16 INTRODUCTION TO VIRTUAL AND WEB MAPPING

CHAPTER PREVIEW Much of the mapping done today is designed for the World Wide Web or other virtual environments. Common types include static, interactive, and animated maps. These maps are constructed in a variety of raster and vector formats, depending on the capabilities needed. The virtual maps are typically stored on a server, and are delivered to the map reader's monitor as a Web resource via the Internet—the "medium" for most virtual mapping today. The medium places some important constraints on virtual map design, perhaps the most important being screen resolution and the amount of screen "real estate." But perhaps even more powerful than the limitations are the opportunities that the medium affords. Interactive and animated cartography are popular today because of the medium, and can be a major part of the solution to the screen real-estate constraint. Future developments are likely, and the term cybercartography describes a research agenda that can embrace new technologies and cooperation among government, educational, and private agencies. ■

In the previous chapter, a variety of subjects dealing with modern printing techniques were presented. We now turn our attention to Web and virtual mapping, perhaps one of the most exciting and dynamic areas within the discipline of cartography. In Chapter One, we introduced the term **virtual map,** which in its modern use means any map that is presented on a monitor display or is projected onto a screen. Most virtual maps today are found on the World Wide Web. However, the television weather map, the map viewed from a CD or DVD, and a map displayed in a PowerPoint presentation are also examples of virtual maps. Even a map layout that appears on the monitor before the cartographer prints the map is also a virtual product. In fact, most virtual maps *can* be printed, if need be, but this chapter will place the most emphasis on virtual maps that are *designed* for virtual viewing on the map reader's monitor display.

VIRTUAL AND WEB MAPPING INTRODUCTION

Virtual maps are often created as **static, interactive,** or **animated** maps. The earliest digital atlases, such as Smith's (1988) *Electronic Atlas of Arkansas,* were produced before the popularity of the Web. These atlases were built primarily using static maps, which are the easiest of the three types to create. On the Web, it is still quite common to see static virtual maps. Many of these are essentially exported map layouts designed in a GIS or in artistic drawing software. Scanned printed maps, such as the images found at the Perry-Castañeda Library Map Collection (2007), are another example of static maps that are also quite common on the Web.

Interactive maps are those maps in which the map reader can click and interact with features or layers on a map, often in the same way that a GIS user might interact with map layers in a GIS. For example, some interactive maps allow the reader to click and identify features, turn on and off certain classes of features, or pan and zoom across the map. The specific type of interactivity is determined by the map author. With some interactive maps, the map reader might be not only interacting with the map on the Web browser but also with an underlying online GIS. For most interactive maps on the Web, however, the function and scope of the map is not as extensive as that of a geographic information system.

STRATEGIES FOR LEARNING TO BUILD WEB PAGES

One of the most common ways to put virtual maps online is to build a Web page. There are two aspects of building a Web page to consider: the design and layout of the page, and learning how to program the code behind the Web page. Both are incredibly deep topics, and mastering the skills to be able to wear the title of "Web programmer" or "Web designer" can take years (and is far beyond the scope of this text). However, building a *simple* Web page can be an extremely effective vehicle for display of online maps. This brief discussion is intended to provide a starting point for those beginning to develop basic Web skills.

Most of today's Web page layout software is very easy and intuitive. However, you don't need an expensive software package to make a Web page. A simple text editor (such as Notepad) can be used. *If* learning HTML coding is important to you, you should consider *no*t using a professional design package that writes the code for you while you are first learning the language, because it can be too much of a crutch.

There are a number of great online tutorials that are free for Web design and HTML programming, such as the ones at w3schools.org. It can be really effective to view the instructions on the screen, where you can copy and paste examples of code from their page into yours, and see what that particular code does. If reading from the screen is not to your taste, there are hundreds of hardcopy books available at the library or your local bookstore. Both approaches work well for individuals who prefer learning at their own pace.

If classroom instruction is your learning style, you could consider taking a course at your local community college, vocational school, or university. If formal courses are too much, many communities offer low-cost introductory workshops on the basics of Web design and HTML. These types of classes can give a quick jump-start to getting your maps online.

Finally, remember that designing a simple Web site does not have to be complicated. In fact, most Web surfers tend to bypass complex and/or poorly organized pages. If you have a number of maps to present, consider making an index page with small-sized (both physically small and file-size small) thumbnail images of your maps that are hyperlinked to the main maps.

Animation puts an element of motion into the maps. In some cases, the entire map may seem to move, such as maps that change their projection. In other cases, just a select symbol or element may be animated, perhaps to draw extra attention to that feature. The most familiar animated maps are perhaps those found in news broadcasts where weather maps are "put in motion." During a select time period, the symbolization for precipitation will expand, contract, appear, and disappear in a few seconds, and weather front symbols will cross the map and high and low pressure cells will move accordingly. Some of these weather maps will even tilt, and the viewer is treated to a three-dimensional view of the area, which often includes a virtual fly-through of the terrain.

The most common venue for virtual maps is the Internet. People who "surf the Web" for maps do so on a Web **browser**—the program such as Internet Explorer or Mozilla Firefox that allows the reader to view and interact with information on the Internet (the distinction between the Internet and the World Wide Web will be discussed later). Most static maps that are generated in one of the more popular Web formats (also discussed later in the chapter) are viewable in the Web browser. However, some maps, particularly interactive maps, are not always directly supported by the browser. Browsers often require "plug-ins," (also called "add-ons" or "helper applications") in order to view some maps or run specialized Web applications. Plug-ins are programs that extend the capabilities of the browser to accommodate the various functions and display of specialized file types. For example, Flash is a popular plug-in that allows the playing of Adobe (formerly Macromedia) Flash (.swf) files, a popular format for interactive mapping. For file types that are not supported by the browser or its plug-ins, most browser software will prompt the user to either save the file or select a program from a list of programs currently installed on the computer that the Web surfer thinks will successfully open the file.

Creating virtual maps for the Internet requires an understanding of the basics of the technology and how that technology affects virtual map design. The next three sections provide a broad overview of three major areas with which the cartographer should have some degree of familiarity: how to select an appropriate format for the virtual map (Map Formats and Structures); the technology and terminology of the virtual map medium (Understanding the Medium); and some of the major design issues that are inherent in virtual mapping (Design Implications for Thematic Mapping). An introductory approach to these topics is taken here—the student is encouraged to see the linkages between these broad areas.

It should be noted that Web page design or programming techniques, although important, are beyond the scope of this text. Entire curricula are written on these topics. To those who wish to learn these skills, we point out that there are literally hundreds of texts available on these topics, as well as numerous online sources. Since many maps often have a Web page context, the boxed discussion, "Strategies for Learning to Build Web Pages" provides more information on how one can proceed if you wish to create your own Web site.

MAP FORMATS AND STRUCTURES

One of the largest challenges facing many map designers is to decide on the format for their map layout. There are scores of possible choices. One popular option is to save the map layout in the native format from which the cartographer is working. A native format is simply the preferred, designated, and often default format for the particular GIS, mapping, or artistic software being used by the cartographer. But when the layout is complete, what format choices are available so the map can be easily viewed on the Web? Does the format support interactivity or animation, or is the format best suited for static maps? Are there other functional and/or aesthetic differences between the major format types? In this section, we explore some of the more popular raster and vector formats used in Web and virtual mapping.

Raster Graphics

The raster format is one popular choice for Web and virtual-based cartography. The raster format is used in remotely sensed imagery and digital aerial photography, scanned maps and documents, picture images from digital cameras, and images of completed map layouts (see Figure 16.1). Many of today's online map collections, particularly those that contain volumes of scanned maps, such as those found at the Perry-Castañeda Library Map Collection (2007) mentioned earlier, contain hundreds of raster images.

In the early years of virtual cartography, most map layouts were presented in a raster format and were often referred to as bitmaps. Today, the raster image (or simply **image** among Web developers) remains a popular choice for map designers, even with the advent of vector Web formats that provide a potential for a higher degree of user-interactivity. There are four primary reasons that the raster image format is still commonly used among cartographers for their map layouts:

1. The most common image formats can be viewed in most browsers without the use of an plug-in.
2. Images are easily incorporated into Web pages as well as presentation software and other documents.

