web or attached to e-mail so they are viewed on the screen. For these purposes, small files that are easy to send over the Internet are favored. The leading format for images used in these ways is JPEG, the format most often used to store captured images. However, rival formats have been developed to improve on JPEGs or to serve other purposes. Here are some of them.

FlashPix® File Format (.FPX)

Most file formats present photographers with a dilemma. Low-resolution images are fine for display on the Web but high-resolution images are much better for printing and publishing. Large high-resolution files make both editing and display time-consuming. The **FlashPix®** format developed by Kodak, Hewlett-Packard Company, Live Picture Inc., and Microsoft attempted to solve these problems. Images in the FlashPix format are stored at multiple resolutions, and each resolution is further subdivided into square tiles.



The base of the pyramid represents the source image, such as a GIF or JPEG. As you move up through the pyramid, each image is half the size (in both width and height) of the image below. In addition, each image in the pyramid is split into tiles that are 64 x 64 pixels. Courtesy of Live Picture.

FlashPix applications select the best resolution for the current application. For example, a low resolution image is selected for screen display and a high resolution image is selected for printing. However, even when a low-resolution image is displayed, as the one below is, you can look at its higher-resolution versions.

When you edit a FlashPix image, the different resolutions and square tiles into which it's divided come into play.

- To speed up editing, you can edit the low-resolution version and then apply your changes to the higher resolution version.
- When you edit a small area, only the affected tiles are updated on the screen. This saves time because the entire image isn't redrawn each time you work on a small area.
- Any edits that you make are stored in a separate file that the application automatically applies to any resolution. You don't need to maintain separate image files for each change you make. You can save a series of small files and then apply them to high-resolution images at any time. This greatly reduces both required memory and disk space.
- FlashPix images carry all of their original image and color information through the entire process of editing and printing.

The problem with FlashPix images is that they never really caught on. One problem was its zoom function. When you zoom a FlashPix image, the entire image doesn't get larger, just a part of it. It's like looking at a large mural through a cardboard tube. Since photographer's consider the edges of their images as important as the center, they weren't enamored of a format that didn't display their images in their entirety. Even the

FlashPix developers were hard pressed to justify this feature. The most commonly stated benefit was that you could zoom in to look at the buttons on a shirt you were considering on an e-commerce site. Because of the lack of demand, most Web hosting services didn't install the software necessary for Web sites to post FlashPix images. No one ever hold funerals when products or formats die, but from what I can gather this format is dead. Many of it's features will be incarnated in the newer JPEG 2000.

GIFs (.GIF)

GIF (Graphics Interchange Format) format images, pronounced "jiff," are widely used on the Web but mostly for line art, not for photographic images. This format stores up to 256 colors from an image in a table called a **palette**. Since images have millions of colors, a program such as Photoshop selects the best ones to represent the whole when you save the image in this format. When displayed, each pixel in the image is then displayed as one of the colors from the table, much like painting by numbers.

There are two versions of GIF in use on the Web; the original GIF 87a and a newer GIF 89a. Both versions can use interlacing; storing images using four passes instead of one. Normally, when an image is displayed in a browser, it is transmitted a row at a time starting at the top row and filling in down the page. When saved as an interlaced GIF, it is first sent at its full size but with a very low resolution. This allows a person to get some idea of all of the contents of the image file before it is completely transmitted. As more pixels are sent in the next three passes the image fills in and eventually reaches its full resolution. The newer GIF 89a version adds some additional capabilities that include the following:

- Image backgrounds can be made **transparent**. To do so, you specify which color in the table is to be transparent. When viewed with a Web browser, the browser replaces every pixel in the image that is this color with a pixel from the web page's background. This allows the background to show through the image in those areas. You have to choose the transparent color carefully. If you select one that occurs anywhere in the image besides the background, your image will appear to have "holes" in it.

- Images can be **animated**. By rapidly "flipping" through a series of images, objects can be animated much as a movie simulates motion using a series of still images. This works best with line drawings but can also be done with photographs. Depending on bandwidth, the animation may not work the first time. However, once it's stored in cache and replayed, it will work fine.

White background

White background made transparent.

GIF images are limited to a maximum of 256 colors. These colors, stored in a table, index, or palette, are often referred to as **indexed colors**. When you convert a photograph to GIF format, most graphics programs will allow you to dither it. This replaces lost colors with patterns of those available in the palette. Dithering improves the appearance of the image, but it also increases the size of the file. Although GIF photographs often look OK on-screen, they suffer if compared side-by-side with images saved in JPEG and other formats. The GIF format is best used for line art such as cartoons, graphs, schematics, logos, and text that have a limited number of colors and distinct boundaries between color regions. GIF images are compressed using a "lossless" form of compression called LZW (Lempel-Ziv-Welch). The amount of compression achieved depends on the frequency of color changes in each pixel row. This is because when two or more pixels in a row have the same color, they are recorded as a single block. Hence, a picture of horizontal stripes will compress more than one of vertical stripes, because the horizontal lines would be each stored as a single block. Photographs with large areas of identical colors such as skies, snow, clouds, and so on, will compress more than images with lots of colors and patterns. To save a 24 bit image as a GIF, you must reduce the bit depth down to 8 bits. To reduce file sizes in GIF format, you can further reduce the number of colors in the image. This is difficult with most photographs, but not with line art. For example, if your image has 16 or fewer colors, you can convert it to a 4-bit (16-color) palette. Most graphics programs will allow you to do this. Even with photographs you can sometimes reduce the image to fewer colors than actually exist without noticeable loss. The discarded colors are those that are seldom-used or transitional colors between more frequent colors. When working with grayscale images, GIF works as well as JPEG because almost all programs use 8-bits (256 colors) for gray scale images.

PNG (.PNG)

PNG (Portable Network Graphics), pronounced "ping," was developed to replace the aging GIF format and is supported by both Microsoft Internet Explorer and Netscape Navigator. PNG, like GIF is a lossless format, but it has some features that the GIF format doesn't. These include 254 levels of transparency (GIF supports only one), more control over image brightness, and support for more than 48 bits per pixel. (GIF supports 8 for 256 colors). PNG also supports progressive rendering, as interlaced GIFs do, and tends to compress better than a GIF. The format has never caught on and remains a curiosity on the Web.

Portable Network Graphics logo.

Printing Formats

EPS (.EPS)

EPS (Encapsulated PostScript) files, pronounced a letter at a time "E-P-S," use a format developed by

Adobe for PostScript printers. These files generally have two parts. The first is a text description that tells a PostScript printer how to output the image. The second is an optionally bit-mapped PICT image for on-screen previews. Once an image has been saved in the EPS format, you can import it into other programs and scale and crop it. However, its contents are often no longer editable except by a few programs such as Adobe Illustrator. For this reason, these files are generally created at the end of the process when they are about to be incorporated into a printed publication.

Editing Formats

When editing photos, you usually preserve the original file and save the one on which you're working in an uncompressed or lossless format. One such format, TIFF has already been discussed. Here is a brief discussion of some other leading file formats. None of these formats are compressed, so their file sizes are quite large compared to JPEG images.

Photoshop (.PSD)

When working on images in Photoshop, there are many features, such as layers, that serve a purpose only when editing. For this reason, Photoshop has its own native format you use to save file while working on them. This format saves everything you've done to the image so you can just reopen the file and continue working. When finished, you usually save the image in another, more common format such as TIF, JPEG, or BMP.

PICT (.PIC)

The **PICT** format, pronounced "pick," was introduced along with MacDraw software for the Macintosh. It has since become a Macintosh standard.

BMP (.BMP)

BMP, pronounced a letter at a time "B-M-P," files use a Windows bitmap format. These images are stored in a device-independent bitmap (DIB) format that allows Windows to display the bitmap on any type of display device. The term "device independent" means that the bitmap specifies pixel color in a form independent of the method used by a display to represent color.

Scanning Formats

This is something of a made up category since it has only a single entry; Photo CD disks. Although film and print scanners have become very common and are widely used to scan images for storage on CD disks, the Photo CD from Kodak was the first widely available such format.

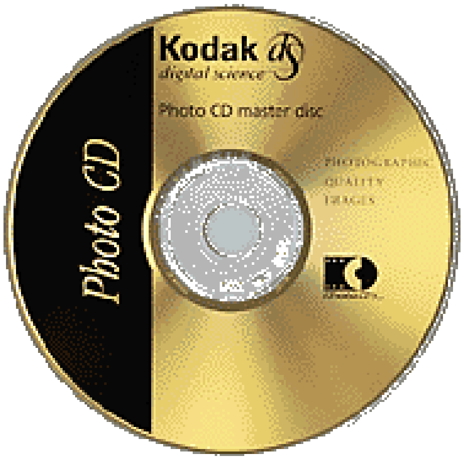
Kodak originally hoped that these discs would catch on in the consumer market. The plan was to have mom or pop select the best photos from their vacation and have Kodak scan them onto a CD disc. The family would then gather around the TV set for an old fashion slide show using a CD Disc player much like the DVD players we now use for movies. Alas it never came to pass, but the format was saved when it caught on amongst professionals and advanced amateurs. It's those groups that have kept the format alive. Before Photo CDs came along, they were paying $25 to have a slide scanned and now they could get the same results for a buck or two.

Kodak's **Photo CD** is designed to give you high quality image scans at low cost. You can have your slides or negatives scanned onto these discs at your local photofinisher or any service bureau that offers this service. The quality you get is much higher than you would get from the most expensive digital cameras. Prices vary but range somewwhere around $1US and varies somewhat depending on the level of service. Once scanned onto the disc, the images can be displayed on a TV using a Photo CD player or copied into your computer from any CD drive that supports the Photo CD format (almost all now do). To help you find the image you want, the Photo CD comes with a set of index prints. These tiny prints allow you to quickly locate images and their files on the disc.

Don't confuse Photo CDs with Kodak's new Picture CDs. Photo CDs use a special file format are are intended for professional or commercial use. Images can be scanned into this format at any time. Picture CDs are aimed at consumers and must be scanned at the time film is first developed. They are stored in the universally supported JPEG format. The biggest difference is with Photo CDs you can go through your photos and have only the best scanned. With Picture CDs, everything on the roll is scanned; good, bad, and indifferent.

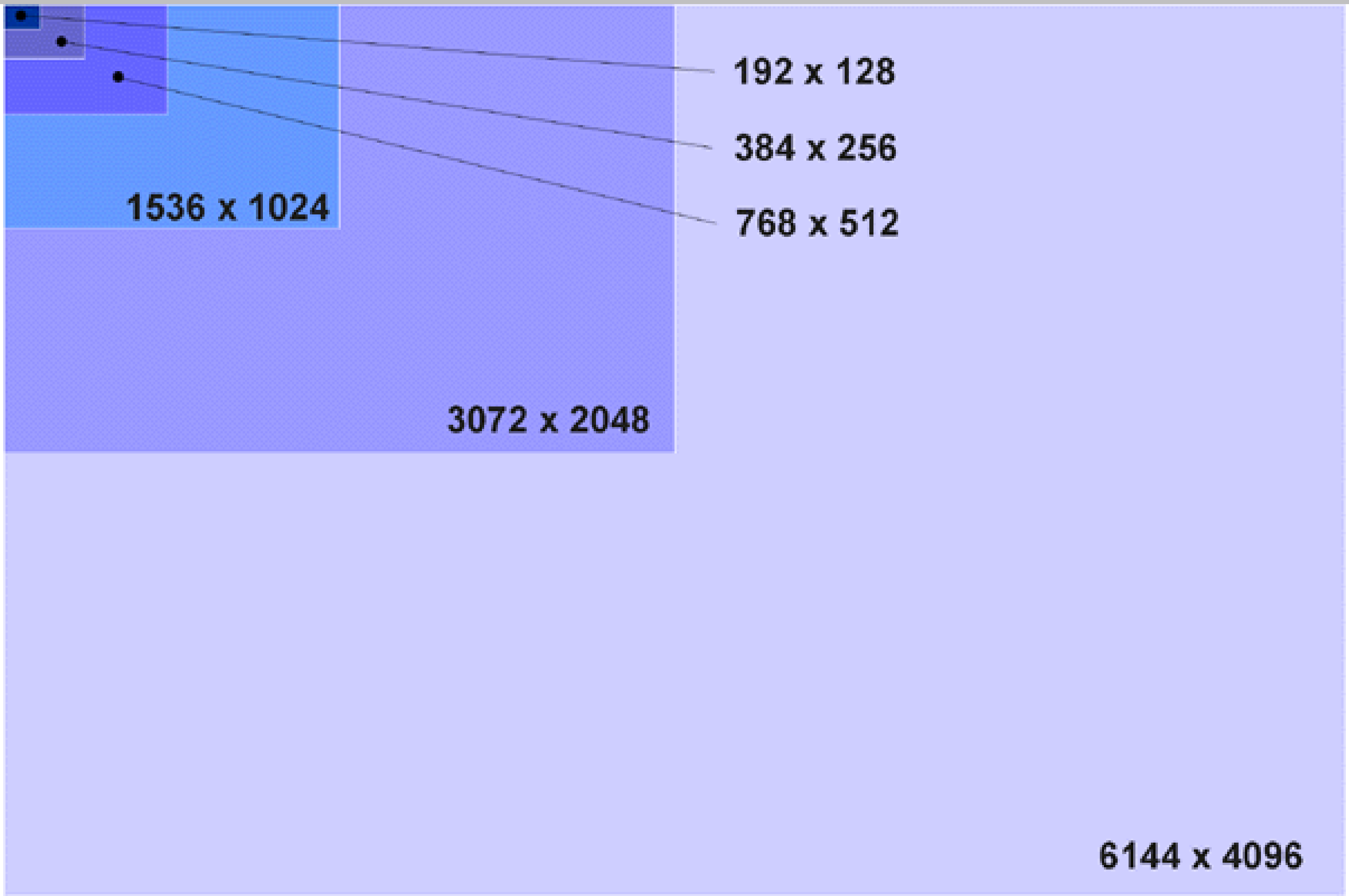
The PCD N2000 lets you display images on a Photo CD Disc or play audio and interactive elements with a Portfolio CD Disc.

Photo CD images are stored in a proprietary file format called an **Image Pac** containing thirteen individual files. These files include five different resolutions for the image (each one-quarter the size of the next largest). The files range in size from 72 kilobytes to 18 megabytes. The images are stored using the Photo YCC color encoding metric, developed by Kodak. Also included are other files used when you convert an image color from Kodak's YCC color encoding scheme to another color mode such as RGB (red, green ,blue) and CMYK (cyan, magenta, yellow, and black).



Kodak's PhotoCDs have become the optical storage medium of choice fdor many photographic applications. Courtesy of Kodak.

Photo CD Resolution File Size			
Base/16	128 x 192	70 kilobytes	Small Thumbnail
Base/4	256 x 384	280 kilobytes	Thumbnail
Base	512 x 768	1.12 megabytes	Same resolution as TV
4 Base or Base*4	1024 x 1536	4.5 megabytes	Same resolution as HDTV
16 Base or Base*16	2048 x 3072	18 megabytes	
64 Base or Base*64	4096 x 6144	72 megabytes	Pro-Photo CD only



Here are the relative sizes of the images stored on Photo CDs. The largest size only comes on Pro Photo CDs.

Photo CD disks come in a number of flavors, each designed for specific applications. Master disks come in two flavors—**Photo CD Master discs** and **Pro Photo CD Master discs**. Both can only store images that originated on film and were digitized using Kodak scanning systems and software.

- Kodak's **Photo CD Master**, developed for 35mm images, can hold about 100 images in the first five resolutions discussed above.
- Kodak's **Pro Photo CD Master**, designed for larger film formats up to 4 x 5, includes the five resolutions on the Photo CD Master plus an optional sixth resolution of 4096 x 6144 pixels (Base*64). Depending on the film format and/or the resolution of the scan, a disc can hold between 25 and 100 images.
- The Kodak **Photo CD Portfolio 1I** disc is more like a multimedia disk. In addition to images, it can also store text, audio, and even software. It isn't just a storage media, but can also be programmed to give branching presentations. These discs differ from Master discs in two key respects. The images don't have to originate on film, but can also come from other sources such as digital cameras and scanners. Also, the images don't have to contain all of the resolutions stored on a Master or Pro Master disc. The highest required resolution is 512 x 768. Since only base-level images are required for this format, each Portfolio II disc can contain about 700 images, one hour of digital audio or a proportional combination (such as 350 images and 30 minutes of sound).

In addition to having images scanned, you can also request other services when putting images onto Photo CD discs.

- Images at Base resolution and Base/4 can be **watermarked** with a design of your choice so they can be viewed but not output without the watermark.
- Images at 64 Base, 16 Base, and 4 Base can be **encrypted** so they can't be accessed, leaving only lower-resolution versions of these images accessible for viewing.
- Images can be cropped, dust and scratches removed, and the "video safe" area can be verified.
- Images can be **tagged with text** identifying copyrights, photographer names, and other information.

Kodak Photo CD Disc Summary			
Basic Features	**Photo CD Master**	**Pro Photo CD Master**	**Photo CD Portfolio II**
Image formats	35 mm film	35 mm, 120, and others up to 4"x5"film	Photo CD or other digital images
Number of Images	100	25 - 100 depending on resolution	700 (base resolution)
Other media	None	None	Audio, branching, text and graphics, and edited images

Compression

When you take a photograph, the size of the image file is huge compared to many other types of computer files. For example, a low-resolution 640 x 480 image has 307,200 pixels. If each pixel uses 24 bits (3 bytes) for true color, a single image takes up about a megabyte of storage space. As the resolution increases, so does the file size. At a resolution of 1024 x 768, each 24-bit picture takes up 2.5 megabytes. To make image files smaller and more manageable, almost every digital camera uses some form of compression. **Compressing images** not only let's you save more images on the camera's storage device, it also allows you to download and display them more quickly.

How Compression Works

During compression, data that is duplicated or which has no value is eliminated or saved in a shorter form, greatly reducing a file’s size. When the image is then edited or displayed, the compression process is reversed.

There are two forms of compression—lossless and lossy—and digital photography uses both forms.