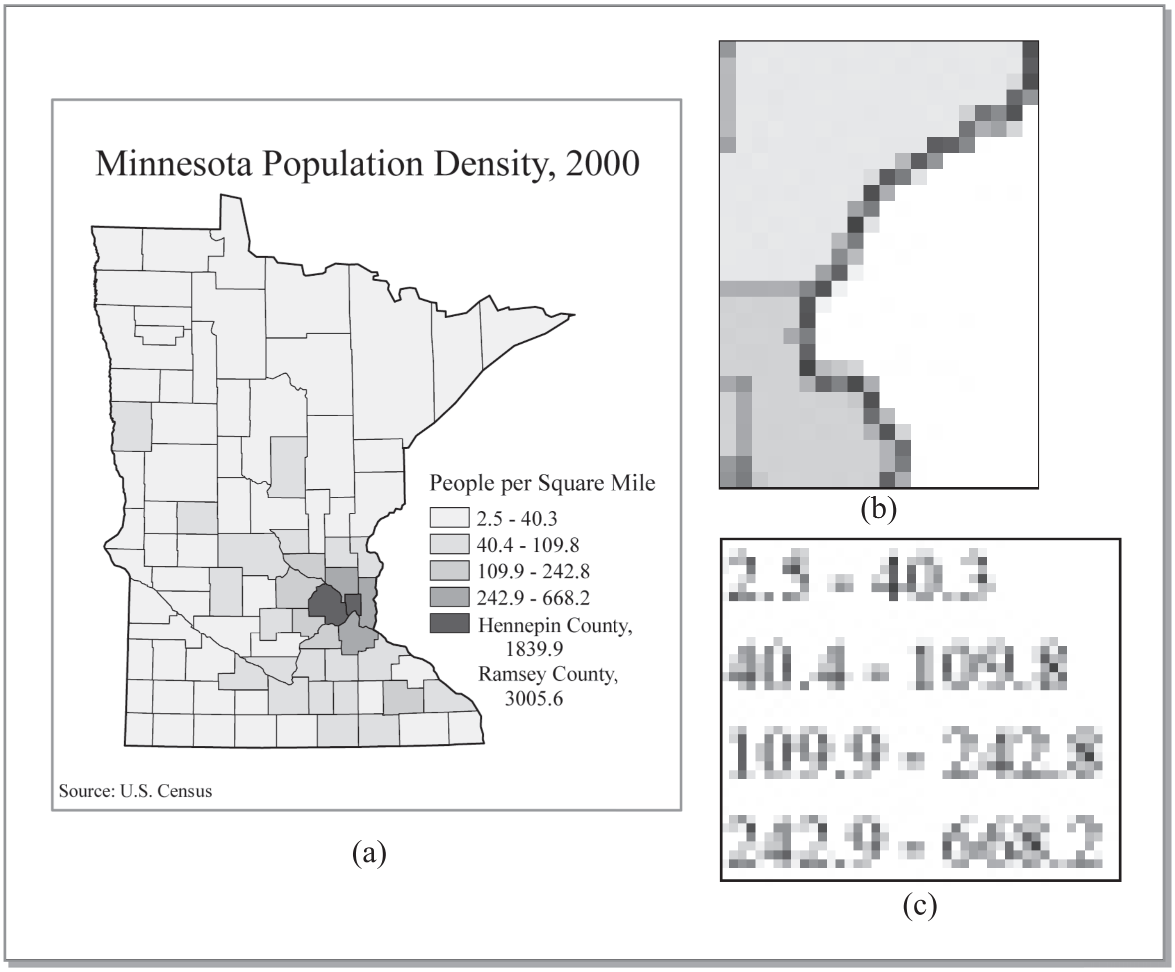


FIGURE 16.1 RASTER IMAGE OF FIGURE 1.8.
Figure 1.8 is converted to a raster image format in (a). When part of the image is zoomed into, the pixels are easily seen in (b) and (c).

3. GIS, mapping, and artistic drawing software can quickly and easily export a map layout to the most common raster formats.
4. Images can easily be extracted and saved from the Web page by the map reader.

If the cartographer is willing to accept the limitations of the raster image format, such as the fixed *resolution* and less potential for interactivity, the quickest and easiest solution for many cartographers is raster graphics.

Raster Concepts

The anatomy of most raster images is described using the same terminology as display monitors (see discussion), since monitors are also raster devices. Images have rows and columns of **pixels.** The number and size of the pixels in the image defines its **resolution.** Although images can be prepared at fairly high resolutions (usually for printing), images prepared for the Web are typically created at 72, 96, or 150 pixels per inch (ppi). Some Web designers will try to make the image's pixel dimensions less than a typical display monitor screen resolution, such as 800 * 600 pixels, in order to fit on a display screen.

The number of simultaneous colors that can be displayed is called the **bit depth.** The number of binary bits assigned to each pixel in an image determines the number of colors that can be displayed. Since there are only two possible numbers in a bit (each bit can have a value of 0 or 1), the number of potential colors is 2 raised to the power of the number of bits for each pixel. For example, if the bit depth is 8 bits, then 2^8 generates 256 possible combinations of zeroes and ones, usually expressed as color values of 0 – 255. Twenty-four-bit depth results in over 16 million colors, and is sometimes referred to as true color. In 24-bit color, 8 bits are allocated to each red, green, and blue color channel (256 intensity values for red, green, and blue, respectively). Table 16.1 illustrates the relationship between bit depth and number of colors.

Two hundred fifty-six colors are usually sufficient for most thematic maps. For example, a typical choropleth map may use only four or five hue values for the classes, along with black for text, white for a background, and perhaps gray for the enumeration unit borders. For maps or map layouts that incorporate imagery or photographs, a greater bit depth becomes necessary to accommodate a photograph's continuous tones, that is, the subtle but often numerous changes from pixel to pixel in an image. For these purposes, using a 24-bit depth image is common, not because all 16.7 million possible colors are required for photographic quality detail, but because it is the default bit depth on some of the most common true-color file formats (discussed later in "Selected Raster Image Formats").

There is some debate about whether bit depths greater than 24-bit are really necessary. As discussed in Chapter 14, the human eye can see only about 10 million colors. So why are values beyond 24-bit depths an option in so many graphic software programs? Two reasons are usually given. First, the higher bit depths do not always mean more colors. A 32-bit depth image, for example, refers to an image that allocates 24 bits for color but reserves the last 8 bits as an **alpha channel.** This channel is often used for creating masks in some software, or specifying transparency values. Second, for higher bit depths that do imply a greater number of colors (for example, a 48-bit depth that will produce trillions of colors), some graphic artists point out that the extra headroom allows for a greater editing flexibility (Fraser and Blatner 2005). However, most browsers and many monitors are not set up for the greater bit depths. Therefore, for most virtual mapping applications, 24-bit depth is usually the maximum.

An image's file size (for example, in terms of kilobytes [Kb], megabytes [Mb], and so on) is an important consideration for cartographers (see Table 16.2 for an explanation of storage sizes and terms). The final file size is determined primarily by the combination of the image resolution, the bit depth, and the compression (optional processing that reduces file size) used in a particular image file format type. A Web page with physically larger, higher resolution images with greater color depths and less compression will typically load more slowly and require more storage space than smaller, lower resolution images at lower bit depths and greater compression. Therefore, it is often desirable to minimize file size when preparing images for the Internet. Before surveying specific format types, it is important to briefly examine the impact of resolution, bit depth, and compression on an image's file size.

TABLE 16.1 BIT DEPTH AND NUMBER OF POSSIBLE COLORS

Bits per Pixel	Number of Colors	Comments
1	2	Black and white line work; simulated grayscale via dithering
2	4	
3	8	
4	16	
8	256	Color numbers 0–255 in a color palette
16	65,536	
24	16.7 million	Usually 8 bits per red, green, and blue channels
32	16.7 million	Additional 8 bits for transparency in the RGB model; 8 bits per channel if CMYK is used
48 (and more)	trillions (and more)	Useful if the image is going to be post-processed; otherwise is beyond human eye capabilities

TABLE 16.2 STORAGE TERMS AND SIZES

Term	Abbreviation	Actual Size in Bytes	Mathematical Power
Bit	b	0.125	2^0
Byte	B	1	2^3
Kilobyte	Kb or Kbyte	1,024	2^{10}
Megabyte	Mb	1,048,576	2^{20}
Gigabyte	Gb	1,073,741,824	2^{30}
Terabyte	Tb	1,099,511,627,776	2^{40}
Petabyte	Pb	1,125,899,906,842,624	2^{50}
Exabyte	Eb	1,152,921,504,606,846,976	2^{60}

The most significant component of a file's size is its resolution. A higher resolution results in a relatively large file size. Most artistic drawing software packages support a process called **resampling,** which is used to decrease the number of pixels in the image. Fewer pixels result in a decrease in the image's file size and reduce the quality and/or the physical size of the image.

A reduction in bit depth will also have an impact on file size, though usually not to the degree that resampling will. It is usually more common to reduce bit depths in images with more than 24 bits to make the image compatible with most browser/monitor combinations. Common bit depth transformations include a reduction to 24 bits when many colors are needed (such as when a photograph is in the layout or is included in the background, or if some sort of continuous shading is used) and a reduction to 8 bits when 256 colors will suffice (such as most thematic maps). When bit depth reductions are made, a **color palette** is often employed. A color palette is a collection of solid colors that are a subset of possible colors. The palette is usually not fixed, but can be adjusted to include the color options desired for a particular map. Palleted color is most common on lower-bit-depth images, especially 8 bits or less. Note that if *more* colors are needed than a lower-bit-depth palette can provide, it is often possible to "create" or emulate other colors by **dithering.** Dithering is the display of alternating pixels of two different hues or shades to create a visual impression of a color beyond what is on the color palette. For example, alternating black and white pixels will give a visual impression of gray. Unfortunately, patterns of dithering can often be seen if one looks closely enough at the image. Therefore, we usually recommend using sufficient bit depth (for example, 24) to include the needed colors for maps that incorporate photographic imagery.

Image compression will also reduce file size. Compression can fall into two categories, lossy and lossless compression. With **lossy compression,** image information is actually being lost in the compression process. The image's file size is reduced but at the expense of image quality. The designer will often have control over the amount of compression that is applied to the image. The greater the compression that is applied, the more information that is lost, resulting in a smaller file size and increasingly lower quality (see Figure 16.2). With **lossless compression,** the image's file size is reduced without losing image quality. Lossless compression algorithms will compress only information that is totally redundant, such as large homogeneous areas of a single color (for example, a large area of white space or a single color value for its pixels will allow for a great amount of compression in that part of the image). No information is actually lost in the compression process. The amount of compression that occurs is a function of the algorithm and is not under the direct control of the cartographer. Which type of compression (if any) that can be applied depends on the file format chosen for the image.

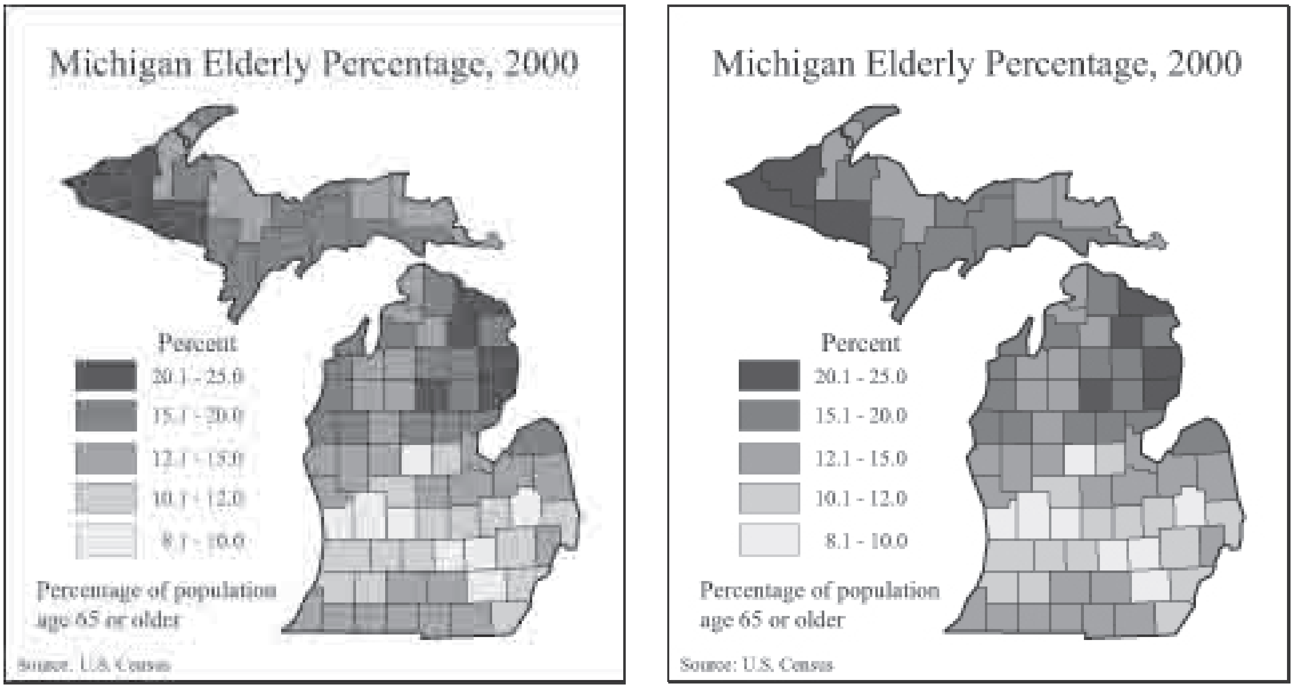
Selected Raster Image Formats

There are quite a number of raster image formats that a cartographic designer can use. These include formats that are proprietary to specific software, such as those for Adobe Photoshop (PSD), Corel PhotoPaint (CPT), Erdas Imagine (IMG), or those formats native to an operating system, such as the Windows Bitmap (BMP) format. Several types that are used extensively in Web and virtual cartography merit further discussion.

JPEG. The JPEG file, short for Joint Photographic Experts Group, is one of most common image formats on the Web today. It can be recognized from its file extension, usually .jpg, .jpeg, .jpe, or .jp2 (the latter is a newer modification of the jpeg format). At a 24-bit depth, the JPEG image can display over 16 million colors. This format also supports lossy compression. When used for satellite and aerial photographic imagery, the JPEG can be georeferenced with real-world coordinates to make it usable in GIS and mapping software.

This format is currently the most popular for distributing photographs, because it is effective for images with large hue and value ranges (particularly if little or moderate compression is applied). Thus, the JPEG format is popular for maps or map layouts that include imagery. It is important for map designers to note that lossy compression in JPEGs sometimes leaves some visual artifacts around letters and lines when a vector map in a GIS, mapping, or artistic drawing software is exported to a JPEG image.

GIF. The GIF image, along with the JPEG, is another important raster image format for the Web, since these formats are



(a) (b)

FIGURE 16.2 LOSSY COMPRESSION IN TWO JPEG IMAGES.

Figure 6.1 is converted to a compressed JPEG, resulting in image degradation in both (a) and (b). The amount of compression is greater in (a) than (b), but (b) will have a larger file size than (a). Caution is obviously urged if compression is to be used.

supported by all modern browser software. Short for Graphics Interchange Format, the GIF was developed in the late 1980s by CompuServe, and is now currently licensed by Unisys. The GIF employs an 8-bit depth, a 256-color palette, and a LZW (Lempel-Ziv-Welch) lossless compression algorithm. As a proprietary format, software manufacturers that employ GIFs or the LZW algorithm must pay a fee for their use.

Even at this relatively low-color-bit depth, the GIF is useful for cartographers primarily because many maps, such as a land-use map of 15 or 20 colors, do not require the use of more than 256 colors. The reduced file size from the lower bit depth and the universality of the GIF format make it a popular choice when exporting a map layout to an image format.

Two other capabilities add to the GIF's usefulness. First, the GIF format can also be used for short animation sequences. Although this capability is often associated with clip art that often clutters many Web pages, the format can be useful for making animated maps, usually of shorter duration (formats used for lengthier animations are discussed in the upcoming paragraphs). Second, the GIF file also allows for binary transparency, meaning that one color on the color palette can be set to a transparent setting. This feature allows backgrounds to show though every pixel that has a transparent value, although this can produce a jagged appearance between transparent and nontransparent areas.