Lossless compression

Lossless compression (also called *reversible compression*) uncompresses an image so its quality matches the original source. Although lossless compression sounds ideal, it doesn’t provide much compression. Generally, compressed files are still a third the size of the original file, not small enough to make much difference in most situations. For this reason, lossless compression is used mainly where detail is extremely important as in x-rays and satellite imagery. A leading lossless compression scheme is LZW (Lempel-Ziv-Welch). This is used in GIF and TIFF files and achieves compression ratios of 50 to 90%

Lossy compression

Although it's possible to compress images without loosing some quality, it's not practical in many cases. Therefore, all popular digital cameras use a **lossy compression** (rhymes with *bossy*) that degrades images to some degree and the more they're compressed, the more degraded they become. In many situations, such as posting images on the Web, the image degradation isn't obvious. However, enlarged prints show it off.

Although lossy compression does not uncompress images to the same quality as the original source, the image remains visually lossless and appears normal. The trick is to remove data that isn’t obvious to the viewer. For example, if large areas of the sky are the same shade of blue, only the value for one pixel needs to be saved along with the locations of where the other identical pixels appear in the image. The leading lossy compression scheme is JPEG (Joint Photographic Experts Group) used in JFIF files (JPEG File Interchange Format). This scheme allows you to select the degree of compression. Compression Ratios between 10:1 and 40:1 are common.

Because lossy compression affects the image, most cameras allow you to choose between different levels of compression. This allows you to choose between lower compression and higher image quality or greater compression and poorer quality. The only reason to choose higher compression is because it creates smaller file size so you can store more images, send them by e-mail, or post them on the Web. Most cameras give you two or three choices equivalent to Good, Better, Best although the names change. (If there were truth in labeling they would be called worst, worse, and good.)

A Short Course in Digital Photography

6. Photo Printers

CONTENTS

As Ansel Adams said "The negative is the score, the print is the performance." This is just as true in today's digital world as it was in Ansel's silver-based one. If you haven't seen photographs printed on color printers, you are in for a big surprise. The output you can get from printers costing a few hundred dollars will shock you. The results may not be the same as prints made with traditional photography, but in many ways they have a look and feel all their own. Because of the wide choice of papers, inks, and technologies available, printed images vary a lot. This doesn't mean they have poor quality, it just means they are different. At the moment, two types of printers stand out, ink-jets for low cost and dye subs for high quality. Before looking at them in more detail, let's look at how printers work.

Selection Criteria

When choosing a color printer there is no better way to compare than to print one of your own images on a variety of them and compare the results. Barring that, you can read reviews or ask around. When doing so, here are some things to keep in mind: Specialized photo printers may not work as well on general tasks such as word processing. Even if they do, their per/page costs may be higher and their operation slower. The cost of the printer isn't the only consideration. You also have to factor in the costs of paper and ink or toner. These recurring costs can soon exceed the cost of the printer. Processing images takes a lot of power, so printers often have as much computing horsepower and memory as a PC. Some printers form the complete image in memory prior to printing it. Doing so speeds things up if the printer has enough memory. The proportions on the image sensor and the printer may or may not match. If they don't match, you may experience "cropping" or have to reduce the size of your image to fit on the page. This is especially true on snapshot printers and self-service printers in photo shops.

A Word About Printer Resolutions

When it comes to printers, resolution is not the final determiner of color or quality. For example, an ink-jet printer with a resolution of 1400 dpi won't give as good a print as a dye-sub printer at 300 dpi. This is because, each pixel on an ink-jet printer isn't a single drop of color but a cluster of many drops. The accuracy with which this is done can have a profound impact on the "perceived" resolution of the image. For ink-jet printers, the size of the small ink drops is more important that the dpi. For example, some of the best printers use only 300 x 300 addressable dots per square inch but use between 25 and 36 dots per pixel.

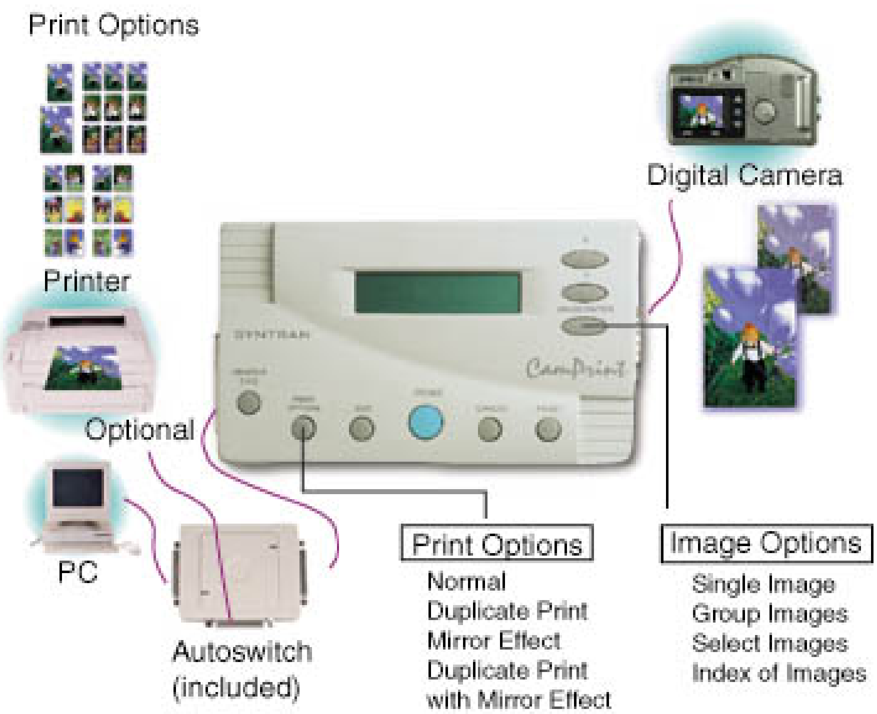
Bypassing the Computer

Until recently, the computer was a digital photography gatekeeper. To go anywhere, the image had to first be transferred to the computer. This is changing as advances make it possible to send images to the Internet directly from the camera and to a printer. There are two models for this independence. In one model, the printer has built-in slots into which you can plug flash-memory cards. In the other model, a device is used to connect the camera to the printer.

Some printers now have slots in them for flash memory cards so they can make prints without a computer. Each printer has it's own unique features.

The Lexmark Photo Jetprinter 5770 reads both SmartMedia and CompactFlash camera cards. In addition, there are multiple picture formats, frames and text messages with the exclusive Built-in Camera Computer. Courtesy of Lexmark.

One of the devices used to connect your digital camera to almost any printer, is the CamPrint. This device lets you print a single picture, a group of pictures, selected images, or an index of images (a contact sheet) on one sheet of paper. CamPrint also allows you to choose the size of the pictures and the number of copies.



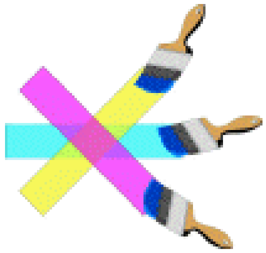
The CamPrint acts like a hub to which other devices can be connected. Courtesy of Syntran Color Imaging.

How Color Images are Printed

Color printers create images by dividing a page into thousands, or even millions, of tiny dots, each of which can be addressed by the computer. As the printer moves across and down the page, it can print a dot of color, print two or three colors on top of each other, or leave the spot blank (white). To understand digital printing, you need to know a little about the colors that are used and the patterns in which they are printed.

CMYK Colors

As you've seen, color displays use three colors, red, green, and blue (RGB) to create color images on the screen. This process is referred to as additive color because adding all three colors together forms white. Color printers use a different process, called subtractive color. This process uses three subtractive primaries—cyan, magenta and yellow. When two of these are overprinted, they form red, green, or blue. When all three are overprinted, they form black. Most printers include a separate black color to provide a deeper black than that formed by combining the primaries. This is useful, not only for richer blacks in photographs, but also when printing text. These four colors give the color system its name—**CMYK** (C for cyan, M for magenta, Y for yellow, and K for black). If your browser has a Shockwave plug-in, you can assemble a full-color image from the three basic colors at Konica's site in Japan.



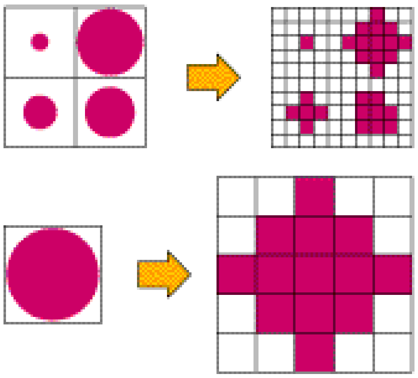
When you use cyan, magenta, and yellow inks or pigments, you create subtractive colors. This illustration is still rough and will stay that way to I can figure out how to easily combine the colors in CorelDraw or give up and turn it over to a real computer artist. In the meantime, you might want to visit Olympus to see another illustration of the same things.

By leaving a spot blank, or by using one or more of the three subtractive primaries on a single dot, the printer can create eight primary colors as follows:

Color 1	Color 2	Color 3	Combined
White	White	White	White
Cyan	None	None	Cyan
Magenta	None	None	Magenta
Yellow	None	None	Yellow
Cyan	Magenta	None	Blue
Cyan	Yellow	None	Green
Magenta	Yellow	None	Red
Cyan	Magenta	Yellow	Black

Halftones and Dithers

On most printers (dye-sub is an exception), each printed dot has the same density of color. If the printer only combined these solid colors, it would be limited to the eight primary colors describe above. To get the millions of colors in a photograph, the printer has to "fake" it by generating a pattern of small dots that the eye blends to form the desired shade. This process is called **halftoning** or **dithering** and designing printer software that does it well is as much art as it is science. As a result, printers vary widely in the methods used and the results obtained. One sign of halftoning being well done is when a smooth gradation of color in the original looks smooth in the print. If the process isn't well done, these smooth transitions will be made up of distinct bands of color and may also include moiré or doily patterns. Halftoning is done by arranging printable dots into grid-like groups, called **cells**, and then using these larger dots as a single unit to print pixels with. Each cell may be 5 by 5 or 8 by 8 dots in size. The three or four primary colors are printed combined in a pattern of dots in these cells, and the eye perceives them as intermediate hues. For example, to print purple the printer uses a combination of magenta and cyan dots. For less saturated hues, the printer leaves some dots unprinted and hence white in color.



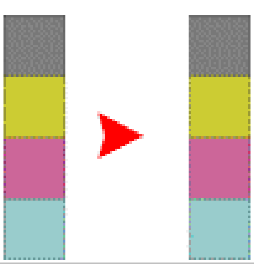
The printed forms on the left in each picture are actually made up of square pixels as shown in the right-hand objects. Courtesy of [Tektronix]

Halftoning has long been used in the conventional printing industry and you can see it by looking at a magazine photo with a magnifying glass. It is also embedded in page description languages such as Adobe's PostScript Level 2. However, printer manufactures try to improve on these standards with their own proprietary systems that are better matched to their printers.

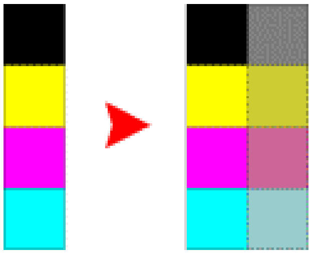
Color Gamut

Color gamut refers to the range of colors that can be reproduced by any device. Unfortunately for photographer's mother nature's color gamut is a lot larger than any we can reproduce with light, inks, dyes, or pigments. The best we can do is get as close to the original scene as possible. Your first experience with the limitations of color gamut is if you shoot both slide and print film. The slides are always richer and brighter than the prints because slide film has a larger color gamut.

One way to think of color gamut is to imagine that you have a set of dull inks. You're asked to use them to print bright colors. It can't be done because the color gamut of the inks is smaller than the color gamut you're asked to create. On the other hand, if you have a set of bright inks, you can reproduce the colors of the dull inks because they fall within the color gamut of the inks you're using.



Dull inks with a small gamut only let you create dull colors.



Bright inks with a large gamut allow you to create both dull and bright colors.

When reproducing colors on the screen or printed page, we use what are called **color models**. One model, called **Lab**, has the largest gamut. Within the color model can be found all of the colors of the two most popular color models: RGB and CMYK. The RGB gamut includes only those colors that can be displayed on a computer screen. Some colors, such as pure cyan or pure yellow, can’t be displayed accurately on a monitor. The CMYK model, used for printing, has the smallest gamut. When colors in an image can not be displayed or printed because they aren't in a device's gamut, they are called **out-of-gamut colors**.

Until recently, there were no inexpensive color printers but great strides have been made over the past few years. There are now a variety of printers at a variety of price points. When you choose a printer to print photographs, it's not always the most expensive kinds that give the best looking results. Let's take a look at some of the ways printers transfer images to the page.

Liquid Ink-jet Printers

Liquid ink-jet printers propel fine droplets of liquid ink toward the surface of paper. In today's marketplace, this technology is the low-cost entry point for personal printing and low-volume color printing.

Tektronix's Phaser 140 is an ink-jet printer. Courtesy of Tektronix.

Quality

These low-cost printers do an amazing job of printing photo-realistic images on a wide variety of papers.

The Epson Stylus 800 is a photo quality ink-jet printer that prints 1440 dots per inch for less than $400. Courtesy of Epson.

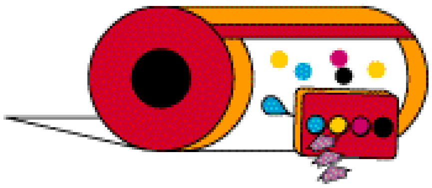
Materials

These printers use ink-jet cartridges. Although you can print photos on plain-paper, you'll find that liquid inks tend to soak into the paper taking the color along with them. You'll get richer colors using coated papers that are less absorbent and designed specifically for photographs. The ink dries partly by absorption and partly by evaporation. If the paper is too absorbent, the image looks washed out.

Ink cartridges courtesy of Tektronix.

Transfer process

A cartridge of ink is attached to a print head with up to hundreds of nozzles, each thinner than a human hair. The number of nozzles and the size of each determines the printer's resolution. As the print head moves across the paper, a digital signal from the computer tells each nozzle when to propel a drop of ink onto the paper. On some printers, this is done with mechanical vibrations. Piezoelectric crystals change shape when a voltage is applied to them. As they do so, they force ink through the nozzles onto the paper. Each pixel in the image can be made up of a number of tiny drops of ink. The smaller the droplets, and the more of them, the richer and deeper the colors should be.



Piezoelectric crystals force ink through the nozzles onto the paper. Courtesy of Tektronix.

Inkjet printing, like conventional printing on a press, is binary. These printers can only put ink down or not put ink down. They can't control the density of each dot. To achieve the illusion of continuous tones, the percentage of area covered by ink is modulated in one or both of two ways:

1. A screening process maps the desired variations in density into variations in dot size. Thus, as the desired density increases, the dot sizes increase and a higher percentage of the white space is covered with ink.

2. If the printing process supports smaller dots of a fixed size, area modulation is achieved by varying the number (rather than the size) of dots that are printed in any given small area.

There are two pitches of concern with such printing: the dot pitch and the screen pitch. For example, an inkjet printer may have a raw dot pitch of 1200 dpi. An equivalent screen pitch may be defined as say, 75 lpi, where "lpi" refers to the equivalent dot pitch of a screen (lines per inch). Thus, each screen cell (75/inch x 75/inch) contains 1200/75 x 1200/75 = 64 raw dots. In such a case, each screen cell could be printed at any of 65 levels (0 to 64 dots). This process would then be equivalent to a 65 level, 75 pixel/inch printer.

Dye Sublimation Printers

At the high end where quality is very important, you'll find dye-sublimation printers (called dye-subs, but more accurately dye-diffusion). The "dye" in the name comes from the fact that the process uses solid dyes instead of inks or toner. "Sublimation" is the scientific term for a process where solids (in this case dyes) dyes are converted into a gas without going through an intervening liquid phase.

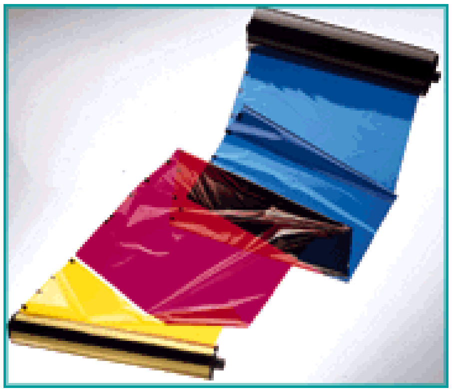
The Olympus P-400 is a high-speed dye-sublimation printer that prints an A4-size (8.25"x 11.7") photograph in only 90 seconds. True, continuous-tone dye-sublimation technology provides professional photo prints with accurate color reproduction for ultimate output quality. Prints from the P-400 look and feel like traditional photographs. (The cost per A4-size print, including paper and ink, is a competitive $1.90.)

Quality

When printing color photographs, there's nothing like dye sublimation printers. These printers produce photo-realistic continuous-tone images that look like they came from a photo lab.

Materials

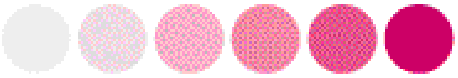
Dye sub printers have their colored dyes in a transfer roll or ribbon. This roll contains consecutive page-sized panels of cyan, magenta, yellow and black dye. (A three-color transfer roll produces blacks that are a composite of CMY but they are not as rich.) These printers require special paper that's designed to absorb the vaporous dye on contact. Cost per page is high, $3 to $4 dollars for a letter sized page.



Tektronix offers three high-quality transfer rolls for the Phaser 450. Each roll consists of page-sized panels of ink that are passed over a tightly focused heating element and diffused onto dye sublimation paper or transparency film. Courtesy of Tektronix.

Transfer process

During printing, separate passes are made across the print for each of the four colors—cyan, magenta, yellow, and black. (Maintaining accurate registration for each color requires precise paper feeding one reason these machines are costly.) A thermal print head, consisting of thousands of heating elements, contacts the media being printed on and vaporizes the solid dyes. The resulting gas diffuses into the surface of the paper. What makes these printers unique is that the heating elements on print head can be set to any one of 256 temperatures. The hotter the temperature, the more dye is transferred to the paper. This precise control of the amount of dye that's vaporized controls the density or intensity of the resulting dot on the paper and produces continuous-tone images.