PNG. The Portable Network Graphic, or PNG file, was designed as a nonproprietary Web standard that may someday replace the GIF (and possibly the TIFF file, discussed next). PNG supports both 24-bit true color and 8-bit paletted colors. Two hundred fifty-six levels of transparency are supported in the true color version of the format, providing a smoother transition between transparent and nontransparent pixels. Because lossless compression is used, PNG file sizes are larger than a comparable resolution and bit depth JPEG file.

Although PNG files do not support animation directly, because it is an open source (meaning that the code is nonproprietary and is widely available on the Internet), it is possible for software designers to create their own versions of the format, which could include animation. Most browsers support PNG files without the use of a plug-in, although a few browsers do not implement some of PNG's features (such as transparency) correctly.

TIFF. The Tagged Image File Format, or TIFF file, is another format that has been around since the 1980s but has seen many upgrades to its structure. These files can have extensions of .tif or .tiff. The TIFF can support a great number of color modes, bit depth levels, alpha channels, and other features, and can incorporate lossless or lossy compression (lossless is most common if compression is used at all). The net result is that TIFF files are usually some of the largest of the raster image formats. Thus, TIFFs are almost never used in a viewable form in a Web page (at least without a plug-in). They are either converted to JPEG, GIF, or PNG for direct viewing in a Web browser, or are made available as downloadable files when retention of the TIFF format is desired.

The TIFF format is important for cartographers for several reasons. Its robust structure and flexible capabilities have made it one of the most universal image formats in the graphics world. It is a standard for scanned documents, such as maps, pictures, and other materials. TIFFs are also popular for storing satellite and aerial photographic imagery. Some versions of TIFF are capable of storing georeferencing information, so they can be used in GIS and mapping software. They can also contain pyramid information that allows for display of the image at multiple resolutions. It should be noted that converting TIFFs to other image formats for easy display in a Web page usually results in a loss of the format's capacities and/or a degradation of its image quality.

Animated Raster Map Formats

There are several raster based formats available for creating animated maps. Some of the most popular include the cross-platform MPEG, Flash Video FLV, Microsoft Windows AVI or WMV, Apple's QuickTime format, and the Real Media format most often associated with digital video. Media so created are normally viewed in the browser (often with an appropriate plug-in) or in an external player. Animated maps stored in these formats are usually designed to be viewed in a linear fashion and for limited interactivity. That is, the map reader usually does not interact with the map beyond that which is provided in the standard controls for animated playback (for example, start, stop, pause, rewind, and so on.).

Vector Graphics

Vector graphics are the format of choice for most cartographers. For most mapping endeavors, whether in a GIS or mapping package, in an artistic drawing program, in computer-aided design (CAD), or in some combination of these environments, vector graphics are involved for most symbolization and other basic map elements in a typical layout. There are some distinct advantages to the vector format for Web cartography:

1. Cartographic symbolization using vector point, line, and area symbols is a natural, more aesthetic expression for features and map elements, particularly if the map is resized or rescaled.
2. The interactive capabilities are much greater in vector formats, since map features are treated as discrete objects.
3. The format is extremely versatile, since most vector formats can also include text objects and raster imagery (in some cases, this includes animated raster graphics). Vector animation is also supported in some file formats.
4. Vector file sizes are typically much smaller than for raster images.
5. Browser and plug-in support for Web vector formats is increasing.

Vector Concepts

The familiar point, line, and area representations of features form the basis of the vector data model. Point, line, and area features are treated as objects with changeable properties. A line object, for example, may have properties such as length, width, and color (even though the line being represented only has one dimension–length). An area feature will not only have outline color and width but will also have fill characteristics such as color or pattern. Vector features can be resized without the pixilation that occurs in raster formats. However, the amount of zooming that can take place is not endless; it is usually incumbent on the cartographer to set limits to the amount of zooming that is practical for his or her map.

Beyond these basics, vector structures have a fairly high variation in capabilities, depending on the format selected. Some formats support artistic embellishments such as shadow effects, gradient fills, and smoothing of curves. Many formats also accommodate raster images and text objects. Still other structures can incorporate interaction and animation.

As with raster graphics, there are a number of formats that are native to certain software packages. The ESRI shapefile (SHP) or the AutoCAD Drawing file (DWG) are two common formats in the GIS and CAD worlds respectively; Adobe Illustrator (AI) and CorelDraw (CDR) files are common artistic drawing software formats. Native formats are often preferred while working on a project within a specific software package, but if the information needs to be transferred or formatted for Web viewing, the graphics are usually saved to a format that can be used in a Web browser, or exported to another finishing program.

There are a number of formats that are designed to be cross-platform (between software programs and operating systems), for transferring vector graphics from one program to another. Many of these transfer formats are more precisely termed **metafiles.** Metafiles are sets of drawing instructions that inform the software how to draw the objects, based on their properties, and can usually accommodate text and raster imagery.

It is important for cartographers to understand that once graphics are exported to a metafile format, the linkages to the data, including the map's coordinate system are usually lost during the transfer process. Also, the quality of the transferred graphics can vary tremendously depending on the source program, the destination program, and the format selected. If you are transferring files from one program to another, experimentation is usually required to find out which format works best with your software configuration.

A number of well-established metafile formats exist that are primarily designed for drawing software or for transferring graphics across a variety of platforms. One of the earliest cross-platform formats was the Computer Graphics Metafile (CGM). Windows Enhanced Metafiles (EMF) are a common structure for transferring objects between Windows software programs. Encapsulated Post Script (EPS) files, discussed in Chapter 15, are used to transport PostScript Language files and are often used in printing environments. Although not usually categorized as a metafile, EPS files are sometimes used like a metafile as a vehicle for transporting graphics from one software package to another.

Selected Vector Formats

Most of these formats discussed so far are usually not directly placed into a Web page. They are most commonly converted into a format supported by browsers or browser/plug-in combination that can be used by many viewers. Four popular vector formats with a wide range of capabilities are discussed in more detail. For purposes of this discussion, they are treated as vector files but, as with metafiles, can often accommodate raster imagery and text as well.

Flash SWF. One of the first vector formats to be developed and arguably the most popular vector format for the Web is Flash SWF (sometimes pronounced "swiff"). SWF is a format for mixing vector, text, and raster objects (including controls for digital audio and video), and allows for a large degree of user interactivity and/or map animation. For example, maps stored as SWF files enable the map reader to pan and zoom on the map. Some other common options that map designers often include are point and click to obtain information about a specific feature, interactive legends to turn on and off features, and controls to start and stop a map object's movement. SWF files can be created in the Adobe Flash authoring system software, although some graphics programs can also export layouts to the SWF format.

For most of the features to work correctly, the map reader must have the most current Flash plug-in (Flash Player). Although SWF is a proprietary format, it is popular among cartographers for two primary reasons. First, Adobe asserts that over 90 percent of all browsers are Flash-enabled (Adobe Corporation 2007), so it is likely that the map reader will be able to see a Flash map. Second, basic map interactivity (panning and zooming) can be achieved without learning the program's scripting language (although one will have to learn the scripting language for more advanced functions).

SVG. Another vector format that cartographers should be aware of is the Scalable Vector Graphic, or SVG. SVG allows not only for combining vector, raster, and text objects but also for interactivity, animation, and other special effects (Neumann and Winter 2003). It is seen by many professionals as a vector Web alternative to SWF for those who do not wish to use (or perhaps are prohibited from using) a proprietary format.

SVG is based on XML, or Extensible Markup Language. Map layouts can be exported to SVG format directly from software such as ArcGIS, but to make the map interactive for the Web, the cartographer will have to write his or her own XML code. To view SVG files, a plug-in such as Adobe SVG Viewer is required.

PDF. Another popular format is the Adobe Portable Document (PDF) file. The PDF format is perhaps best known for cross platform distribution of text documents that can be viewed on the screen *or* printed at a fairly high quality. This duality of purpose is a hallmark trait of the PDF format (see discussion in Chapter 15 for its use in the printing and production aspects of cartography). Like SWF, SVG, and other metafile formats, the PDF file allows for the mixing of vector objects, text, and raster imagery. Zooming, panning, and insertion of hyperlinks are possible in a PDF file, but the format does not allow map animation or the degree of interactivity like that of the Flash format. Most browsers are enabled with Adobe Acrobat Reader, the plug-in necessary to view PDF files. Cartographers often choose to distribute maps via PDF when they want the map reader to be able to print out the map, or if the final use (virtual viewing versus printing) is unknown. A number of U.S. government Web sites distribute maps on diverse topics such as park trails, land use, and population density in the PDF format.