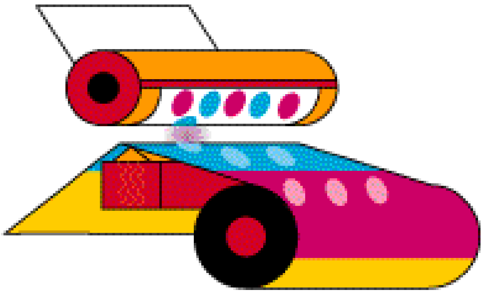
The hotter the print head, the more dye and denser the pixel. Courtesy of Tektronix.

A dye-sub printer prints square dots each of which is denser in the center and lighter on the perimeter. By varying the amount of power delivered to the printhead for each dot, the amount of dye transferred to each dot and hence the dot's density can be varied from no dot at all, to a small light dot, up to a large dense dot. Because the size of the dots doesn't change, the colored parts of the smaller dots have white space between them. At higher energies, the colored areas of each dot become larger and denser, eventually merging into the adjacent dots.

Because the dyes are transparent, a cyan dot may be printed on top of a magenta dot to make a blue dot. By varying the amount of C, Y, and M, any color within the printer's color gamut may be produced.

Black (K) is normally used in these printers only for text, although it may sometimes be used within a continuous-tone (contone) image via the process known as "undercolor removal." (Calculating how much cyan, magenta, and yellow from the image and how much black to add to it.)

Because they can vary the density of each color, dye-sub printers are the only ones that don't have to use halftoning or dithering to create a wide range of colors. And because there are no dithered dot patterns, the colors are applied in a continuous tone; hence the photorealistic images.



Courtesy of Tektronix.

Despite their name, most dye-sub printers actually work by dye diffusion, not by sublimation. Early in the development of these printers it was mistakenly believed that the dyes were transferred by sublimation. However, the dyes are actually transferred by diffusion from the ribbon to the media. This diffusion is activated by two processes; heat from the printhead and pressure in the printing region. Springs or weights force the printhead to push the inked ribbon into contact with the media, so that diffusion can occur. A more accurate term for this process is actually "Dye Diffusion Thermal" or "D2T" printing. There are some high-end printers such as Kodak's "Approval" system, which do work by sublimation. These printers use a laser to vaporize the dye, which then deposits itself on the media and solidifies. Such printers are the exception rather than the rule, and are capable of very high dot pitch, up to 3000 dpi.

Solid Ink-jet Printers

Solid ink-jet printers are great for producing reports and publications with color graphs or other graphics on ordinary paper. They are also the hands-down winner for producing high-quality transparencies at low cost. And, if you're producing a black-and-white document with just a page or two of color charts, you can do so without having to print the charts on a special paper that stands out from the rest of the document.

Quality

Solid ink-jet printers produce high-quality images with sharp edges and good color reproduction.

Tektronix's Phaser 300X color printer can handle any paper you'd like: 16-lb. bond to 80-lb. cover. Letterhead, book, text, writing, cover stock, drafting vellum, recycled, or anything else that looks interesting. It's the world's most versatile color printer. Courtesy of Tektronix.

Materials

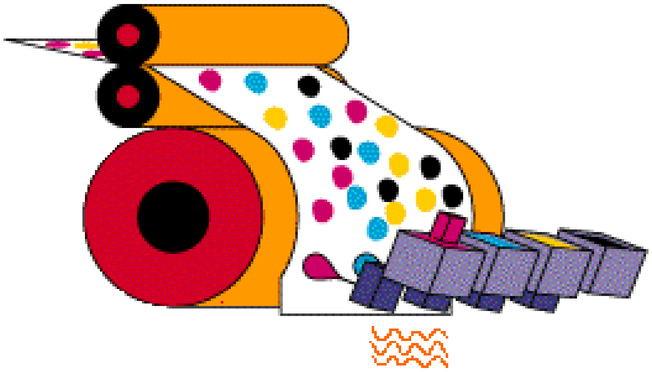
Cyan, Magenta, Yellow, and Black color sticks (solid bricks—a bit like colored bars of soap) are installed in the printer. Solid ink printers can print on nearly any kind of paper stock, an important feature if you make color proofs. For example; if you are a package designer, you can simulate the appearance of a new design for your client by outputting the proof on the same stock as the final packaging. Solid ink printers work well with colored stock. These printers apply extremely vibrant and opaque color and are ideal for graphics.

Inks.gif (3066 bytes)

Ink sticks courtesy of Tektronix.

Transfer process

Solid ink-jet printers use solid ink sticks that are melted into a reservoir and sprayed through tiny nozzles onto the page where it immediately hardens. (These are sometimes referred to as phase-change printers because the ink moves from a solid to a liquid phase to be printed then back to a solid phase on the page.) As a final step, the paper moves between two rollers to cold-fuse the image.



Courtesy of Tektronix.

Thermal Wax Printers

Thermal-wax transfer was once the workhorse of print technologies, and can still be a very effective technology. Thermal-Wax printers are fast, deliver vibrant colors, are great for printing presentation graphics and the per-page cost is low.

Quality

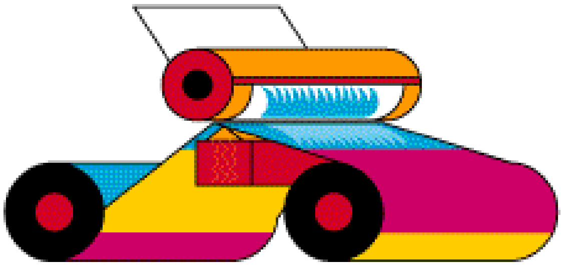
Thermal-wax printing can produce vivid colors on a variety of office laser papers but the quality of continuous tone images does not approach that of dye-sub printers.

Materials

Instead of inks, thermal-wax printing uses a transfer roll or ribbon of colored wax that is segmented into page-sized sections each of the three subtractive colors (and optionally, black). The paper is a special paper but you can also use transparency film. Thermal Wax Transfer is one of the most widely used processes in scientific, technical, and business printing.

Transfer process

As the ribbon coated with cyan, magenta, yellow and black wax, in page-sized panels is moved over a thermal printhead, thousands of heating elements on the printhead, capable of precise temperature variations, causes the wax to melt and adhere to specially coated paper or transparency material. The final printed image is composed of tiny dots of colored wax.



Courtesy of Tektronix.

Color Laser Printers

Laser printers revolutionized black-and-white printing, making graphics and desktop publishing possible. However, color laser printers on on the margins of photographic printing. Not only are their costs high, but their quality has not yet matched the very inexpensive ink-jet printers.

Tektronix's Phaser® 360 Color Printer is the first Adobe® PostScript® 3 color printer. Courtesy of Tektronix.

Quality

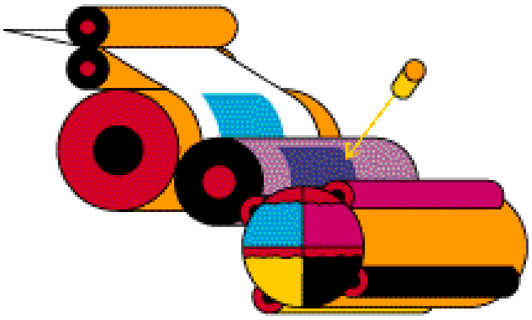
Photographs printed on a color laser can be good and the best can rival the photo-realistic images created with dye sublimation printers. The toner is also fairly durable and it's less sensitive to fading from exposure to light than some other technologies.

Materials

The colors for laser printing are contained in four separate toner cartridges, one each for cyan, magenta, yellow and black. No special paper is required, but you can use different kinds to change the "look" of the print.

Transfer process

Laser printers use a technology similar to that used in copiers. A laser beam is focused on a photoelectric belt or drum, creating an electrical charge in areas where toner is to adhere. Charged toner is then attracted to those places on the belt or drum. Electrostatic charges cause the toners to adhere to the belt. With black and white printers, this process happens once but with color printers it is repeated for the cyan, magenta, yellow and black components of the image. The image, composed of the four toner colors, is then transferred to a drum which rolls the toners onto the sheet of paper or transparency. The toners on the paper are then fused using either heat or a combination of heat and pressure.



Color laser courtesy of Tektronix

Other Printers

Now that you understand a little about how printers work and what your choices are, let's look at some specific printers. These aren't the typical laser, ink-jet, or dye-sub printers you find in stores and catalogs. They are variations on these themes.

Thermo Autochrome

The TruPhoto Digital Photo Printer (4" x 6") uses a technology termed Thermo Autochrome. This process uses a thermal head and ultra violet light to process pigments in the paper. There are three layers of colors in the paper, yellow, magenta and cyan. Each color has sensitivity to a temperature. Yellow reacts to a low temperature while cyan reacts to the high temperature and magenta is in the middle. The printer passes the paper past the thermal head 3 times. The first pass heats the yellow layer then the ultra violet light fixes the yellow so that it can no longer be processed. The second pass heats the magenta and the ultra violet light fixes it. The third pass heats the cyan, there is no fixation after the cyan heating. This process is a continuous tone and does not use any other median other than heat, light and TA paper.

- TA prints are permanent and resistant to fading.
- TA paper is the only consumable. Ink jet printers use 4-6 inks released from a jet onto the paper.
- Ink jet printers use dithering Inks can rub off onto another median.
- Dye-sublimation printers use a ribbon to transfer color to the surface and it can be rubbed off

Snapshot Printers

Snapshot printers can use any printing technology but generally makes prints that are smaller than 8 x 10. Many have a lower resolution than their larger cousins. Their prints look good but when placed side-by-side with chemically produced prints, you may notice that they aren't as clear and colorful and yet they cost more than prints. Some of these printers connect directly to cameras so you can bypass the computer altogether.

The Olympus P-300 Personal Photo printer prints 4" x 5.5", 300 dpi, photo-quality dye-sublimation prints in true 24-bit color at a rate of 1.5 minutes per print. Courtesy of Olympus.

The Fujix Pictrography Printers

The Fujix Pictrography™ 3000 printer creates silver-halide, 24 bit images with the full depth and richness of a traditional color photographic print. Joel Meyerowitz uses one of these printers.

Printing Services

When it comes to the really high-quality or unusual printer, it's unlikely that you'll want to own one due to the cost. However, there are places that offer digital printing services that you can take advantage of.

Kodak Picture Makers

In camera stores, you may have seen Kodak Picture Makers. These easy to operate, self-service printers make prints from prints, slides, negatives, photo CD discs, Digital camera memory cards, and JPEG and FlashPix-format floppy diskettes. To do this, the station has integrated drives, scanners, printers, and a display monitor. Before making a print, you can zoom and crop, use red-eye reduction, adjust color and density, and add mattes and borders. You do all of this by making simple choices displayed on a touch-sensitive screen.

The Kodak Picture Maker makes incredible prints from slides, negatives, prints, or digital files. Courtesy of Kodak.

Large Format

When you want poster-sized prints, you have to locate a large format ink-jet printer. These printers feed large sheets of paper much like a plotter and the ink-jet printing head lays down lines of ink as the paper passes through the printer. One large format printer from HP prints 2' by 3' images at 600 dpi. Generally you'll find these printers at service bureaus where they'll charge you by the size of the print.

The Tektronix Phaser 600 is a solid ink printer that can print a 34" x 44" print in 12 minutes in Standard mode and 24 minutes in Enhanced mode. Courtesy of Tektronix.

Iris Prints

Iris inkjet printers were originally developed for printing proofs in the printing industry but have been adapted to art uses. Images from these printers have a photo-realistic quality and amazing dynamic range. Using only four ink nozzles, one for each CMYK color, they can print up to 300 dpi in such a way that it visually simulates an 1800 dpi print. They do this by using an 8 x 8 cell for each pixel and an ability to vary the size of each dot placed in that matrix. And color quality isn't their only advantage, they can also print on large, thick material such as heavy artists water-color paper, polyester, cloth, and most other materials that will accept water-base inks. In some corners of the art world, Iris ink-jet prints are called "giclée" prints on the assumption that if it sounds French it sounds like art. However, the term "Giclée" means "squirt or spurt," hardly an art-like term. The first use of this printer for art prints is credited to the rock musician Graham Nash. Nash, working with printmaker Jack Duganne and a friend R. Mac Holbert formed a company called Nash Editions Ltd. in Manhattan Beach, California in 1991. Because of the use of these printers for expensive art prints, a lot of effort has gone into fade-resistant inks and UV protective layers that ensure a print's longevity. How successful these efforts have been, only time will tell.

Iris 3047HS courtesy of Scitex.

Fiery

Fiery Color Servers from Electronics for Imaging (EFI) turn standard digital color copiers into networked color printers that produces brilliant, photographic-quality images at an affordable price. You'll find these systems at many service bureaus. These systems are also used to scan photographs and images on the copier, manipulated on your desktop, then printed back via the copier that scanned them. The Fiery XJ+ Color Server has a built-in color management system that gives you control of color from screen to document. Fiery technology is also available as the XJe embedded controller. The XJe is embedded in desktop color laser printers from Canon, Digital and IBM as well as in the new Ricoh Aficio 2000 series digital color copiers.

The Fiery® ZX™ Servers drive high-speed color copiers and black and white digital presses. Courtesy of [efi](efi).

Film Recorders

Film recorders, also called film printers, are used to create slides, prints or chromes directly from your desktop.

The Polaroid ProPallete creates 35mm positives and negatives with photographic-quality. Prints with up to 8000 lines of resolution. Courtesy of Polaroid.

Papers, Inks, and Longevity

Papers and inks have affects on both the initial image quality and eventual archival quality. When images fade, memories are lost. This has been a problem throughout the history of photography. Most papers, inks, and toners have unknown archival qualities. If you have the original digital file, this is no problem. But will you be able to find it ten years from now? And if you can, will the media still be readable. No media is permanent and you may be out of luck.

To check on the archival quality of printers, you might want to visit Wilhelm Imaging Research, Inc or International Association of Fine art Digital printers. Artists care much more about longevity than commercial users because their prints are expected to last as long as possible in private and museum collections. A comparative table of print processes can be found at Wilhelm's site.

Papers

Color photographs printed on regular paper with an ink-jet printer lack density, contrast, brilliance, and sharpness. Part of this problem is due to the paper itself. Its surface is rough, dull and absorbs ink. If you look at a photographic print, you'll see that the paper is brighter, heavier, and the surface is smoother and less porous. Your ink-jet prints can get much closer to photographic print quality if you print on special photographic printing paper. These inkjet papers are specially coated, glossy, and heavier to make it look and feel very much like conventional photo paper. You can also use transparency film that has a special coating to give you bold, vibrant colors and sharp text. Your choices are amazing and have a huge affect on your results. Shop around on the Web, or visit your local computer or office supply store to see what's available.

Inks and Longevity

As with papers, there are two important points about inks: their quality and their durability. Most inks fade very quickly when exposed to direct sunlight. However, most also fade in dim light so you can't count on hanging them on the wall for years like you can traditional photographs. Inks are improving and some, like Ilfojet Archiva Ink will last 20 years before fading 25%. Some printers place a protective film over the final image to protect it from mechanical abrasion and from UV light that would otherwise fade the image over time.

Dye diffusion printing uses transparent dyes. Ink jet printers also use transparent dyes, or in some cases, transparent pigments. A dye is a colorant that is dissolved in the ink, while a pigment is a suspension of colorant particles.

The Luminos Photo Corporation carries a line of inkjet photographic papers and inks that have been designed to produce prints that will resist fading in indoor lighting. Their Lumijet Fine Art Preservation Series Media uses "an ink-receiving layer that does not impair the fade resistant characteristics" of their new Lumijet Fine Art Preservation Inks. The color Preservation Inks are available in two different sets for Epson inkjet printers.

- Preservation Platinum, is said to have a fade resistance of 65-70 years when used with the Preservation Series Media under "average display conditions."
- Preservation Silver offers an average display life of 25-30 years.

The papers, in sizes from 8.5"x11" to 17"x22", include Gallery Gloss with the look and feel of conventional glossy photographic paper; Soft Suede with a soft matte finish; Classic Velour with a velvet-like feel; Flaxen Weave that replicates the fabric used in Renaissance wall hangings; and Museum Parchment, which resembles parchment paper.

One thing you may have noticed about inks is their high price. Printer manufacturers often price their printers low and make their big money in the consumables. It's the old razor/razor blade concept. They try to increase their profits in two ways: selling all colors in a combined package and keeping you tied to their own inks. Most printers print images using CMYK, so there are four colors of inks: cyan, magenta, yellow, and black. Most printers have a separate black cartridge but combine the cyan, magenta, and yellow into a single cartridge. Rarely if ever, will all three of these colors be consumed at the same rate. For example, if you're printing construction signs, the yellow ink is used long before the cyan and magenta. However, if all colors are in a single unit, you have to replace the entire cartridge. Better printers allow you to replace just the used up color. To keep you from using less expensive inks from other manufacturers, printer companies often tell you that doing so will void your warranty. Forcing you to buy consumables only from them is called a **tie-in sales provision**. In the box below is a direct quote of what the U.S. Federal Trade Commission advises manufacturers about such provisions. (The provisions in your country may vary.) If you run into a situation where the printer company tells you you must use their inks, request from them a copy of the waiver they received from the warranty staff of the FTC's Bureau of Consumer Protection that allows them to use a "tie-in sales" prohibition.

Tie-In Sales Provisions

Generally, tie-in sales provisions are not allowed. Such a provision would require a purchaser of the warranted product to buy an item or service from a particular company to use with the warranted product in order to be eligible to receive a remedy under the warranty. The following are examples of prohibited tie-in sales provisions.

In order to keep your new Plenum Brand Vacuum Cleaner warranty in effect, you must use genuine Plenum Brand Filter Bags. Failure to have scheduled maintenance performed, at your expense, by the Great American Maintenance Company, Inc., voids this warranty.

While you cannot use a tie-in sales provision, your warranty need not cover use of replacement parts, repairs, or maintenance that is inappropriate for your product. The following is an example of a permissible provision that excludes coverage of such things.

While necessary maintenance or repairs on your AudioMundo Stereo System can be performed by any company, we recommend that you use only authorized AudioMundo dealers. Improper or incorrectly performed maintenance or repair voids this warranty.

Although tie-in sales provisions generally are not allowed, you can include such a provision in your warranty if you can demonstrate to the satisfaction of the FTC that your product will not work properly without a specified item or service. If you believe that this is the case, you should contact the warranty staff of the FTC's Bureau of Consumer Protection.

Color Management Systems

As images pass from scanners to screens, and then to printers or Web pages, the colors shift about because each device has it's own unique way of defining and displaying them. For the same reason, images edited on your screen, posted to the Web, and then viewed on your screen look different. They also look different if you print the Web page on your printer and someone on the other side of the world prints it on theirs. To try to make colors more consistent across a range of devices, color management systems are used. However, even then colors will never match perfectly for a number of reasons. Some of these include the following:

- The screen and printer use different color systems—RGB on the screen and CMYK on the page. RGB produces colors, not with pigments or inks, but by combining red, green, and blue light sources. CMYK reproduces colors by combining pigments or inks. The results are viewed in reflected light. When you print and image displayed on the screen, the RGB must be converted to CMYK and that process isn't perfect.
- Experienced photographers know that slides have more contrast and color richness than prints do. This is because slides are viewed by transmitted light and prints by reflected light. The same is true of a display monitor and printout. An image displayed by transmitted light on the monitor is going to be better than one viewed by reflected light on a piece of paper.
- Displays don't have to use halftoning to create colors because they can vary the intensity of color at each pixel. (The only printer type that can do this is the dye-sub.) Each pixel contains three phosphors—one each for red, green and blue. To display a red object, the monitor uses an electron gun to "turn on" the red phosphors in the appropriate area. Turning on all the phosphors produces white. To create shades of color, the monitor's electron gun can be controlled in eight steps for each of the three phosphors, for a total of 24 steps for each pixel.

To make your prints more closely match what you see on the screen, you can make a printout and then use it as a guide when adjusting the screen colors. However, you may now be looking at an image on the screen that you don't like. In some cases, it's hard to make the mental adjustment required to edit the "false" colors on the screen. To get serious about matching screen to print colors, you need a **color management system** (CMS). Without such a system, colors change as they move from stage to stage in the imaging process.

What's a Color Management System?

Color management systems are designed to keep the colors of your images as consistent as possible through capturing or scanning, displaying, and printing. They specify colors in terms of an objective, device-independent standard rather than in device-dependent terms such as RGB or CMYK. These color management systems include:

- Microsoft Image Color Management 2.0 (ICM) is based on Linotype-Hell's LinoColorCMM (Color Management Module) already used in Apple's ColorSync. This means color consistency is achievable in NT and mixed Windows and Mac environments.
- Kodak Digital Science Color management System.
- CIELAB (The Commission Internationale de L'Eclairage) also known as L*A*B.
- HiFi Color
- Kodak's YCC color space is based on a 1950s TV color model. It can be easily converted to other color models with varying loses of color values.
- The PANTONE® Matching System.

- PostScript Level 2 which uses the international color standard known as CIE XYZ, developed by the Commission Internationale de l' Eclairage (International Commission on Illumination).
- EfiColor™ from Electronics for Imaging, Inc. (EFI)
- ColorSync™ from Apple Computer, Inc is now supported by Microsoft's Internet Explorer 4 so color management now extends to the Web.
- ColorSense™ from Kodak.

What's a Color Model and Color Space?

As a photographer, you've seen colors change as the source of the light changes. It even changes out of doors as the sun makes it's arc across the sky. If colors change so easily, how then do we get an absolute handle on them? We do so, by measuring them under very controlled conditions and assigning numbers to them. The first such system was the CIE color system developed in the 1930s. Colors are read by colorimeters (color light meters) and plotted on a chromaticity diagram. This assignment of numbers to specific colors and plotting them on a chart is a **color model**.

What is a Color Profile?

Once a color model has been created to specify colors, only part of the job is done. That's because different systems use different models. For example, your monitor is based on a RGB color model and your color printer is based on a CMYK model. A **device color profile** is used to relate different color models such as these. Here's a simple table that shows how five basic colors can be related using tables. For example, when a red color on the screen is sent to the printer as the series of numbers 255,0,0; the printer uses the profile to see that it should assign the color 0, 100, 100,0.

	RGB Color Model			CMYK Color Model			
Color	R	G	B	C	M	Y	K
Red	255	0	0	0	100	100	0
Green	0	255	0	100	0	100	0
Blue	0	0	255	100	100	0	0
Black	0	0	0	0	0	0	100
White	255	255	255	0	0	0	0

Evaluating Your Prints

The first step in evaluating a print is to examine it carefully. Ideally, the brightness and color of the light should be the same as that under which the picture will finally be viewed. This is seldom completely practical, but you should at least be aware that viewing conditions affect the way a picture looks.

When viewing your prints, you can use either window or electric light as long as it's bright enough to see details clearly. Avoid very dim light, not only will the print be hard to examine but it will appear darker than when you show it under average illumination. Very bright light is good for examining fine details, but don't use it to evaluate overall lightness or darkness because the print will appear lighter than it will under average conditions.

A color print viewed in daylight will appear slightly bluer than the same print viewed in tungsten light, such as a household bulb. For viewing color prints, use Deluxe Cool White tubes or a mixture of one 75-watt frosted tungsten bulb with two 40-watt Deluxe Cool White tubes.

When checking for details, you may want to use a loupe or magnifying glass.

A Short Course in Digital Photography

7. Photography on the Web

CONTENTS

Very few photographers put their photos in a box and slide it under the bed. Most of us want to share them with others. Until recently, only a lucky few were able to show images to a circle much bigger than friends and family. However, for good or bad, we can now share them with the world. There are a number of ways to do so. You can "broadcast" them to a large audience by placing them on the web where anyone can see them, or you can "narrow cast" them to specific individuals. For example;

- You can post them on your own Web site
- You can post them on one of the picture networks and leave them open to the public or protect them with a password
- You can send them as post cards
- You can send them by-email

Each of these methods has its own attractions and they really don't overlap a lot. It's possible you may use one or all of them at different times, depending on what you're trying to accomplish. Lets take a look at each of them in more detail.

Photographic Information on the Web

Until the development of the Web, photographer's only sources of information where magazines and courses. However, things have changed dramatically and the Web probably now offers more new information than all other media combined. You can chat with photographers, view their work, read technical information from manufacturers, and even buy equipment.

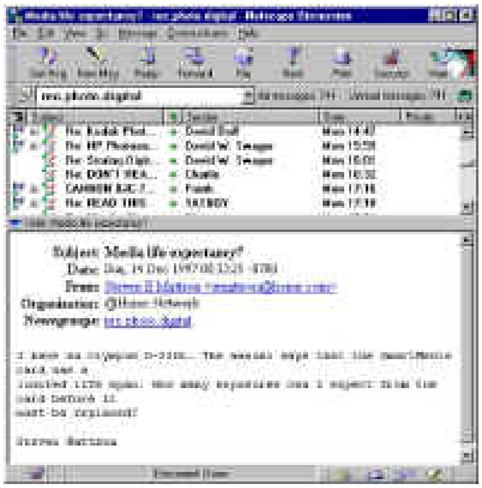
Internet Photography News Groups

Usenet (Users Network) is a collection of thousands of ongoing topical discussions called **newsgroups**. Each newsgroup covers a specific topic such as alternative living or zoology. Also known as bulletin boards or discussion groups, newsgroups are used by people to share common interests. Usenet is not a part of the Internet, or even a network of any kind. It is system for carrying on discussions that can be delivered in a number of ways, the Internet being just one of them. A complete listing of photography related news groups can be found on the Greek Photo Web. You can also search for news groups on Deja News. Here's a link to Deja News just click the **Find** button to see what messages have been posted on the topics entered in the text box or enter your own search terms and then click **Find**.

Search Discussion Groups For:

photography | Find

Newsgroups are like ever changing bulletin boards where you can post messages, called articles, for everyone else to read. They can then respond to your messages with a public posting of their own or by private e-mail. Some news groups are moderated so a person reads each message before it is made available to others. To read the groups that interest you, you use a newsreader program or your Web browser.



News groups displayed in a Web browser.

All news groups are organized into seven categories, each with its own name. There are also other newsgroup categories that are not technically a part of Usenet but are available on some systems. One of the more controversial such group is alt, a news category for alternative subjects and lifestyles. This news group category is not carried on all systems.

Usenet Newsgroup Categories	
Name	**Description**
comp	computer subjects
sci	scientific subjects
soc	social and cultural issues
rec	recreational topics such as hobbies, music, art, and sports

talk	current events, debates, controversial issues
news	newsgroup topics dealing with the Usenet system
misc	other topics

Newsgroups within these categories often have multipart names, listed in increasingly narrower order from left to right and separated by periods. For example, rec.music.folk is one of many groups in recreation and folk is one of many groups in music.

Flame wars

When someone says something insulting to others or is misunderstood on Internet, other people get angry and begin to send in heated responses. In a very short time charges and insinuations are flying fast and furiously back and forth. These colorful exchanges are referred to as flame wars. If you're at the receiving end, you've been flamed. In other cases, people use ALL CAPS to show that they are shouting at you. Keep your eyes open, you may be spammed! As you get more involved with the Internet, you may find yourself the recipient of a mass-mailing called a spam. They are called spams because they reminded some wit of a routine in Monty Python's Flying Circus that goes: "Well there's egg and bacon; egg, sausage and bacon; egg and spam; bacon and spam; egg, bacon, sausage and spam; spam, bacon, sausage and spam; spam, egg, spam, spam, bacon and spam; spam, spam, spam, egg and spam; spam, spam, spam, spam, spam, spam, baked beans, spam, spam, spam and spam; or lobster thermidor aux crevettes with a mornay sauce garnished with truffle pate', brandy and a fried egg on top of spam." The spammer gets a list of the names of people using Usenet newsgroups and then sends the same message to everyone on those lists. People on the Internet are not happy about these mailings. There is always a temptation to return such a message to where it came from in the hopes that if everyone does the same thing you'll flood their system. Unfortunately this usually does no good because spammer are hit and run artists. All you'll do is cause harm to another innocent party who was used by the spammer.

Mailing lists

Mailing Lists use e-mail to keep groups informed on topics or events such as when a particular Web site has been updated. A mailing list is managed by a program called a **listserver**, the most popular being Majordomo, Listproc, and Listserv. A good place to locate mailing lists is Liszt, the mailing list directory.

While some mailing lists accept mail from anyone, most are set up to only accept mail from subscribers. There are also moderated lists and mail can be obtained in digest form or individual messages. Some make their list of members available, others do not. Each list has two addresses:

- One address is used for administration and commands. Its e-mail address is the one you use to subscribe and unsubscribe to the list. Generally you mail to this address with a specific message on the e-mail's subject line or in the body. Generally, a message with the word HELP sent to this address will return a list of commands you can use.
- Another address is the one you use to mail to every other subscriber.

People who get these two addresses confused are not well liked. If you send a command such as **UNSUBSCRIBE *LISTNAME*** to the wrong list and it's mailed to a thousand people, imagine the flames in your inbox the next time you check your e-mail (actually most people are forgiving). When you subscribe to a mailing list, don't be surprised to find lots of e-mail every day. Some lists may forward fifty or more such e-mails. If you leave on vacation without first unsubscribing, you could have hundreds of e-mails when you return. There are many variations in the way to subscribe (signon) to and unsubscribe (signoff) from mailing lists. Read the list's instructions carefully and be sure to save the address you used to sign on. You'll want it later when you sign off. There is a great deal of variation in the way these lists work, so be sure to read the instructions carefully and print them out so you have them later.

- Some listservers "object" to anything being written on the **Subject** line but these are in the vast minority these days. And that is a good thing because some e-mail programs will not send outgoing mail with the **Subject** line blank. For these lists, enter anything you want—just remember, what's on the line is ignored.
- Some listservers or other mail-distribution schemes use the **Subject** line to subscribe and unsubscribe you. In most cases, including a subscribe request both on the subject line and the first line of the message body is generally OK.
- To subscribe, enter **SUBSCRIBE** in the body, or on the **Subject** line. Some listservers require a real name after **SUBSCRIBE**, others need the name of the list (**SUBSCRIBE listname**), or your e-mail address (**SUBSCRIBE your e-mail address**). Those that require a real name typically can't identify a real name from an e-mail address or a fictitious name—they just want something.
- To unsubscribe, most listservers require just **SIGNOFF listname**. Adding a name or an e-mail address may even prevent the request from being processed. You may have to send your signoff request from the same address used to sign on. If your e-mail address has changed the server may refuse to signoff.
- If your e-mail automatically adds a signature file at the end of your messages, this can cause you problems when subscribing and unsubscribing. To be safe, you should delete it before sending a signon or signoff request.

The table below describes some of the mailing lists that apply to digital photography. To help you, it lists the procedure you use to subscribe and unsubscribe. To locate other mailing lists, check out RIT and the Greek Photo Web.

Mailing List Name	To Subscribe (signon)	To Unsubscribe (signoff)	To Send E-mail to the Entire List
RIT PhotoForum is a mailing list devoted to photography and imaging educators, professionals and students everywhere	E-mail to to listserv@rit.edu with the words **Subscribe PhotoForum** in the body of the message	E-mail to to listserv@rit.edu with the words **Unsubscribe PhotoForum** in the body of the message.	E-mail to photoforum@listserver.isc.rit.edu
Ansel Adams provides a forum for discussing the life and work of Ansel Adams. There are also periodic announcements about exhibitions, publications and reviews.	E-mail to ansel-l@comp.book.uci.edu with the word **SUBSCRIBE** on the subject line.	E-mail to ansel-l@comp.book.uci.edu with the word **UNSUBSCRIBE** on the subject line.	

Panorama mailing list.	E-mail (WITH NO SUBJECT) to mailserv@cc.monash.edu.au with **subscribe panorama-L YOUR EMAIL ADDRESS** in the body of the message.	E-mail (WITH NO SUBJECT) to mailserv@cc.monash.edu.au with **unsubscribe panorama-L YOUR EMAIL ADDRESS** in the body of the message.	
Digicam is for general discussion of the purchase and use of digital cameras.	E-mail to majordomo@leben.com with **subscribe digicam** in the message. No subject is required.	E-mail to majordomo@leben.com with **unsubscribe digicam** in the message. No subject is required.	E-mail to digicam@leben.com.
Epson-Inkjet is about Epson Inkjet printers.	E-mail to majordomo@leben.com with **subscribe epson-inkjet** in the message.	E-mail to majordomo@leben.com with **unsubscribe epson-inkjet** in the message. No subject is required.	E-mail to epson-inkjet@leben.com.
Scan is for discussions about film and print scanners	E-mail to majordomo@leben.com with **subscribe scan** in the message.	E-mail to **majordomo@leben.com** with **unsubscribe scan** in the message. No subject is required.	E-mail to **scan@leben.com**.
Hyperzine	E-mail to listserver@hyperzine.com with **subscribe hyperznews** in body.	E-mail to listserver@hyperzine.com with **unsubscribe hyperznews** in body.	
3D is for people interested in 3-D (stereo) photography.	E-mail to 3D-REQUEST@LBL.GOV with **SUBSCRIBE 3D** in the body.	E-mail to 3D-REQUEST@LBL.GOV with **UNSUBSCRIBE 3D** in the body.	

Forums and Discussion Groups

Similar to Newsgroups, forums or discussion groups are generally offered on various Web sites and deal mainly with topics related to the site manager's interests. You can read posts by other users or post you own questions or comments.

- HindSight Forums are sponsored by a company that publishes image management software for the Macintosh.
- Kodak Discussion Forums where you can discuss digital photography and Kodak products and services with other customers.
- ACE Photographic and Imaging Forum. Feel free to post questions about photographic and digital imaging technique and equipment. Answer or share your thoughts about any of the postings made by others.

Photography Web Sites

There are thousands of Web sites dealing with photography. They include photographers, galleries, museums, and companies. Since the list is ever changing and always expanding, the best approach is to use a search engine such as Yahoo or Alta Vista to find what you want.

- ALL-IN-ONE Search Page is a compilation of various forms-based search tools found on the Internet.
- Alta Vista is one of the most powerful search engines.
- HotBot is one of the latest and greatest.
- Yahoo is one of the first Web directories and search engines.
- Excite lets you search for both Web sites and Usenet newsgroups via plain text or keyword methods. Its NetReviews offers brief reviews of Web sites organized by subject.
- InfoSeek has both a free and a paid-for search capability. Its free service includes both Web sites and newsgroups, but it will list only ten matches for each search.
- Lycos developed by Carnegie-Mellon University is one of the older and more powerful search engines. It also includes a list of the Web's 250 most popular sites.
- Magellan Internet Directory offers both ratings and detailed reviews for the Web sites it covers.
- Open Text index.
- PC Photoforum (http://www.pcphotoforum.com/index.shtml)
- The Guide to Searching the Net is the novice's guide as well as the expert's resource to searching the Web. Use it initially to become acquainted with the search resources which are on the Web, and then later as a starting page for your Internet searches.
- The World Wide Web Worm.
- WebCrawler provides Web statistics and a description of the Web robot technology it uses to index sites.

Chat Rooms

Chat sessions on the Web are a form of CB where people type messages back and forth in real time. Kodak offers an on-line chat session called PhotoChat. PhotoChat is different from most chat sessions because it allows you to include photographs. You can use these sessions to ask questions and exchange images. Transcripts of previous sessions are stored in an on-line archive so you can access them. They also use the service to offer "Show-And-Tell," a weekly PhotoChat session featuring a guest expert. To use PhotoChat, your browser must be Java compatible (most are). Another chat room is available on this site.