VRML. Finally, we mention Virtual Reality Markup Language (VRML). VRML is a format that allows for the display of three-dimensional vector graphics, although it can display two-dimensional graphics as well. These graphics can be rotated and scaled as desired by the map reader, and they can be used to interactively "explore" the surface, be it real or statistical. VRML graphics can be created from GIS and artistic drawing software packages that export to VRML, and can be viewed with an appropriate plug-in. VRML has held promise for the mapping community throughout the last decade, but has not yet realized its full potential in Web mapping.

UNDERSTANDING THE MEDIUM

In the previous sections, we have talked about the virtual map, particularly those maps that are meant to be viewed on a Web browser, and some of the most common formats in which they can be created. This section is written to give the cartographer a rudimentary understanding of the environment in which these virtual maps are used and displayed. The environment, or "medium," includes the Internet and the display monitor. The Internet is the medium in which most virtual maps travel, and the display monitor is the medium through which those same virtual maps are viewed. Both have an impact on virtual map design, which will be addressed in the last section of this chapter.

Key Internet Concepts

Perhaps no other development, save for the computer itself, has so dramatically affected the way maps are viewed, studied, read, responded to, constructed, and visualized as the introduction of the World Wide Web. It is important then, to have an understanding of the Web's basic framework and terminology, and understand how virtual maps can be delivered.

The origins of the Internet began in 1969 when experiments by the United States Department of Defense led to the development of Advanced Research Projects Administration (ARPANET) along with the first Internet protocol (IP). In the 1970s, industrial firms related to defense were the first to join the network, and then major universities came onboard. In the 1980s, the National Science Foundation became involved with the development of NSFNET, giving the system a temporary boost during a time of rapid Internet growth. By the late 1980s and into the 1990s, commercial establishments were allowed to join the growing "network of networks," and thus the infrastructure for the modern-day Internet was set in place.

The Internet's early success was due to four primary factors. The first was the ever increasing development of computer technology, notably increasing processing power and storage capability. The second was the underlying principle of **dynamic rerouting.** If one node on the Internet is shut down or becomes temporarily unavailable, then the information simply follows a different route. Third, by the late 1980s and early 1990s, most of the world had adopted transmission control protocol/Internet protocol (TCP/IP) for sending information across the Internet in "packets" (W3C 2007), and allowed disparate computer types to communicate with each other across a myriad of connection mechanisms. Fourth, by the 1990s, so many industries, commercial entities, independent organizations, government agencies, and educational institutions worldwide had joined the Internet that no single entity could claim "ownership" of it. Therefore, while a corporation or a country's government can restrict or shut down their particular node or nodes, takeovers, crashes, and the like of the entire Internet are not possible.

The World Wide Web

As successful as the concept of the Internet was, it would be in a form that most readers today would scarcely recognize—or perhaps even enjoy using. Prior to the early 1990s, the Internet was text-based and command-line driven, sometimes requiring the typing of many commands to accomplish simple things that we take for granted, such as emailing a friend, downloading a map (in the latter case, the map would have to be opened in an appropriate software package), or the easy searching for information via Google and other search engines that we enjoy today. It was not until the development of the World Wide Web and the modern graphical Web browser that "surfing the Web" would become the nearly universal concept that it is today.

The World Wide Web is a system that allows for linking of *resources* (text information, pictures, maps, videos, or other Web sites) on the Internet via **hypertext** (text that links to resources) and **hypermedia** (multimedia objects such as graphics that link to resources). The Web browser (as discussed in the first section above) allows for the Web surfer to view and interact with those resources. The Web and Web browser *combination* is what allows people to point and click on a certain highlighted text or graphic, and have new resources appear on the screen or become available for downloading.

Web resources are addressed and located according to a universal naming convention. This convention can be observed in examining a Web page's URL **(uniform resource locator),** which is usually listed at the top of the screen in the Web browser (W3C 2007). At a fictitious "My Site" Web site, for example, we can see the URL of some typical Web resources:

• My Site Web site	http://www.mysite.edu
• Web page at My Site	http://www.mysite.edu/population.html
• JPEG map of United States Population Density	http://www.mysite.edu/docs/USAPopDensity.jpg
• PDF version of the same map	http://www.mysite.edu/docs/USAPopDensity.pdf

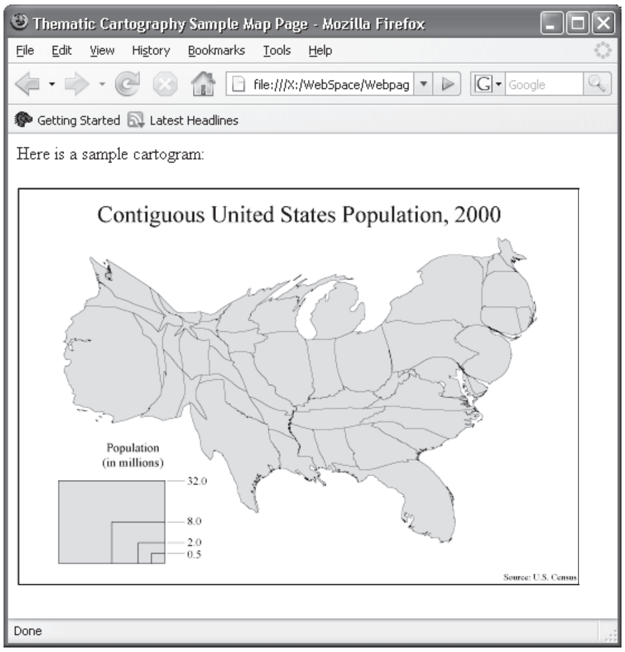
The domain name, such as mysite.edu, census.gov, or ebay.com can provide a context for the resources being accessed. Specific types of Web sites can be identified by the suffix or extension, such as government sites (.gov), business sites (.com or .biz), educational sites (.edu), and independent or nonprofit organizations (.org). In some cases, there will be a zone designation for a particular county, state, or country.

The second URL above (population.html) is for an individual Web page at the My Site website. A Web site can be as simple as a single Web page, or the HTML extension indicates that the Web page is written in **hypertext markup language.** Although there are many Web languages, HTML is considered the *lingua franca* of the Web (W3C 2007). A typical Web page will combine text, graphics, and other multimedia elements depending on the page's purpose and readership. Figure 16.3 is a simple Web page with a map graphic. The figure illustrates both the image file embedded in HTML code (Figure 16.3a) and how it appears to the map reader in the Web browser (Figure 16.3b). As noted in the boxed text "Strategies for Learning to Build Web Pages," a Web page such as this can be created in dedicated Web page creation and editing software, or can be directly coded using a simple text editor.

Web sites are often structured in a manner similar to how files and folders (or directories) are set up on a personal computer. In the second and third examples, the choropleth map USAPopDensity is available both in

```
<HTML>
<HEAD>
<TITLE>Thematic Cartography Sample Map Page</TITLE>
</HEAD>
<BODY>
Here is a sample cartogram:
<BR><BR>
<IMG SRC="cartogram.png">
</BODY>
</HTML>
```

(a)



(b)

FIGURE 16.3 HTML EXAMPLE IN AND ITS WEB PAGE APPEARANCE.

In this simple Web page example, the HTML code and the reference to the map graphic (a) and how it appears in the Web browser (b).

JPEG and PDF formats. They are both stored in the "docs" directory. The directory (or directories) between the domain and the resource is called the path, similar to the path for files stored on a personal computer. When the resources are accessed, the JPEG will open directly in the browser window, as will the PDF file (although the window will be somewhat modified by the Adobe Acrobat plug-in). A Web site can be as simple as a single Web page or it can be as complex as hundreds of Web pages in an extensive directory structure. An example of the latter is the United States Geological Survey Web site (www.usgs.gov). This site is popular with geographers and cartographers because of the wealth of maps, data, and other information it contains.