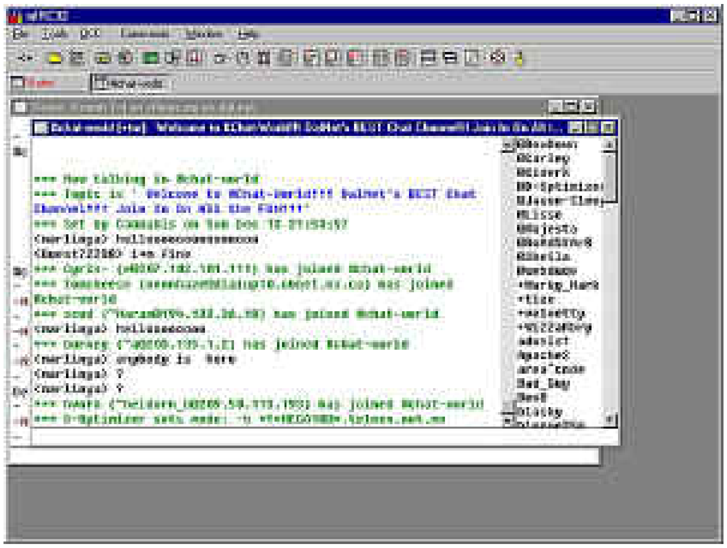
Kodak's PhotoChat lets you chat and exchange images with other photographers in real-time.

Internet relay Chat (IRC)

IRC is a very popular way to chat with other users in real time. In IRC, the chat "rooms" are called "channels" and there can be any number of people on a channel at any one time. Since so many discussions can be interleaved, this isn’t for everyone. It's like an Internet CB radio.

To chat, you first need to download and install chat client software. One of the most popular Windows chat clients is mIRC.

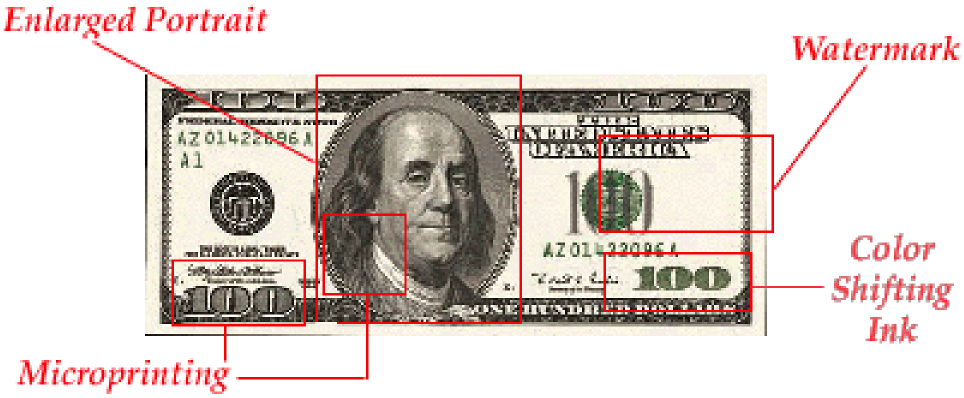
Once the IRC software is installed, you then need to find a channel that’s discussing something in which you are interested. A great place to look for IRC channels is Liszt. If you have installed a chat client and then click on a channel name on Liszt's directory, your client is loaded automatically. If you've never doine IRC before, Liszt is also a great place to look to see if there are any channels that interest you.



When connected to an IRC channel, the messages each person sends are listed in the order in which they are received.

Protecting Your Work

Watermarks were first used in Europe to identify the guild that manufactured paper. They were like trademarks or signatures. Watermarks in paper are created by varying the paper's density. Normally invisible, a watermark image becomes visible as darker and lighter areas when the paper is held up to the light. Wire or relief sculptures are placed in the paper mold and when the paper slurry is drained of its water and dried the thinner areas created by the wire or sculpture show clearly when held up to the light. Watermarks are still used in quality stationary and have even been added to U.S. currency.



Watermark on new $100 bill shows Benjamin Franklin when you hold the bill up to the light.

Digital watermarks for photographs work differently then those used for paper. There are two basic kinds: visible and invisible.

Visible watermarks

A visible watermark is a translucent image overlaid on the primary image. The watermark doesn't totally obscure the primary image, but it does identify the owner and prevents the image from being used without that identification attached.

Invisible watermarks

An invisible watermark is embedded in an image and although it isn't visible, it can be displayed with the appropriate software. There are two basic types of invisible watermarks:

- A watermark can prove an image's authenticity if manipulating the image destroys the watermark. An intact watermark is proof that the image hasn't been altered or tampered with. Journalists and courts are among those interested in ensuring images haven't been doctored.
- A watermark that resists destruction can establish an image's ownership. For example, images posted on the Web can't be copied and used undetected.

Invisible watermarks, such as those developed by Digimarc, are hidden in the image and can survive image cropping and file format changes. They are almost indestructible. However, with a reader, you can display them and learn who created the photograph and how to get in touch with them. This is like free advertising. If someone sees your image, and wants to contact you about reusing it, they can easily do so.

However that's not all. If someone takes one of your images and posts them on the Web, a search engine designed to look for watermarks can locate the images. This way, people can't use your images without your permission.

Copyright Issues

In most countries around the world, it is recognized that writers, artists, programmers, sculptors, and entertainers have a right to their own work. Generally these rights are protected by copyright laws. For example, in the United States, they are protected in the U.S. Constitution (Article I, Section 8) where it grants the right to copyright works so as "To promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

Copyrights and plagiarism

When you find things in places like the Web that are interesting, there is a tendency to want to print them out or save them on your disk. In most, but not all cases, this is perfectly legal and ethical. Problems begin to arise however, when you decide to incorporate some of the text or photographs in one of your own reports, presentation, or Web sites. Now you are using the materials for other than your own personal use. This raises two big questions: copyright infringement and plagiarism. Almost any material that you find in print or electronic form is copyrighted—the rights to use it belong solely to the owner of that copyright. However, even uncopyrighted materials are protected. Using the material without written permission violates the owner's rights and subjects you and your school or organization to penalties and embarrassment. In addition, even when materials are not copyrighted or even if you have written permission to use them, you could be guilty of plagiarism—the representation of someone else's work as your own. Let's look at an example. The paragraphs in the following section "What are copyrights?" are adapted directly from the U.S. Library of Congress' page on the Web. Including this material in this text without written permission is OK in this case because many (but not all) government materials fall into what is called the public domain. The author also avoids a charge of plagiarism because he credits the source of the text and does not claim it to be his own.

What are copyrights?

Copyright is a form of protection provided by the laws of the United States (title 17, U.S. Code) to the authors of "original works of authorship" including literary, dramatic, musical, artistic, and certain other intellectual works. This protection is available to both published and unpublished works. Section 106 of the Copyright Act generally gives the owner of copyright the exclusive right to do and to authorize others to do the following:

- To reproduce the copyrighted work in copies or phonorecords;
- To prepare derivative works based upon the copyrighted work;
- To distribute copies or phonorecords of the copyrighted work to the public by sale or other transfer of ownership, or by rental, lease, or lending;

- To perform the copyrighted work publicly, in the case of literary, musical, dramatic, and choreographic works, pantomimes, and motion pictures and other audiovisual works; and
- To display the copyrighted work publicly, in the case of literary, musical, dramatic, and choreographic works, pantomimes, and pictorial, graphic, or sculptural works, including the individual images of a motion picture or other audiovisual work.

It is illegal for anyone to violate any of the rights provided by the Act to the owner of copyright. These rights, however, are not unlimited in scope. In some cases, these limitations are specified exemptions from copyright liability. One major limitation is the doctrine of "fair use."

The U.S. Copyright Office. The one in your country may be different.

What is fair use?

Is copying that article from a Web magazine or newspaper into an e-mail message to a friend fair use? Nope, you're infringing the owners copyright. Basically, the copyright law says "...the fair use of a copyrighted work, including such use by reproduction for purposes such as criticism, comment, news reporting, teaching (including multiple copies for classroom use), scholarship, or research, is not an infringement of copyright." Even for these uses, whether a specific use is fair or not depends on a number of factors.

1. The purpose and character of the use, including whether such use is of a commercial nature or is for nonprofit educational purposes.

2. The nature of the copyrighted work.

3. The amount and substantiality of the portion used in relation to the copyrighted work as a whole.

4. The effect of the use upon the potential market for or value of the copyrighted work.

Fair Use

- criticism
- comment
- news stories
- teaching
- scholarship
- research

What is public domain?

When something is in the public domain, you're free to use it any way you see fit. However, you are still expected to credit the source and not claim it as your own. How do you know if something is in the public domain? Partly it is common sense. Recent ads, logos, cartoon characters, illustrations, or photographs are almost certainly not in the public domain. However, 18th-century photographs and illustrations most likely are. In that gray area from 1900 through 1970 or so, some things remain protected while others don't. What is protected and what isn't depends on what type of property it is and when it was first copyrighted. If you have questions, you have to search the records of the U.S. Copyright Office yourself, or hire a qualified researcher (or the Copyright Office itself), to do the search for you. Even then, the Copyright Office states "Copyright searches cannot be considered conclusive... but at least will show a good faith effort. The responsibility of determining whether to use an item or not rests with you." Just to muddy the waters for you, even though something hasn't been registered with the Copyright Office doesn't mean it isn't protected by what's called a common law copyright. Two good sources of copyright information and Kodak's and the United States Copyright Office.

Work Created	Copyright Terms
Works Originally Created On or After January 1, 1978	Automatically protected from the moment of its creation for a term enduring for the author's life, plus an additional 50 years after the author's death. For works made for hire, and for anonymous and pseudonymous works (unless the author's identity is revealed in Copyright Office records), the duration of copyright will be 75 years from publication or 100 years from creation, whichever is shorter.
Works Originally Created Before January 1, 1978, But Not Published or Registered by That Date	The duration of copyright in these works will generally be computed in the same way as for works created on or after January 1, 1978: the life-plus-50 or 75/100-year terms will apply to them as well. The law provides that in no case will the term of copyright for works in this category expire before December 31, 2002, and for works published on or before December 31, 2002, the term of copyright will not expire before December 31, 2027.
Works Originally Created and Published or Registered Before January 1, 1978	Under the law in effect before 1978, copyright was secured either on the date a work was published or on the date of registration if the work was registered in unpublished form. In either case, the copyright endured for a first term of 28 years from the date it was secured. During the last (28th) year of the first term, the copyright was eligible for renewal. The current copyright law has extended the renewal term from 28 to 47 years for copyrights that were subsisting on January 1, 1978, making these works eligible for a total term of protection of 75 years.

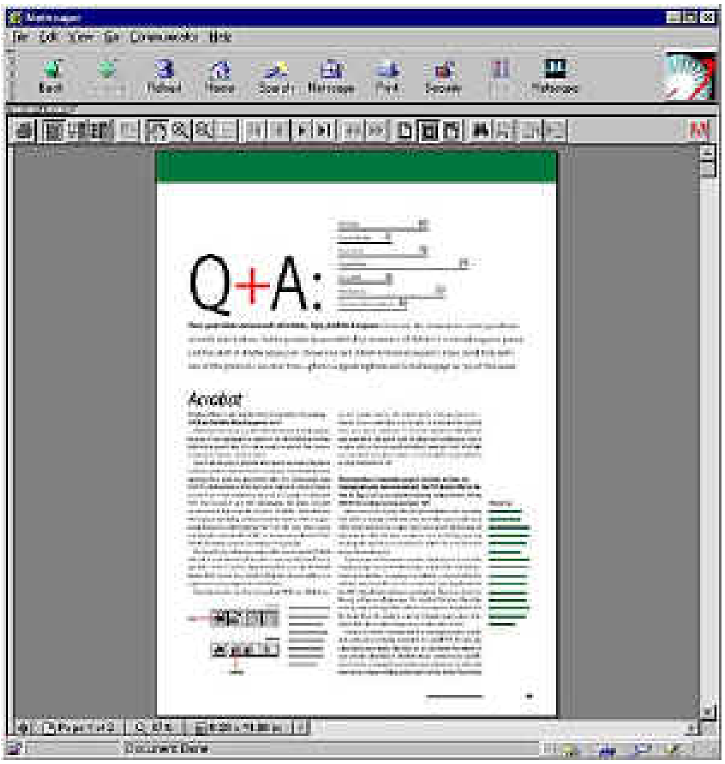
Preparing Images for the Web

When creating images for the Web, the most important thing is to keep the images small; maybe 20 Kilobytes or so. If one takes longer than a few seconds to load, the viewer has probably moved on. Here are some other things to consider that either improve the image or make it smaller.

- When editing an image, use the highest possible resolution and color depth. Be sure to save this file in the program's native format or a format such as BMP or TIF that uses lossless compression.

- Use your program's unsharp filter to sharpen the edges in the image and remove blurring that derived from the original photograph or scanning process. This filter identifies any adjacent pixels that have a specified difference in brightness and increases the contrast between these pixels by a specified amount.
- Reduce the image's resolution to 72 dpi and then resize it for screen display. The most common display today runs in 800 x 600 mode but some run higher and some run lower. The best compromise is a horizontal image about 600 pixels wide or a vertical image with between 400 and 500 pixels vertically.
- Save the image in the JPEG format with a low or medium quality level.

When you want to publish photographs and text on the Web and retain high quality formatting, you have to move beyond HTML. The most popular format now is Adobe's PDF (Portable Document Format). With the Adobe Acrobat authoring system, you create the document in a program such as Word, QuarkXPress, or PageMaker and then use a menu command to save it as an Adobe PDF file. Any user with an Adobe Acrobat plug-in for their browser can then open the document of their system and it looks exactly like the original.



With the Adobe Acrobat browser plug-in installed, you can view richly formatted PDF files.

A Short Course in Digital Photography

8. Panoramic & Object Photography

CONTENTS

Most images on the Web are static, they just sit there like a picture hung on a digital wall. However, there are other photographs that you can pan and rotate. These images are products of immersive imaging techniques. There are two basic types; panoramas and objects.

Most photographs, even those taken with a wide-angle lens, show just a sliver of the overall scene. To take in the entire scene you have to spin around in a 360-degree circle, looking from a single point in space out to a surrounding environment. There are some cameras that will do just that. Others just take in slices that are wider than normal lenses without capturing the entire 360-degrees. Both types of cameras are expensive and there are now much less expensive digital ways to combine a series of photos into a seamless panorama.

There are a number of basic techniques used to capture panoramic images. The most popular include the following:

- Panoramas can be pieced together from a series of separate images. Once the images were mounted side-by-side on a cardboard backing. Now they are often digitally combined using stitching programs that seamlessly piece together a series of frames in panoramas covering 360 degrees or more.
- Cameras with a fixed lens and film take images just like a normal camera but on panoramic shaped frames of film. The 6x17 format is the most common way to do these professionally
- Swing lens cameras take images by swinging the lens during the exposure and painting an image on the film. These images cover less than 180 degrees of the scene.
- Rotational panorama cameras revolve on the tripod while the film moves in the opposite direction in the camera. These cameras can capture over 360 degrees.
- Strip scan panoramas, like those used to capture horses at the finish line paint the image of moving objects onto a piece of film moving at the same speed.

Early Panoramic Photographs

The first panoramas, taken in the 1840s, were made by taking a series of daguerreotype images that could then be framed or hung side-by-side. The same approach was later used with tintypes and paper prints.

An early panorama of Chicago before the fire. Courtesy of the Library of Congress.

By the late twentieth century, motorized cameras were being made specifically for panoramic photography. In one type, the lens swung while the film remained stationary. In another type, the camera rotated on a special tripod to "paint" the image on a moving sheet of film. One of the most famous of such cameras, the Kodak Cirkut camera was patented in 1904. It used large format film, ranging in width from 5" to 16" could produce 360-degree photographs measuring up to 20 feet long.

An old Cirkut camera on its special tripod.

These cameras were frequently used to photograph groups, especially school classes. If you look closely at some of these photos, you'll see the same person appear twice, usually at the far left and far right ends of the picture. As the camera swings by the left end of the scene, someone can run quickly to the other end and freeze. They'll appear in both places. In the business, this is called a "pizza run."

Specialized Panoramic Cameras

There are a number of specialized panoramic cameras. You don't need these to produce panoramas because you can use a normal camera as you'll soon see. However, if you have money to burn, these specialized panoramic cameras create wonderful panoramas for both prints and on-screen uses. Some of these cameras take extremely wide-angle views and others capture a full 360-degree image. One thing to think about when considering film panoramic cameras is the size of their negatives. In most cases the image spans more than a single normal frame. This means that you need special film scanners to digitize the image. These services are both rare and expensive.

Digital Panoramic Cameras

Digital panoramic cameras are still few and far between. The only one I've been able to find is the INNOTECH HT.The site describing this product is in German so if you don't speak that language go to the AltaVista Translation Service and enter the URL (http://www.innotech-ht.com/sasmetri.htm) into the text box. Then select the translation you want, for example, German to English.

Point and Shoot Panoramic Cameras

Point-and-shoot 35mm panoramic cameras, including the latest APS cameras in panoramic mode, just mask out the top and bottom of the ordinary 35mm frame, leaving a long thin image in the middle of the frame. This doesn't change the horizontal angle of view, it just crops out the top and bottom of the image to give a panoramic "look"—kind of a faux panorama.

Kodak MAX panoramic one-time use cameras are an inexpensive way to experiment with panoramic photos. Courtesy of Kodak.

A slide from a point and shoot camera shows the unused bands above and below the "panoramic" image.

When the negative is printed, only the image band is used so it looks like a long narrow panorama.

Super Wide-angle Cameras

Specially designed cameras with super wide-angle lenses can capture wide slices of a scene but no more than 180-degrees. There are many models of these cameras including the Hasselblad Xpan, Linhof Technorama 617 (115º) and the Fugifilm Panorama GX617.

The Hasselblad XPan provides both a panoramic 24x65 mm format and the conventional 24x36 mm on the same 35 mm film. It's the first and only dual-format camera that expands the format instead of masking it, ensuring that every exposure utilizes the full area of the film. In addition, the 65 mm width of the full panorama images is similar to the medium format,ensuring that the Hasselblad XPan will always give you superb image quality. Courtesy of Hasselblad.