When someone writes a Web page, the virtual maps and the HTML code (or other programming), and other resources have to be uploaded and stored on a *server* in order for the public to be able to view the Web page. A server is a computer (or group of computers acting in concert) that make the Web resources that are stored there available to potential users. For example, when a map reader clicks on a link to view a map, it the server's job to send the appropriate map resource back to the map reader's Web browser. This is the simplest model of how the process works. (See the boxed text "Server-Side Mapping" for a brief discussion on another model for online mapping and data distribution.)

The Web page and other resources travel over wireless networks, fiber optic cables, telephone lines, and other Internet transfer mechanisms. A network's **bandwidth** is its capacity for transferring data, including both the uploading of Web pages and other resources to a server and the downloading of resources to the Web browser or one's computer. Some networks have greater capacities than others for handling large volumes of data. It should be noted that video and raster imagery are generally the largest files in terms of storage, and therefore consume the greatest amount of bandwidth of the media types. Text, such as the HTML coding, consumes the least amount. It is important to recognize that in some areas of the world, the audience may be accessing the Internet with a slow modem or using an Internet service provider with limited bandwidth capabilities. In such cases, placing an extremely large map image on the opening (home) page of your Web site, for example, will probably dissuade the would-be reader from downloading your maps or even viewing your Web page.

The Graphics Display Monitor

Web pages and virtual maps are viewed on a display monitor. It is extremely important for the cartographer to realize that display monitors can vary greatly in physical size, resolution, quality, and display of color from monitor to monitor. This means the virtual map will not take on the same appearance in all display environments. This last part of "Understanding the Medium" is devoted to this essential topic.

Graphic monitor displays currently range from the largest format high definition displays, with a diagonal viewing size of over 60 inches (not including projection devices), down to the small personal digital assistant (PDA), with a diagonal view of just less than three inches (Wintges 2003; Peterson 2005) or even less with a cell phone display. For purposes of this chapter, we will be focusing on monitor displays that are typically found on laptops or desktop work environments. Most of these are between 14 and 28 inches diagonal viewing, and will either follow a 4:3 or 16:9 **aspect ratio**—the ratio of the horizontal dimension to the vertical dimension in

SERVER-SIDE MAPPING

In this chapter, we are focusing on the simplest case of designing virtual maps and making them available to the Web, by uploading the map(s), often in the context of a Web site, to a server. When the map is sent to the map reader's browser, all activity associated with the map (including interactivity and animation) happens inside the map reader's computer and is known as "client-side" processing.

Earlier in the chapter we alluded to the fact with some interactive maps, the map reader may be interacting with an underlying GIS or other data distribution software and not be aware of it. A primary example is the zoom-to city mapping Web sites such as MapQuest (www.mapquest.com). The map reader selects an address, zip code, region, or named place. This information is sent to the server and the server generates a new map based on the map reader's information. The server then returns a static gif image or other graphic to the browser. If the map reader wishes to zoom in further, or pan the map to a different location, that information is sent again to the server, and the new map result is presented.

This technology is referred to as server-side processing, and the software that makes it run is called a server-side application. In server-side processing, a majority of the work is done by the application on the server, and the result is then transferred to the browser. Maps so produced are usually not predesigned by the cartographer but are created "on-the-fly" based on the requirements of the map reader as in the MapQuest example. The "map design" at this point is all about developing the interface and the options for the map reader's viewing and interacting with the map. Note that most server-based map applications have a tendency to favor general purpose reference maps, such as those sites that serve zoom-to-city street level maps, or those that deliver satellite and air photo imagery.

This method of distribution is becoming increasingly popular among both private and government agencies eager to find new and better ways of distributing maps, images, data, and related documents. If your site is data or image intensive, (for example, the user of your site can potentially download gigabytes of information), or if you wish to allow the user to do GIS-based processing, then you should consider developing a server-side Web page. Note that developing server-side applications requires access to greater computer resources, increased costs, and programming skills. If GIS analytical functionality is required, access to software such as ArcGIS Map Server is also required.

What about the popular Google Earth? Google Earth, like MapQuest, distributes aerial and satellite imagery from a server as previously described. However, it is sometimes considered a *hybrid* of client and server architecture, because Google Earth allows anybody to create their own content (for example, from their desktop computer) and merge it with the imagery from the server in Google Earth (Plewe 2007). For example, Krygier (2007) developed an animated choropleth map designed for viewing in Google Earth. The map's data, in the form of KML (Keyhole Markup Language) code is stored on the user's computer. KML is a markup language that supports 3-D geographically referenced data. When activated, the map animation runs on top of the imagery.

a monitor display's viewing area. (see Figure 16.4). In many classrooms and university settings, the 4:3 format is more common. The 16:9 format monitors, while more expensive than their 4:3 counterparts, are popular for their ability to show movies in a theatrical (or high definition) ratio.

Display monitors are raster devices. Like the images discussed previously in this chapter's section on "Raster Graphics," display monitors have rows and columns of *pixels*. The number and size of the pixels in the display's viewable area defines its *resolution*. The display monitor's *bit depth* (the number of simultaneous colors that can be displayed) is often called **color depth** when applied to the display. Over 80 percent of all monitors on the Web today are set at 1024*768 or higher resolution, and almost all monitors are set up to display over 16 million colors (24-bit or higher color depth) (W3Schools 2007).

Most display monitors are either CRT (cathode ray tube) monitors or LCD (liquid crystal display) monitors. The CRT monitor uses a set of electron guns that charge sets of phosphor-coated dots that exist for each of the additive colors (red, green, and blue) on the inside of the monitor screen. The speed at which the screen is refreshed is called the **refresh rate.** Screens that have a refresh rate of less than 60 Hz (60 times a second) often have a noticeable flicker, and can produce eyestrain if viewed for an extended period of time. CRT monitor resolution (and color depth) can easily be changed.

The LCD monitor arranges pixels into red, green, and blue sub-pixels. Unlike the dots in a CRT, the pixels are hardwired into a specific resolution (for example, 1024 by 768), so there is a "best" resolution that is associated with each monitor. Setting the resolution to other than the manufacturer's recommendation can lead to results that are less than pleasing (if all of your maps look fuzzy on an LCD display, the screen resolution may be a place to start looking). Like CRTs, they are capable of displaying millions of colors, and the flicker often associated with CRTs is not an issue.

The LCD monitor is rapidly replacing the CRT in many computer environments, but the use of both types is still widespread. Some graphics enthusiasts point out that color and particularly motion is better on the CRT, and if you can obtain one, they are usually less expensive than the LCD