The Linhof Technorama 617 camera has a permanently mounted super wide-angle Schneider Super Angulon 90mm lens, an image circle of 235mm, and a lens protection bracket. ©1997 by B&H Photo-Video. Used by permission.

The Fuji GX617 has four interchangeable panorama lenses. A solid shock protector guards the lenses for extra safety in even the most difficult photographic situations. ©1997 by B&H Photo-Video. Used by permission.

VPanMed.JPG (21399 bytes)

The V-Pan 6x17 panoramic view camera is manufactured by Chet Hanchett of St. Louis, MO. It uses 120 film, giving four images per roll. Like other view cameras, you focus on a ground glass and can switch lenses. It also gives tilts, swings, and shifts typical of a monorail view camera. Courtesy of Panoramics NorthWest, Inc.

Swing-lens Cameras

Swing-lens cameras use a lens that rotates from one side of the scene to the other during an exposure. As it does so, light focused through a slit sweeps along the film and "paints" an image. Since the film plane is curved the image doesn't show any distortion. Lines that are straight in the real world are straight in the image One big advantage of this type of camera is that the lens isn't expensive. It only has to cover the vertical dimension of the film and the width of the slit. Cameras of this type include those by Noblex and Widelux (no longer made).

The Noblex 135-S Standard is a 35mm camera that takes a 136-degree view.©1997 by B&H Photo-Video. Used by permission.

Rotating Cameras

Rotating cameras can capture a 360-degree image by revolving in one direction while the film moves in the other so it's synchronized with the lens motion. As in a swing-lens camera, light focused through a narrow slit paints an image on the film. Cameras in this category include the SpinShot. Hulcher, and those made by Roundshot and Globuscope.

The Spin Shot 35 S captures an entire 360 degree scene. As the Spin Shot 35 S rotates, it automatically pulls the film across the shutter's narrow (1.5mm) slit. This makes a continuous image on about seven inches of standard 35mm film (360 degrees). The image is not confined to 360 degrees or less. As long as the camera scans, an image is made. ©1997 by B&H Photo-Video. Used by permission.

With the Hulcherama and a 35mm lens, a full 360 degree picture can be exposed on a 9 inch segment of film, three of which can be obtained on one roll of 120 film. The Hulcherama can be set up on the tripod and rotated automatically for a 360 degree picture, or it can be operated manually for shorter rotations. (It is started by pressing a remote-type switch mounted in the stationary base of the camera.) Film progression within the camera is synchronized with camera movement and the film is exposed through an adjustable slit, which is controlled from outside the camera. Image courtesy of [Charles Hulcher Co. inc.](#)

The Globuscope courtesy of Everen T. Brown Advertising.

These sample images were scanned into the computer from contact prints. The actual images are of photographic quality since they are made from the actual negatives. Click to enlarge the image. Courtesy of photographer Everen T. Brown.

David Grenewetzki takes digital photos from rockets and remote control airplanes. To take panoramas with a remote control and a Kodak DC20 camera he designed and built this device that repeatedly turns the camera 45 degrees and takes a photo until eight pictures have been taken to cover a full 360 degrees. He uses a Tiffen wide-angle lens to increase the DC20's field-of-view so that I get full coverage with eight shots. He'll even sell you a kit to build your own. Courtesy of David Grenewetzki.

One-Shot Panoramic Camera

Be Here's Portal S1 panoramic lens system uses a standard 35-mm camera body mounted facing straight up and shooting through a hole in a parabolic dish. The surrounding 360 degrees image is reflected off the top of the parabolic dish, then bounced off a small mirror that focuses it down into the camera lens. When taking a photo, you have to stand under the dish to stay out of the field of view. (In 1998 a digital video camera will be introduced so it can be used in place of the 35-mm camera.)

The Be Here lens system captures and entire 360-degree panorama in a single shot. Image courtesy of Be Here.

Once captured on film, the image must be scanned and then processed with Be Here's proprietary panoramic software. This software flattens the donut shaped image, and performs other processing such as evening out the lighting, correcting brightness and contrast, and sharpening the edges slightly. You then save the image in one of the popular panoramic formats such as QuickTime VR.

Two-Shot Panoramic Camera

IPIX images are amazing sphere-like images that include every horizontal and vertical aspect of a scene. To create the images, you take two back-to-back photographs using an 8mm lens and a special IPIX tripod mount—called an IPIX rotator. You then use IPIX software to stitch the two images into a seamless 360-degree sphere. In addition to viewing these images with a browser and the IPIX plug-in, you can also use a separate viewer.

IMAGE NEEDED

IPIX image (http://www.ipix.com/index.html).

Don't expect to try this package at home—it's for serious professionals. In addition to buying the tripod rotator you also pay a fee for each panorama you make with IPIX software (think of it as royalties.) The software has a counter that keeps track of the number you've made—called "clicks." When you exceed the limit you purchase more "clicks" with prices starting at $100 per image and falling depending on the number you buy.

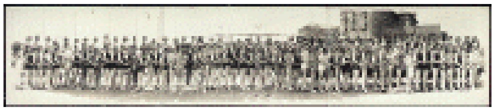
Pin-hole Panoramics

Surprisingly, lenses are not actually needed to take a picture. You can make a camera out of a shoe box with a small hole in one end. Known as a **pinhole camera**, this primitive device can actually focus an image and record it on film. To make a photograph, the box is loaded in the dark with a light-sensitive film or paper and the pinhole is covered with opaque tape. Peeling the tape back (much like a shutter) to uncover the pinhole (much like a lens aperture) begins the exposure, recovering the pinhole ends it. The exposed film or paper can be removed in a darkroom and the image developed.

The Pinoramic 120 camera is made of cherry and brass and incorporates a pneumatically operated shutter (that's what the bulb is for). Standard 120 film produces 6 exposures approximately 4.75 inches across. The pinhole is 60 mm effective length and f/200 aperture. The film is wrapped around a curved film plane at the back of the camera. This allows 120 degrees of lateral coverage with no exposure falloff across the image. Courtesy of Mottweiler Design

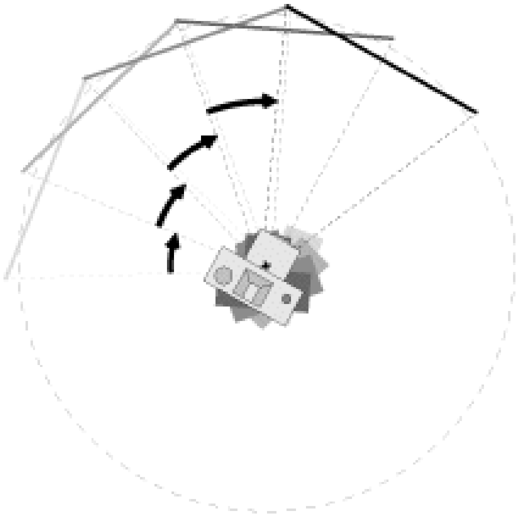
Panoramas with Regular Cameras

Although panoramic photographs have been taken in sections and pasted together for years, it was the development of computer software that made seem-less panoramas possible with a regular camera.



Long Beach, California, Bathing Beauty Parade, 1927. Courtesy of the Library of Congress.

To create a seamless panorama with a regular film or digital camera, you begin by capturing a series of images around a single point of rotation, the optical center of the lens. Later, you stitch these views together with software.



Individual, but overlapping pictures are captured around a point of rotation. Image courtesy of Apple.

Hardware and Techniques

There are a few important ingredients in getting good panoramic images.

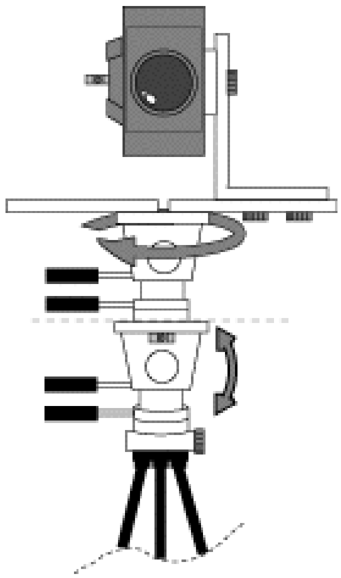
- You can use almost any kind of camera but you may have to be careful with the choice of lens.
- Wide angle lenses require fewer pictures to cover the same view but make things appear smaller and more distant.
- Rectilinear lens—those that make straight lines in the scene appear as straight lines in the image are required by may stitching programs. Most lenses are rectilinear, but "fish eye" type lenses aren't.
- The camera must be absolutely level as you rotate it.

- The images must be taken at specific increments and overlap by just the right amount; 25% on each side.

Leveling the Camera

The camera must be as level as possible as you rotate it in a circle so the photographs will line up when they are later stitched together. Some tripods have twin-axis bubble levels to guide you, but you can also use a small handheld level.

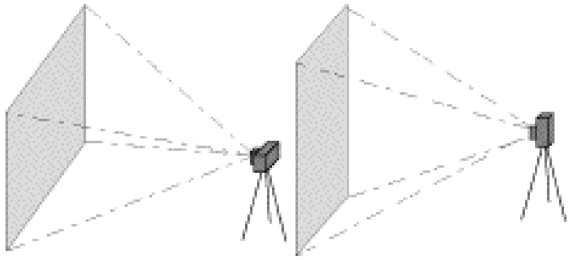
One of the problems with leveling a tripod is that the place where you mount the camera and the join where the head rotates aren't necessarily aligned. This means that you can level the mounting area and it will become out of level as you rotate the head. You need to take some time to get it right. If you are a perfectionist, you can use two pan/tilt heads mounted together. You adjust the lower head to provide a level or tilted surface, and the upper head to rotate the camera.



Camera setup with two tripod heads. Image courtesy of Apple.

Orientation

The camera's orientation depends on the scene that you are capturing. For most scenes the camera is mounted horizontally in landscape mode. This is easier to do and also requires fewer images to cover a scene. However, some scenes have vertical elements that require you to mount the camera vertically in portrait mode. This mode also gives you more ability to pan the image if you convert it to QuickTime VR or similar format.



Landscape orientation. Image courtesy of [Apple](#). *Portrait Orientation Image courtesy of [Apple](#).*

To shoot with the camera in a vertical position, you'll need a bracket that keeps the axis of rotation centered on the optical center of the lens as you rotate it. These brackets hold the camera vertically and allow you to side it sideways to position the lens over the center of the tripod.

The Peace River 3Sixty is an indexing panoramic mount compatible with most standard 35 mm SLR film and digital still cameras using a rectilinear wide angle lens for overlapping coverage of 360 degree scenes. It allows you to shift between increments of 12 & 18 and allows the camera to rotate more easily in one direction than the other to reduce the possibility of shooting images out of sequence. Image courtesy of Peace River Studios.

Incrementing the Images

When you take a series of images, you nave to be sure they cover the entire 360-degrees and overlap by 50%. You can guess-timate this but it helps to have a tripod head designed for the task. Some come with degree marks to guide you, but better ones come with detents so the camera snaps into place at the exact position.

The Kaidan Landscape Bracket (QPLB-1) uses detent discs with click-stops to let you easily rotate the camera the correct increments. Image courtesy of Kaidan.

A wide angle lens will let you see a larger vertical field of view; however, it also gives the impression of "pushing" objects in the view farther away. The number of images you have to take depends on the focal length and angle of view of your lens.   It also depends on the camera's orientation since you'll need more if the camera is mounted vertically.

To calculate your lens's angle of view, use the following formula:

2*arctan(X/(2*f*(M+1)))

- X= width, height, or diagonal of the film.
- f=focal length of the lens
- M=0 for a distant object

For example a 35mm frame is 24x36 mm, so with a 50 mm lens and a distant object (i.e. M virtually zero), the coverage is 27 degrees by 40 degrees, with a diagonal of 47 degrees.

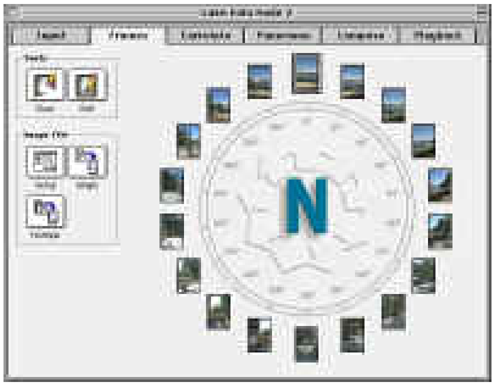
Focal Length	Angle of View	Number of views	Increment between shots
24mm	84°	8.57	42%
35mm	63°	11.43	
50mm	46°	15.65	

Exposure

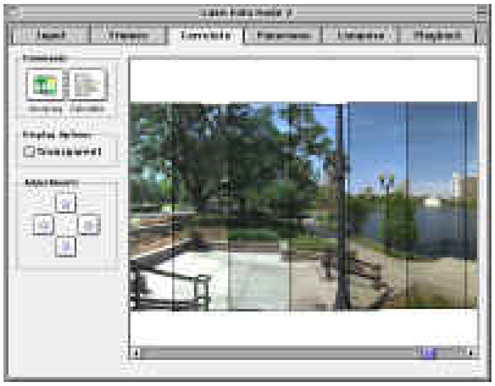
The software you use to stitch images together can even out the lighting in a scene but it helps if you give it good images to work with. To do so, take the camera off autoexposure and use the same exposure for all images in the series. Try to avoid extremes in lighting. These occur on bright sunny days when there are bright highlights and dark shadows. The problem is compounded because you have to shoot into the sun. If you can pick your time, pick a day when it's cloudy bright—overcast but with slight shadows on the ground. If the sun is out, shoot at mid-day to keep the lighting even. If you have to shoot at other times, position the camera so direct sunlight is blocked behind a tree or building when photographing in its direction. When shooting indoor panoramas, set up the camera to avoid shots of windows with direct sun shining through.

Panoramic Stitching Software

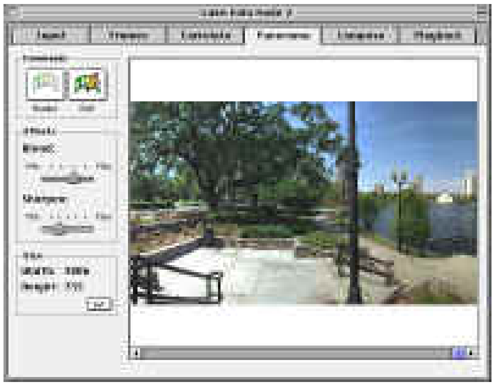
After you shoot a series of images for a panorama, you then have to digitize them if you didn't use a digital camera to capture them. Once in a digital format, you use software to stitch the digital images together into a seamless view. Here's how you do it with Rounabout Logic's Nodestar program.



You first acquire and arrange your source images in the "Frames" panel Courtesy of Roundabout Logic.



Nodester then calculates the frame overlap in the "Correlate" panel. You can fine-tune the results if necessary.



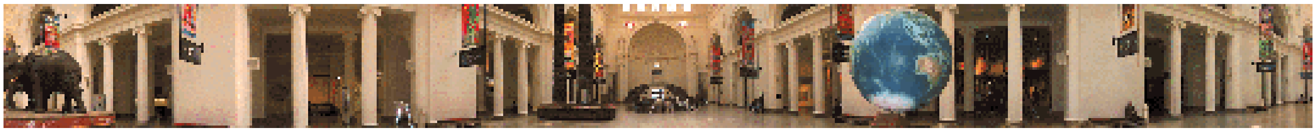
Nodester automatically blends each frame to generate a seamless panoramic image in the "Panorama" panel.

You can output the finished panorama as a still image in any of the popular formats such as bmp or JPEG. You can also save panoramas in one of the supported interactive formats such as QuickTime VR. These formats let a user view the image on the screen, pan it, zoom it, and click hot spots embedded in it. For example, you can pan around a panorama of a room and click a doorway to display a panorama of an adjoining room.

The software you use depends to some extent on what output format you have chosen. For example, if you are planing to use an IPIX format, you have to also use their software to create the image and to view it. Other formats are more open. For example, a number of stitching programs will output interactive QuickTime VR panoramas (called "movies").

- Apple's QuickTime VR Authoring Studio for the PowerPC.
- PictureWorks' Spin Panorama transforms multiple still images into 360° QuickTime VR panoramic movies.
- Live Picture's PhotoVista stitches images taken with fisheye lenses of 16mm focal length or greater and images taken with wide-angle rectilinear lenses of 13mm focal length or greater. The resulting panoramas can then be viewed using the Live Picture Viewer, a browser plug-in, or the Live Picture Viewer—Java Edition. On the PhotoVista Macintosh version you can also save the finished images as QuickTime® VR format.
- Roundabout's Nodester is a Macintosh tool for creating panoramic photographs using QuickTime VR standard.
- Unlike other panoramic imaging programs, PanoramIX does not require a fish-eye camera or software developer's kit to produce or view panoramic images.

- Orphan Technologies' PanDC (PowerPC only) rotates a digital or film-based camera to capture 360 degree panoramas or 160 degree stereoscopic panoramas. If you capture the image with a digital camera, it can correct the image for lens asphericity.



PanDC software (for MacOS PowerPC systems) uses a digital camera and a camera mount to make digital panoramic images. PanDC allows the automatic creation of partial or full 360° panoramic images, and up to 160° stereoscopic panoramic images. The resulting images are compatible for use as QuicktimeVR content. PanDC's stitching process is completely automatic and only takes about 6 minutes to stitch a full 360° panorama. Image courtesy of Orphan Technologies

- VideoBrush Photographer automatically stitches together a series of photographs into a single high-resolution image. To capture an entire scene, simply take a series of overlapping photos which "paint out" the scene. Your snapshots can cover a monument from top to bottom, a street fair from end to end, or a full 360-degree view of a family gathering-no need to back up or step out of the scene. Photographer will stitch these together into a single image, composing a wide-angle view out of the many separate photos.
- One interesting variant is VideoBrush Panorama that captures video sequences and turns them into panoramic images.

Panorama Viewing Software

You can post static panoramic images on the Web in the usual JPEG format. However, it you want to add interactivity to them, you need to choose an interactive format to save them in. The great thing about panoramas, especially 360-degree views is that you can pan and zoom them. From a central observation point, called a node, a viewer can look in any direction and may zoom into or out from a particular view by changing the zoom angle of their view.