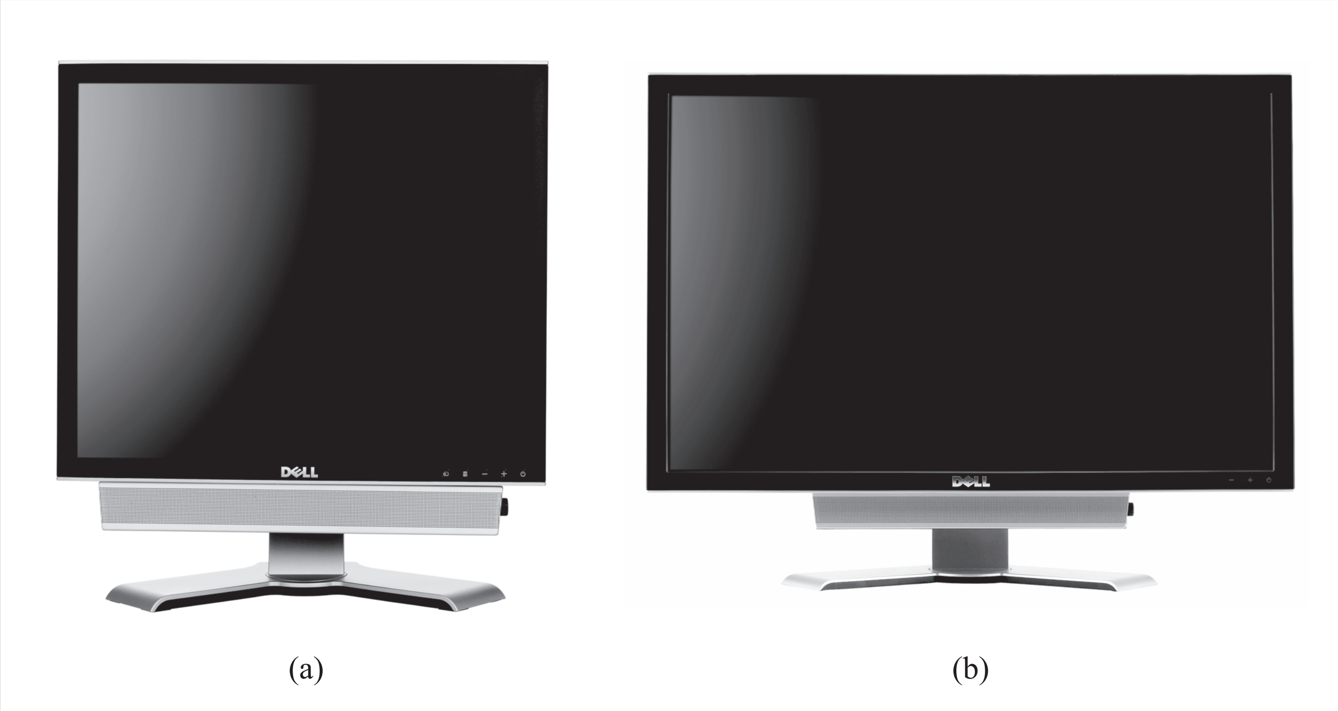


FIGURE 16.4 TYPICAL MONITORS AT BOTH 4:3 AND 16:9 ASPECT RATIOS.
The 4:3 monitor (a) is common in many academic settings, but the 16:9 monitor (b) is popular with those wanting the capability to view high definition (theatrical or wide-screen format) movies. Source: Courtesy of Dell Inc.

monitor. However, the CRT is bulkier and heavier than the LCD monitor, and uses more power as well. Even though the LCD monitor is hardwired for a "best" resolution, there is no flicker and therefore eye fatigue is noticeably reduced when using an LCD. It appears that the LCD will be the standard in the near future.

It should be noted that monitor resolutions are lower than printed graphics. Most display monitors operate at approximately 70 to 100 pixels per inch (depending on the size and resolution of the monitor), but printed graphics range from 600 dpi (dots per inch) in some inkjet printers, to 2400 dpi in many color laser printers, to over 4000 dpi in some high-end service bureau devices. This is one reason why the 72 dpi raster map (a common resolution for images on the Web) that looks so good on the screen often has such a poor printed appearance. Map designers should realize that limited screen resolution can be a liability, particularly with regard to text and in-map labels. Map design issues related to resolution will be discussed later in the chapter.

One other topic that is often overlooked in discussions about display monitors is the graphics card. The quality of the display, including the properties of resolution, color depth, and refresh rate (applied to a CRT) are a function of the *combination* of the monitor and the graphics card. The graphics card does the graphics processing and takes the load off the central processing unit (CPU). Advances in technology mean that the occasionally annoying trade-off between resolution and color depth is less of an issue now than a decade ago. Most graphics cards work reasonably well for two-dimensional graphics, but for three-dimensional animated graphics (such as a detailed terrain fly-through), a more expensive higher-end graphics card will produce noticeably better results.

The virtual map designer should also take notice that his or her map may take on a different appearance with different monitor brands and graphics card combinations, and with changes in settings to those hardware elements. Graphics on Apple monitors, for example, generally take on a darker appearance than with other brands. As noted in Chapter 14, display monitors have different internal settings that can be adjusted by the user, including contrast and brightness, and can radically change the intended look of a map. Again, understanding that the appearance of your virtual map will somewhat change from monitor display to monitor display is an important aspect of Web and virtual mapping.

DESIGN IMPLICATIONS FOR THEMATIC MAPPING

In the previous sections of this chapter, we have addressed some introductory concepts in Web and virtual cartography (including static, interactive, and animated maps); explored file formats and structures common for this type of mapping; and covered the basics of Internet, Web, and monitor technology through which these types of maps are delivered. In this final section, we explore some general map design issues that pertain specifically to Web and virtual mapping, focusing on both the limitations imposed and the opportunities afforded by the medium as discussed so far in the chapter.

Constraints of the Medium

Many issues are considered constraints in Web and virtual mapping. These can range from restrictions on map file sizes imposed by storage and/or bandwidth limitations to the expense and hassle of uploading the maps to a server (discussed earlier in "Understanding the Medium"). In virtual map *design,* however, the most important constraint is the resolution of the display monitor. The monitor's decreased resolution when compared with most printed maps, coupled with the monitor's size and fixed aspect ratio, places significant limitations on the cartographer's layout space and the map's potential detail level.

Limited Screen Real Estate and Resolution Ramifications

One of the major impacts of the monitor's resolution, size, and aspect ratio combination is on the overall screen "real estate." Decreased screen real estate lessens the area with which the thematic cartographer can create the map layout, including the map body, legend, title, and other basic map elements introduced in Chapter 1 (a complete discussion of basic map layout occurs in Chapter 12). Kraak (2001) notes that a number of Web maps lack many of these basic elements due to the lack of space, although we would also suggest that in many cases inadequate cartographic training and knowledge also plays a major role.

Some cartographers get around the space issue by placing all ancillary elements, such as the title, legend, and source statement outside the map graphic. For example, the title and source text may be placed in the HTML code of the actual Web page. In general, we recommend against this practice, particularly for raster image maps, because if the map reader extracts and saves the map from the Web site, important information will be lost when the map reader calls up the extracted map. Legends that are placed on a different Web page (requiring the reader to flip back and forth between pages), or below the map (requiring the map reader to scroll up and down the Web page) disrupt the legend's role as a visual anchor. Excessive flipping or scrolling between a map and legend page can be fairly annoying as well.

The decreased screen real estate also means that the rectangular aspect ratio of the display area makes it easier to create layouts in a landscape orientation. As such, political units with large north-south extents, such as California or Chile, can present quite a challenge to the cartographer. Units with modestly larger east-west extents, such as Colorado, Canada, or the continental United States, are easier to fit on display area, although units with more extreme east-west extents, such as Tennessee or Russia, can also be challenging.

If the cartographer is trying to limit or minimize the amount of scrolling, panning, or zooming that the map reader will have to use in order to take in the whole map, the virtual map will usually have to be more generalized than its printed counterparts. The decreased resolution and the pixel shape limits how small features and text can be on the map and still be legible. Ultimately, this means that fewer features, less detail, and less in-map text will be characteristic of virtual maps when comparing them to printed counterparts at the same scale. This resolution limitation has been called the Achilles heel of the medium (Monmonier 2005).

Other Screen Resolution Issues

All features—points, lines, areas, and text—are affected by the pixel's geometry, as evidenced in the **aliasing** (stair-step appearance) of lines on the map. Since the display monitor is a raster device, all maps are subject to aliasing. Any feature that does not have vertical or horizontal lines or edges is affected, although many artistic software packages provide anti-aliasing procedures that can lessen the jagged appearance of a feature, with varying degrees of effectiveness.

Smaller features can be extremely affected by pixel geometry, such as dots that turn to squares if they are too small in a dot-density map, or with small text labels. At this point, anti-aliasing procedures are usually ineffective. Text that is too small will lose its legibility, as the letters merge and the bowls on the individual letters begin to fill. If the text is rotated or otherwise placed on a curve, aliasing can be even more pronounced as the lines move away from a horizontal and vertical configuration, particularly with serif faces. To ensure legibility, we recommend a text size of at least 8 or 10 points for the final viewing scale of a map in virtual mapping applications.

If a map is originally created in vector format but is going to be exported to a raster image-format, it is wise to create the map at the final scale and size that you want it to be displayed. Images that will be embedded in a Web page can be resized via the HTML coding (or other Web languages). But rescaling or resizing rasterized linework usually results in excessive aliasing and pixilation. If the map ends up too large or too small for the Web page, then we recommend going back to the mapping software, changing the dimensions of the vector map, and re-exporting the map to a raster format. The result will be a more aesthetically pleasing map product.