Panoramic viewing is similar to, but different from VRML. In a VRML environment, you can freely move your viewpoint anywhere in the scene, but the motion is often jerky. Panoramic viewing positions your viewpoint in one spot in relation to the image and you view the scene from only that vantage point. The advantage is that your movement of the image is very smooth and the view is very realistic.

Unfortunately, there is more than one format to use for interactive panoramas and viewers aren't compatible. If you select QTVR panoramas, users without that software on the system can't view the image.

In addition to panning and zooming, panoramas can also have hot spots that link the panorama to other panoramas or objects. For example, a user can pan around a 360-degree view of a room and click doors to move to panoramas of those room.

- The Live Picture Viewer is a small Java applet that displays PhotoVista images on the Web without a plug-in. It downloads with the first picture selected and resides on the system for other images.
- IPIX images can be viewed on the Web with an IPIX plug-in for your browser. They can be viewed

off-line with a separate viewer.
- AlphaWorks (IBM) PanoramIX is a Web browser plug-in panoramic viewer that allows user to view virtual panoramic scenes. With PanoramIX, users can interactively explore panoramic images compiled from photographs, rendered images-even scanned hand-drawn sketches.

Once created, QTVR scenes are saved as a self-contained file. They can play back as stand alone files on either a Macintosh or Windows machine using the MoviePlayer application (provided, of course, that the platform has both the QuickTime and QuickTime VR extensions installed), or directly on-line in a World Wide Web page if using the correct QuickTime and QuickTime VR plug-ins with an Internet browser.

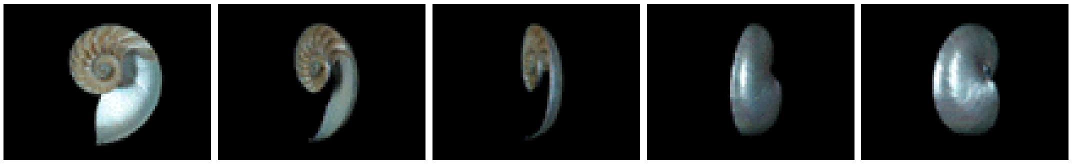
If, however, the scene includes panoramas or objects which contain links to other types of media, such as graphics, text, videos, or sounds, then the scene must be incorporated into a multimedia authoring environment, such as Apple Media Tool, Macromedia Director, or mFactory's mTropolis, to manipulate these other media components.

When you view a QTVR scene on the Web, here are the ways you navigate it.

To:	Macintosh:	Windows:
Pan the image	Click and drag	Click and drag
Zoom in (panoramas)	Press Option	Press Shift
Zoom out (panoramas)	Press Control	Press Control
Jump to another location (panoramas)	Click a jump spot	Click a jump spot
Save a panorama or object embedded in a web page	Press and hold the mouse button; from the popup choose Save	Click the image and select Save from the pop-up menu
Save a panorama or object displayed in a standalone window	Pull down the File menu, and click Save	Pull down the File menu, and click Save As.

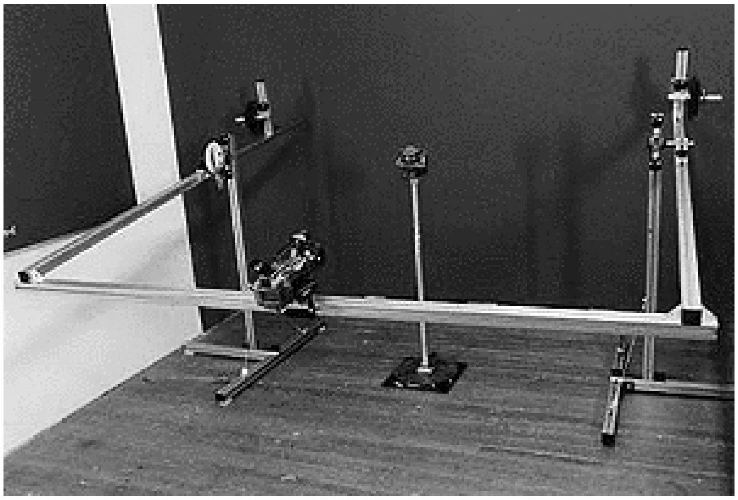
Object Photography

Object photography is the opposite of panoramic photography. Instead of standing in one place and rotating to see a 360-degree view, object photography rotates an object for you so you can see all of its sides.

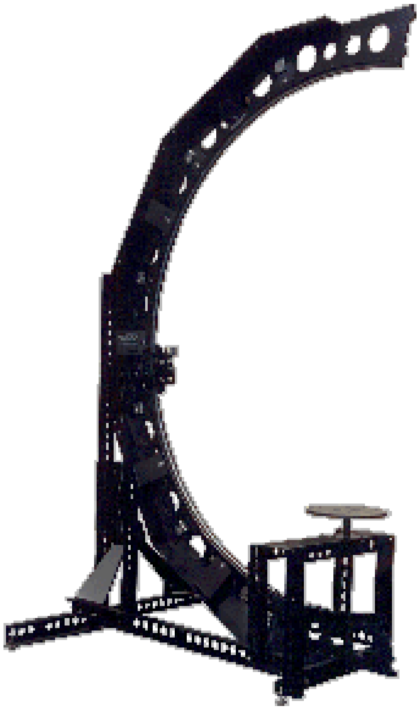


To create a rotational object, you start with a series of images showing the object from various angles. Images courtesy of Peace River Studios.

To accurately capture the series of images, you use an *object rig*. This rig allows you to mount the object to be photographed on a turntable and positions the camera. As the object is then rotated a precise number of degrees between shots, the series of images is captured.



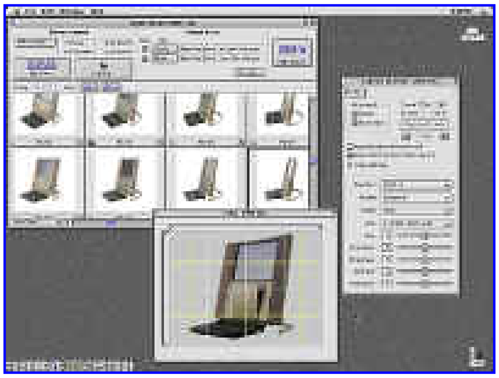
The Portable Object Maker is designed to capture views of objects up to 6 feet in diameter, at precise, user definable intervals. The captured images with the use of Apple's QuickTime VR Authoring Tools Suite, can be made into a navigable object movie. The mechanical functions of this machine are accomplished through the use of an indexable swing arm and an indexable turntable. Image courtesy of Peace River Studios.



The Kaidan Meridan C60 Object Rig is used to mount the camera and object being photographed. Image courtesy of Kaidan.

The object being photographed rests on a turntable that is then incremented between shots.Image courtesy of Kaidan.

Once a series of images has been taken, you use a software program to stitch them together and then output the scene to a disk file. One of the most popular output formats is Apple's QuickTime VR.



Apple's new QuickTime VR Authoring Studio includes Object Maker which combines single frames and outputs a QuickTime VR Object Movie. it works with a variety of turntable and gantry systems to capture video images (or digital, or film-based still images) frame by frame. Image courtesy of Apple.

A Short Course in Digital Photography

9. Stereo Photography

CONTENTS

Photographs are great at rendering the details in a scene but don't readily convey the impression of depth. Everything is rendered on a flat plane. Ever since photography was invented, people have been trying to correct this. There have been hundreds, if not thousands, of stereo patents filed and demonstration devices built. Sir Charles Wheatstone discovered the principles of stereoscopic vision in 1838, a year before photography was invented. 3-D or stereoscopic imagery uses two images of the same scene taken from slightly different viewpoints. Using one of many viewing technologies, the images are combined in your mind producing a third dimension—depth. 3D effects arise from the fact that each of your eyes sees from a slightly different perspective. To demonstrate this, hold your finger about a foot from your nose and close one eye, then reopen it and close the other. Your finger will appear to jump from side to side. This difference is due to parallax.

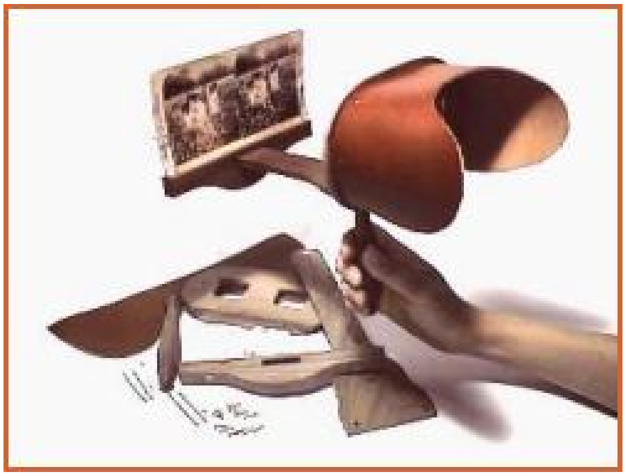
Stereo images displayed on the computer screen can great an illusion of depth. Image courtesy of StereoGraphics.

The First Stereo Photographs

As soon as Henry Fox Talbot's and Daguerre's photographic processes were introduced in 1839, people started making stereo views. In many respects, the results were as good as those we get today. The problem was that the process of making the photos was expensive and there weren't any special or widely available viewers.

The big breakthrough came in the 1850s with less expensive albumen prints and viewers—the first invented by David Brewster, and a later and less expensive one by Oliver Wendall Holmes. Views of foreign places, and other scenes of all kinds, became the rage in Victorian homes and millions were sold. You can easily find some of these views in almost any antique shop although some are very expensive and they are fast disappearing as collectors gather them up. These mass-produced stereo cards have two prints mounted side-by-side on a piece of cardboard. They are inserted into a holder on the viewer and you view them through an eyepiece to see them in 3D.

A Thomas Houseworth stereo of Yosemite.



A Holmes stereo viewer comes in a do-it-yourself kit. Images courtesy of Reel 3-D.

Taking Stereo Images

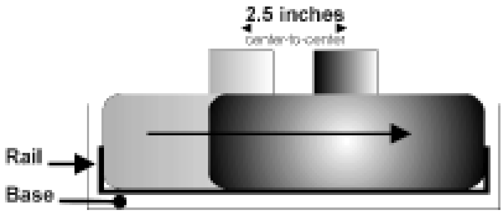
Almost all-stereo images start with a pair of photographs taken a few inches apart. The effect is to duplicate the spacing of our eyes that gives us stereo vision. Although it's possible to take a pair of stereo images with a single camera and lens, it's not the easiest way and the results are somewhat unpredictable. It's important that the lenses be the same focal length, exactly parallel, and offset by just the right amount—called the stereo base distance. For this reason, special cameras are usually used.

The Argus 3D Stereo Camera uses 35mm film. It has 2 matched 28mm lenses, 2 apertures (daylight and flash), and 1 shutter speed so everything is in focus from 2 1/2 feet to infinity. It also has a built-in pop-up flash. Image courtesy of Reel 3-D.

If you don't have a special camera, you can experiment using the one you do have. (Adapted from 3D-Web.)

1. Create a guide that helps you move the camera 2.5" between shots and also keep the lens aligned so it's parallel. Just take a flat board and put a small wooden rail on it. When you slide the camera along the rail

from flush-left to flush right, the lens moves exactly 2.5 inches. You can even add hardware to mount the base to your tripod



2. Select a scene where nothing is moving—not even clouds or leaves in the wind. Be sure to include something in the foreground to give you a stereo effect. (A shot of distant mountains won't have any.) Generally, a 35mm camera with a 35mm lens can handle a depth range from 2 meters (7 feet) to infinity. Photographs taken that only include objects in this depth range will view perfectly well in any viewing device. Here are some guidelines for other scenes:

- If a foreground object is as close as 5 feet, objects more than 20 feet away must be excluded.
- If a foreground object is as close as 3 feet, objects more than ten feet away must be excluded.

3. Use a level to keep the camera level between shots. 4. Set the camera to a small f-stop for maximum depth-of-field. 5. Use the same exposure for both pictures. An alternative approach is to buy two disposable cameras and tape them together. You might want to tape them to a board or tripod so they don't move or learn how to press both shutter releases together.

IMAGE NEEDED

Stereoscopic Photography (http://www.rpm.or.jp/home/h-kouno/3dphoto.htm)

The problem with most stereo cameras is that they are based on old technology. There really isn't a high-quality modern 3D camera at a reasonable price. There are small firms that couple cameras together so you can take stereo images using modern equipment with autoexposure, auto focus, and so on. It's possible to couple two digital cameras in this same way. This eliminates the need to get film scanned to display it on the Web.

David Grenewetzki rigged two Kodak DC20 cameras to produce digital stereo pairs. Believe it or not he does this from remote control airplanes. There are lots more details on his Web site. Courtesy of [David Grenewetzki]

The Reel 3-D twin camera bar lets you mount two 35mm cameras side by side. The rig can then be tripod mounted or handheld. Image courtesy of Reel 3-D.

This beautiful mahogany and brass 5 by 7 inch stereo camera is much like those used in the late 1800s to take stereo images. Courtesy of Mottweiler Design

Viewing Stereo Images

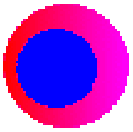
There are several methods that can be used to create stereoscopic images for viewing on a PC or web page. The most common images are:

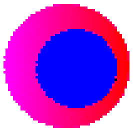
- Cross-eye view images
- Parallel view images
- Anaglyph images
- Page flipped images viewed with shutter glasses
- Line alternate images viewed with shutter glasses and head mounted displays
- Squished Side by Side images viewed on lenticular displays
- Polarized images viewed with polarized glasses

Stereo Pairs

Stereo pairs can be easily viewed with a stereoscope or other viewer. But with practice, you can also view them unaided by such devices. All you have to do it look at them in the right way. When you finally see the depth information you have "fused" the images. When practicing these unaided techniques, take a break if you experience eye fatigue or discomfort. Keep in mind that not everyone can do these techniques.

- A pair of images designed for cross-eye viewing is arranged side-by-side with the image for the left eye on the right, and the one for the right eye on the left. To view them in 3D, you stare at them with your eyes crossed and this takes some practice. To begin, hold your head level and stare at a point between the two images and slowly cross your eyes. The images should merge so a third image appears in the middle in 3D. The original images will still be seen on either side, so ignore them and concentrate on the middle one.





You should see the solid circle floating above the outline circle.If the solid circle is below the outline circle, you have used the parallel free-vision fusion technique.

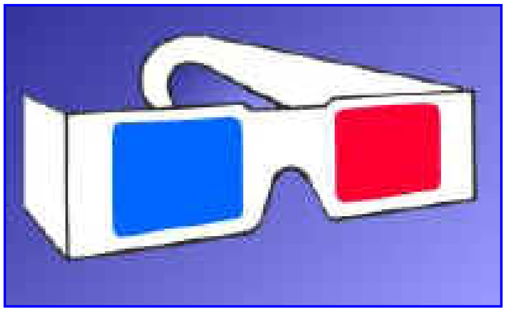
If you can't get the effect, hold your index finger half way between your eyes and the computer screen so both images are still visible. While staring at your fingertip, slowly bring it closer and farther from the screen. At some point, the images should merge into a single 3D image.

- A pair of images designed for parallel viewing (also called relaxed viewing or free viewing) is also arranged side-by-side. However, the image for the left eye is on the left, and the one for the right eye is on the right. To view the images, place your face close to the screen and then slowly back away while staring "through" the images to an imaginary point past them and behind the screen. When there appear to be three images, concentrate on the middle one until it becomes 3D. If you first see four images, concentrate harder on the imaginary point behind the screen until they become three images. It may help if you rotate your head slightly to the right or left while keeping it level.

If you have trouble bringing stereo prints into view, you can use a modern print viewer. There are lots of variations to choose from. Image courtesy of Reel 3-D.

Anaglyph Images

Du Hauron, a French scientist patented the anaglyph method of stereoscopic photography in 1891. Anaglyphs, like other technologies, use a pair of images taken from slightly different vantage points. These two images are then color corrected and superimposed slightly out of register so one image is offset slightly from the other. When viewed through a pair of glasses with different colored lenses, the image appears in 3D. The glasses are usually red and blue, but they can also be other combinations depending on how the image was coded and the color of the glasses used to view them. Normally the red lens covers the left eye and the blue or green lens the right eye, but this can vary.



Here are the familiar and low-cost red & blue anaglyph glasses. Image courtesy of Reel 3-D.

In most cases the original images are converted to grayscale images which are then coded with red and blue colors that are balanced with the red/blue glasses. These are sometimes called "pure anaglyphs." Some images can be displayed in full color but most won't work very well.

The Mars Pathfinder site even offers 3D movies of the rover exploring the surface of the planet.
http://mars.sgi.com/vrml/qtvr_stereo.html

Shutter Glasses

An increasingly popular way to view 3D images on the screen is using shutter glasses. These glasses have high-speed electronic shutters that open and close in sync with the images on the monitor. Liquid Crystals are used for the shutters because an electronic signal can make the crystal turn instantly from transparent to opaque.

- When the left image is on the screen the left shutter is open and the right shutter is closed which allows the image to be viewed by your left eye only.
- When the right image is on the screen the right shutter is open and the left shutter is closed.

If this process happens fast enough, your brain thinks it is seeing a true stereoscopic image. If this shuttering speed is not fast enough, you can still see a stereoscopic image, but you may also see some flickering.

CrystalEyes shutter glasses use a wireless connection and deliver high-resolution stereoscopic 3D images. Many common software applications used in mechanical CAD, molecular modeling, GIS/mapping and medical imaging support StereoGraphics' CrystalEyes on all major UNIX platforms and Windows NT workstations.Image courtesy of StereoGraphics.

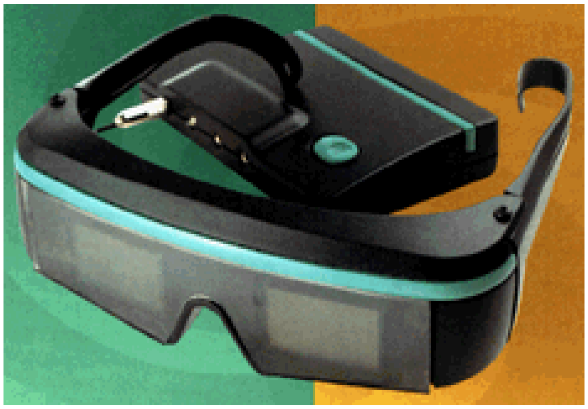
Shutter glasses connect to your video card, parallel port or serial port with wires or with a wireless infrared transmitter. There are three approaches to rapidly alternating the displayed images while coordinating the shuttering of the LCS glasses. All display images in high-resolution and full-color.

- Page flipping rapidly switches the monitor between the right and left images. Special purpose video boards that support high-speed page flipping are available. These video adapters quickly alternate between frame buffers that each contains an entire image. The problem with this approach is that you may experience some flicker.

- Sync-doubling, used by a company called Neotek, displays the left image on the top half of the display and the right image on the bottom half. But you don't see them this way because a hardware device inserts an extra vertical-sync, or "new frame" signal after the computer has displayed the top half. The result is that you see an image that looks like it is page-flipped. In addition, the extra synch signal has the effect of doubling the refresh rate so each eye sees a normal frame rate.

- Line alternate images use a monitor's or head mounted display's ability to interlace images. Interlacing was used on early computers (and TVs) to create images while using little bandwidth. The screen was divided into scan lines. The image was then painted on it using first the odd lines. The scanning beam then returned to the top of the screen and filled in the even lines. When stereoscopic images are interlaced, the odd and even scan lines are used to display the left and right images. On the first pass, the image for one eye is displayed on odd lines. On the next pass, the second image is displayed on even lines. Many video cards have a built-in interlaced video mode that supports this technology.

Because computer display manufacturers dropped interlace mode in the 1980's, these devices require special 'device drivers' supplied by the LCD glasses supplier. There is also a drawback in that each left or right eye view is only made up of either the odd or even lines. This results in only half of the screen being used for each image and a 50% decrease in brightness.



StereoGraphics SimulEyes are lower-cost shutter glasses designed for viewing 3D multimedia and games.Image courtesy of StereoGraphics

Autostereo Images

The problem with most 3D viewing systems is that they require some form of eyewear. However, there are systems that dispense with these by using various techniques to guide the right and left images into the correct eye. These autostereoscopic displays are expensive and display the images in a format that is squashed side-by-side. One big problem with these systems is that you can only view the images from a specific angle. The 3D image isn't seen if you are not positioned correctly.

Pulfrich Images

Strange as it may sound, if video is shot with the camera moving to the left or right, or if an object is spinning, it can be viewed in 3D. To do so, you cover one eye with a dark filter and leave the other eye uncovered. This effect, known as the Pulfrich effect was used for an episode of "3rd Rock from the Sun" in May of 1997. You can purchase a copy of this episode at www.3rdrock.com and view it with one lens of a pair of sunglasses held over your right eye.

Polarized Images

A final way to display images pairs is to display them on the screen one after the other with different polarizations. The first image is displayed with vertical polarization and the second with horizontal. When wearing a pair of glasses with matching polarizations, each eye only sees the image that matches its polarization.

- There are LCD panels that fit over a monitor and polarize the view in sync with the frame rate and allow the use of standard polarized glasses.
- If your system (monitor or presentation panel) has an Active Matrix LCD display, a Vrex micropolarizing filter polarizes every other pixel row into a left and right view. A group can view the displayed or projected image with standard polarized glasses.

Similar in appearance to an anti-glare screen mounted on the front of a computer monitor, the ZScreen enables on-screen images to be displayed with realistic depth, making objects appear to have presence in the user's physical environment. This allows scientific and technical professionals to better see and understand complex interactions between a wide variety of 3D elements, from molecules containing thousands of atoms, to the design and layout of an automobile's drive train and suspension.Stereographics ZScreen. Image courtesy of StereoGraphics.

Web 3D Viewers

The interest in stereo has been given a big boost by computer games but it's now being widely displayed on the Web. Some forms of display don't require any special provisions, but others require a plug-in for your browser or Java capability.

DepthCharge

The VRex DepthCharge plug-in allows you to view a variety of stereo image formats on the Web. The plug-in works on Windows 95/NT, using version 3 or higher of either Netscape or Internet Explorer. It supports the following viewing technologies:

- Cross-eye view images
- Parallel view images
- Anaglyph images using red/green glasses
- Page flipped images with shutter glasses
- Line alternate images for shutter glasses and head mounted displays
- Squished side by side images for lenticular displays

The VRex DepthCharge plug-in allows you to view a variety of stereo image formats on the Web. You'll see this logo on many sites that support the plug-in.

When you are browsing the Web with DepthCharge installed, you'll find monoscopic or flat view DepthCharge images that you can view just like any other image on the Web. When you point to one of these DepthCharge images, your mouse pointer will take the shape of 3D glasses. (Note that some sites display thumbnails that you must first click to display the DepthCharge image.) To display the image in 3D, just click it. To return to the normal browser view, click it again. To specify which view to display it in, right-click the image to display a pop-up menu.

SimWeb3D

SimWeb3D is a Java plug-in for your Windows Web browser that works with SimulEyes™ glasses.

Making 3D Images

In the old days, stereo photographs were mounted side by side on a card or printed on top of one slightly out of register. Today, this work can be done on the computer using a variety of software.

3D Stereo Image Factory™ by SOFTreat

Stereo 3D images can be viewed in 3D Stereoscopic Image Factory™ in many ways. On the low-tech side this includes free viewing as parallel or crossed side by side pairs or with red/blue glasses as anaglyphs. On the Hi-tech side there are Liquid Crystal Shutter Glasses which operate with images prepared for interlacing, page flipping, or sync doubling. Work in your favorite 3D format and explore all the other types too.

Photoshop

You can create anaglyph images with Photoshop.

1. Start with a stereo pair.

2. Remove the red component from the right image.

3. Remove the green and blue components from the left image

4. Superimpose the two images

StereoVR

StereoVR allows you to create your own stereoscopic 3D images and animations. It includes a modeler to make your own 3D mesh wireframes, an extensive library of objects, lighting, colors and textures to render in full color 3D, and an animator to propel your creations right from the computer monitor.

VRex STEREO IPAS

3D Studio users can render stereo 3D images with Vrex's STEREO IPAS plug-in module. This software runs in the 3D Studio keyframer to automatically position two cameras in your already existing or new 3D scenes so the correct left and right perspective views are computed and rendered. You then multiplex the two image files with any VRex S-MUX program.

MUX-IT

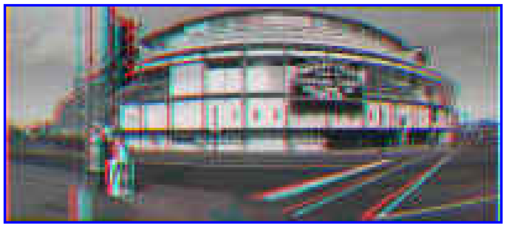
MUX-IT is the VRex program that combines left and right images into a 3D image using the Spatially Multiplexed Imaging (SMI) technique. Pixel rows of the left image are interleaved with pixel rows of the right image to produce a single stereo image for display through the patented µPol optical system.

S-MUX

VRex's most popular stereo multiplexing software, S-MUX provides a familiar interface to easily select and multiplex your graphics into Spatially Multiplexed Images (SMI) for viewing on any VRex 3D display system. Just click on the graphics files for your left and right perspective views, click on the Multiplex icon and you're done! For special 3D graphics applications you'll appreciate the full range of features in S-MUX including real-time editing, parallax adjustment, image scaling, batch animation mode, and more. Available for DOS, Windows and Macintosh.

Stereo Panoramas

The best of all worlds are stereoscopic panoramas. There are a couple of tools available to capture such images.



With PanDC, you can create stereographic images that approach 120° in each half of the stereo pair. To achieve a stereo effect, a series on 15 or more images is taken with the camera moved to the right between exposures of each pair. The distance that you move the camera, called the stereo base distance, depends partly on the scene (you have to experiment). To see this one, first click it to enlarge it. Image courtesy of Orphan Technologies.

By mounting two cameras side-by-side as you take a series of pictures for a panorama, you capture a series of stereo pairs. By stitching those from each camera together into it's own panorama, you create a panoramic stereo pair.

The Kaidan QPST-1 allows you to mount two 35mm cameras side by side for creating stereoscopic panoramas. It's not usable separately, but is an add-on to Kaidan's QP-4 and QP-6 panoramic brackets. Image courtesy of Kaidan.

A Short Course in Digital Photography

10. Caring for your Camera

CONTENTS

Some of the best opportunities for interesting photographs occur during bad weather. You can take advantage of these opportunities as long as you take a few precautions to protect your camera.

A digital camera will last through at least 100,000 shots if properly cared for. Under normal circumstances your camera and lens need less cleaning than you might imagine. Since there is always the possibility that the camera of lens might be damaged during cleaning, do so only when necessary. Do check the camera periodically, however.

Cleaning the Camera and Lens

The outside of the camera can be cleaned with a soft, lint-free cloth. Open the "flaps" to the memory and battery compartments occasionally and use a soft brush or blower to remove dust. Rubbing alcohol (isopropyl alcohol) on a Q-tip can be used to clean metal parts of the camera if necessary.

The first rule is to clean the lens only when absolutely necessary. A little dust on the lens won't affect the image, so don't be compulsive. When needed, use a soft brush, such as a sable artist's brush, and a blower (an ear syringe makes a good one) to remove dust. Fingerprints can be very harmful to the lens coating and should be removed as soon as possible. Keep the lens covered when not in use to reduce the amount of cleaning required.

Clean a lens by first using a brush or blower to remove abrasive dust particles. Then use a lens cleaning cloth (or roll up a piece of photographic lens cleaning tissue and tear the end off to leave a brush like surface). Put a small drop of lens cleaning fluid on the end of the tissue. (Your condensed breath on the lens also works well.) never put cleaning fluid directly on the lens; it might run between the lens elements. Using a circular motion, clean the lens surface with the tissue, then use the cloth of a tissue rolled and torn the same way to dry. Never reuse tissues and don't press hard when cleaning because the front element of the lens is covered with a relatively delicate lens coating.

Avoid Strong Magnetic Fields

Never place the camera near electric motors or other devices that have strong magnetic fields. These fields can corrupt the image data stored in the camera.

Protecting your Camera from the Elements

Your camera should never be exposed to excessively high temperatures. If at all possible, don't leave the camera in a car on a hot day if the sun is shining on the car (or it will later when the sun changes position). If the camera has to be exposed to the sun, such as when you are at the beach, cover it with a light colored and sand free towel or piece of tinfoil to shade it from the sun. Dark materials will only absorb the heat and possibly make things worse. Indoors, avoid storage near radiators or in other places likely to get hot or humid.

Deserts are notoriously hot at certain times of the day and year, but they aren't the only place where heat can affect your camera.

When it's cold out, keep the camera as warm as possible by keeping it under your coat. Always carry extra batteries. Those in your camera may weaken at low temperatures just as your car battery weakens in winter. Prevent condensation when taking the camera from a cold area to a warm one by wrapping the camera in a plastic bag or newspaper until its temperature climbs to that in the room. If some condensation does occur, do not use the camera or take it back out in the cold with condensation still on it or it can freeze up camera operation. Remove any batteries or flash cards and leave the compartments covers open until everything dries out.

In the winter, batteries fail much faster because of the cold. At extreme temperatures, moving parts may even freeze up.

Always protect equipment from water, especially salt water, and from dust, dirt, and sand. A camera case helps but at the beach a plastic bag is even better. When shooting in the mist, fog, or rain, cover the camera with a plastic bag into which you've cut a hole for the lens to stick out. Use a rubber band to seal the bag around the lens. You can reach through the normal opening in the bag to operate the controls. Screwing a skylight filter over the lens allows you to wipe off spray and condensation without damaging the delicate lens surface.

Protecting when Traveling

Use lens caps or covers to protect lenses. Store all small items and other accessories in cases and pack everything carefully so bangs and bumps won't cause them to hit each other. Be careful packing photographic equipment in soft luggage where it can be easily damaged. When flying, carry-on metal detectors are less damaging than the ones used to examine checked baggage. If in doubt, ask for hand inspection to reduce the possibility of X-ray induced damage.

Storing a Camera

Protect stored cameras from dust, heat, and humidity. A camera bag or case makes an excellent storage container. Remove batteries before storing.

Digital cameras have lots of components including batteries, chargers, cables, lens cleaners, and what not. It helps if you have some kind of storage bag in which to keep them all together.

Caring for Yourself

- When hiking outdoors, don't wear the camera strap around your neck, it could strangle you.
- Don't aim the camera directly at the sun, it can burn the eye.

A Short Course in Digital Photography

11. Jump Start in Digital Photography

CONTENTS

Learning a new field can be a little intimidating. There always seems to be so much to learn. But, for most of us the learning process becomes easy, fun, and even exciting once we gain a toehold; a place to begin. The purpose of this short Jump Start section is to get you going immediately. Just follow the steps to begin exploring digital photography right now, even if you don't have a digital camera.

Some things just require a leap of faith. Here Emily tries to fly using wings we spent the day building and decorating.

1. Get Yourself a Photo-editing Program

At the heart of a digital photography system is a photo editing program that you use to work on your photographs. The leading photo-editing program is Adobe's Photoshop, but it's expensive, hard to learn, and there are lots of others on the market. Below are some links to trial versions of leading programs. Just be aware that all but Picture Window and Paint Shop Pro are limited in some respect and the file sizes that you have to download can be quite large. If your modem works at only 28.8K, or even 56.6K, they can take a loooong time to download.

Paint Shop Pro is a proven and popular photo editing program that you can try for free.

- Picture Window by Digital Light & Color works with Windows 95, Windows 98, and Windows NT 4.0 or later. This program is rapidly becoming the favorite of many digital photographers because it's been developed specifically for digital photography.
- Paint Shop Pro is a full-featured program that's very popular, even amongst the pros. The program is shareware, so after trying it, if you like it send in the money they request. They depend on your honesty for the funds they need to continue developing and distributing the program. This is the smallest file to download.
- Photoshop offers a trial version of the leading image editing program. The file is large and the program is complicated. But if you want to try the real thing, go for it.

2. Get Yourself an Image

If you don't yet have a digital camera, get some of your own film images put on a floppy disk or even posted to the Web where you can let others see them. Just call around your local photofinishers and ask if they can put images on the Web or on a disk for you. They can usually do this when the film is developed or later, after you have had time to select only the best images. There are a number of companies that offer these services. To learn more about how they work, just visit the PhotoNet Online site.

PhotoNet dealers can scan your images onto a floppy disk or even posted on the Web. Image courtesy of PictureVision.

It's always more interesting to work with your own images. However, if you don't have any digital images and you want to start right now, grab an image you like off of the ShortCourses Web site (for your personal use only). To use one of the images, you have to first transfer it from the Web page to your own computer's hard disk drive.

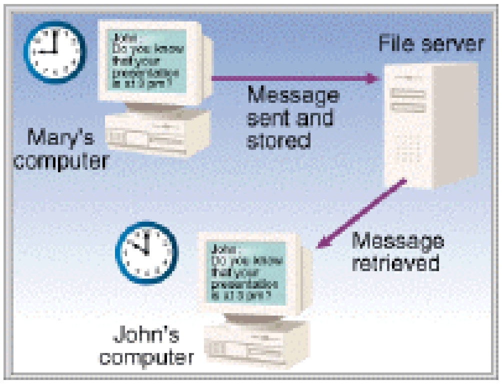
To download this desert scene to your own computer:

1. Click the image of the cactus to enlarge it. (If you don't first enlarge the image, you will download a smaller compressed image that won't have the same high quality but it'll download faster.)

2. Right-click the image with your mouse and select the Save Image As or Save Picture As command listed on the pop-up menu.

3. E-mail Someone an Image

Once photos are in a digital format, there is almost no end to what you can do with them. One of the most popular uses is e-mailing them to friends and family. To do this, you just create an e-mail message the way you normally do and use your e-mail program's **Attach** command to select the image file you want to send (most programs will let you browse to find it on your system).



When you e-mail a message with a photo attached, it is sent to the recipient's service provider where it is stored on a computer called a server. When the recipient checks his e-mail, the message with the image attached is forwarded from the server to his or her system where it can be opened and read.

Once photos are in a digital format, there is almost no end to what you can do with them. One of the most popular uses is e-mailing them to friends and family. To do this, you just create an e-mail message the way you normally do and use your e-mail program's **Attach** command to select the image file you want to send (most programs will let you browse to find it on your system).

When an e-mail with an attached photo arrives at the recipient's end, the photo can be viewed in the message as either a link or as an image. You can right-click either the link or image to display a pop-up menu and use the **Save Image As** or **Save Picture As** command to save the image onto your system's disk. Once extracted from the e-mail message and saved onto the disk, you can then use it like any other digital image on your system.

The first time you e-mail a photo, you might address the e-mail to yourself so you can see what your image looks like when it arrives back on your system.

4. Start Your Own Web Page

There's nothing quite like having your images up on a Web site where anyone in the world can see them. Surprisingly, you can do this without spending a dime because there is a slew of sites that offer you free hosting for personal web pages. All you have to do is register for one of these and then post your images to it. Some sites even provide you with the software you need to lay out your page. Once your images are up on the site, they can be seen by anyone you want to see them. Just send them your site's URL (Web address) and they can go through your images. Here are some sites that offer free Web space. You can find others at Web Site Resources.

- Tripod
- Geocities
- Angelfire
- The Globe

If you don't want to start your own Web site, you can post your images into one of the many on-line photo sharing sites. One of the best, and easiest to use is PhotoPoint. All you have to do is e-mail them an image, and their automated attendant extracts it from the message and puts it into your own 'incoming' album, which is a temporary holding area. The first time you submit photos, the attendant automatically creates a free account for you, and in a few minutes acknowledges receipt by e-mail you a note with your password. You can then go to the site and add captions to your images.