Display Monitor Variations Limit Predictability

Because monitors vary in intensity, brightness, contrast, and so on, it is also important to revisit color (see Chapter 14 for discussion on color for monitor displays). Color depth can also vary, but since a majority of monitors are configured to accommodate over 16 million colors (24-bit depth or greater), the depth is not the issue that it was even a decade ago (W3Schools 2007). Ideally, it would be advantageous to view the maps on a number of display monitor and graphic card configurations. Since this is usually impractically, it is important that virtual maps be designed so that color levels used for features, area class fills (as in a choropleth map), and other map elements have sufficient difference between the color parameter hues, values, saturations so that individual monitor variations will not mask or otherwise adversely affect the intended map message.

ColorBrewer, the online color selection site discussed in Chapter 14 and in other chapters, can also assist with the selection of colors that work well with display monitors (Brewer 2007).

Solutions and Opportunities

With these limitations in mind, we turn our attention to some of the newer mapping techniques afforded by the medium. These include interactive mapping, map animation (virtual mapping concepts that were introduced in the first section), and cybercartography—a new term describing some other exciting possibilities for different kinds of Web mapping. Although any type of virtual map is subject to the medium's constraints, these areas provide at least partial solutions that even well-designed static maps cannot provide to the same extent.

Map Interactivity

Although static maps are currently the most common virtual form, the capability for the users to interact with maps is one of the hallmark benefits to virtual cartography, and can be part of the solution to the decreased screen resolution and real estate problem. Some of the most common functions for interactive maps tend to emulate basic GIS activities, such as panning and zooming, selecting layers of information to be turned on or off, and interaction with individual features. These functions can operate separately or in concert so that not all features need to be labeled or be visible at all times.

Panning and zooming techniques are especially popular for interactive vector reference maps that have not been generalized for smaller scales. Most map users are reasonably comfortable with the concept of panning and zooming (Harrower and Sheesley 2005). However, for most thematic maps, which are typically designed at medium or small scales, we suggest that maps that require *excessive* panning or zooming can interfere with the effort to communicate an overall distribution or pattern. Care in choosing the correct scale and generalization level is still one of the most important roles for the cartographer, and panning and zooming capability should not take away this responsibility.

Layer selection is another popular interactive map technique. With layer selection, layers of information, such as cities, population densities, rivers, and so forth can be turned on or off by the map reader. This allows the map reader to explore relationships between layers and to select a comfortable complexity level. Layer selection is a viable alternative to juxtaposing maps of related information (common in print cartography) in order to make map comparisons, since the limited screen real estate makes virtual multiple map layouts difficult.

Pointing and clicking on features to reveal information and attributes, such as clicking on a city or river to discover its name and population or average daily flow, is another common interactive function. This technique can be applied to most of the thematic map types covered in Part II of this text. For example, in an interactive choropleth map, the map reader could click on an enumeration unit to see its name and specific value.

For the most part, interactive mapping is done in the vector realm. However, there can be an element of interactivity that can be introduced into raster imagery. Web programmers refer to a clickable image as an *image map* (whether or not the image actually is a map). The pixels in an image have absolute X and Y locations. Using HTML, JavaScript, Java, or other programming applications, rectangular, circular, and even irregularly shaped areas can be made active within the image. The map reader can click on these active areas, and perform whatever function has been programmed by the Web page's designer. Thus, a map can be made to display another map, perhaps at a different scale, or have a feature be identified in a text box when clicked—even though it is not a feature-based structure.

Animation

In the first part of this chapter, we introduced the concept of map animation. Using motion as visual variable is an exciting prospect to many map designers. Temporal animations (animated maps that illustrate change over time) are currently the most common type of animated map (see Color Plate 16.1). However, animated maps can be nontemporal as well, such as an animation of one map projection of the world being changed into another to compare projection properties. Animated maps can also take a three-dimensional form. Since three-dimensional animations usually involve topography of an area, they are referred to as a terrain fly-through or fly-over, because the view is like flying though a virtual landscape in a simulated aircraft (see Figure 16.5). But note

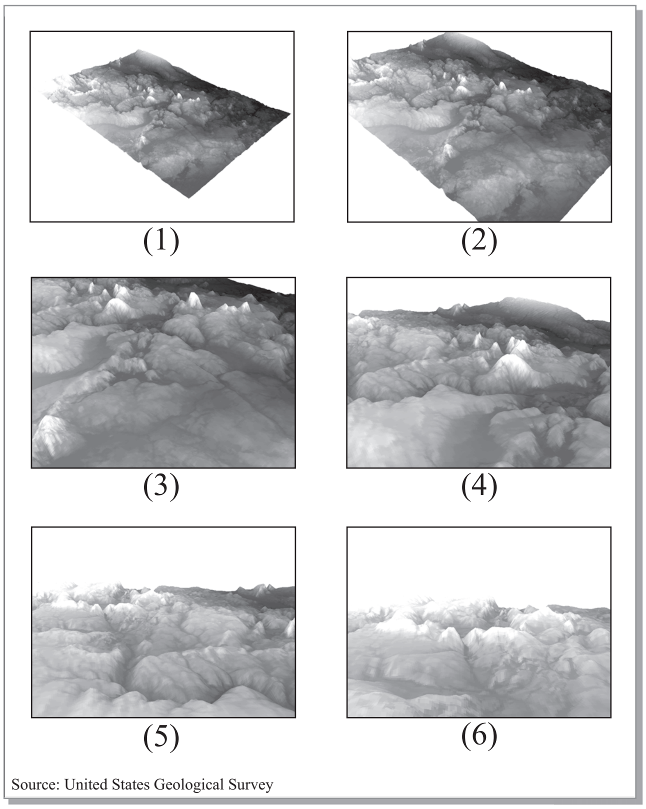


FIGURE 16.5 SELECT FRAMES FROM A 3-D TERRAIN FLY-THROUGH.

that any statistical surface that can be mapped in 3-D form can be made into a fly-over.

Like interactive maps, map animation can be part of the solution to the screen real estate problem, since animation is often used in place of displaying multiple maps side-by-side. For example, if the cartographer's thematic map topic is the change in an area's population density from 1900 to 2000, he or she could create four or five individual maps showing this change, or present the change in one animated map. The single animated map will fit much better on the display monitor than will multiple maps. From a communication standpoint, the current research is not definitive on whether multiple maps or an animation is "better." However, there is research suggesting that map animation can be a viable construct for communicating spatial information (Torguson 1993), even in the context of animation being an alternative to using multiple maps (Griffen *et al.* 2006).

Animated maps predate most current types of virtual maps, having been produced as early as the 1940s (Harrower 2004), albeit using film technology. The first academic paper on the subject by Thrower (1959) started a generation of animation research. This research often included the creation of map animations on a variety of subjects, but this research did not lead to the adoption of animation as a major cartographic form prior to the early 1990s (Campbell and Egbert 1990). Recent advances in technology have made it practical for cartographers to create this type of virtual map and distribute it on the Web, where animated maps of everything from tectonic plate movements to regional histories are now found in abundance. The combination of GIS, artistic drawing programs, and/or dedicated animation software can be used to generate animated maps, although creating them can sometimes be quite labor intensive.

There are two primary types of animated maps in terms of creation and storage (Peterson 1995; Harrower 2004). The first and conceptually simplest is **frame-based animation.** Gersmehl (1990) likened frame-based animation to a "flip-book." That is, a sequence of images is displayed in rapid succession, creating the illusion of motion. Individual frames are created in a GIS or drawing program, and are sequenced and stored as an animated GIF (for smaller animations) or in one of the other animated raster map formats discussed earlier. As noted in that section, animated maps stored in these formats are usually designed to be viewed in a linear fashion and for limited interactivity. Thus, the map reader usually does not interact with the map beyond that which is provided in the standard controls for animated playback (for example, start, stop, pause, rewind, and so on).

The second type of animated map is **cast-based animation,** which is accomplished in software that supports vector formats such as Flash or SVG (discussed earlier). In cast-based animations, cells are individual frames of animation that can have multiple layers. Objects—the cast members—can be placed on these layers, and can either be moved manually on a frame-by-frame basis or by a process called **tweening**—short for "in-betweening" (Peterson 1995). When tweening is used, the cartographer will set up a beginning and ending **key frame,** and the software will automatically generate intermediate frames, moving the object (and, in some cases, changing its shape or color) in the process (see Figure 16.6).

There are three distinct advantages in designing a map using the vector oriented cast-based animation. First, a vector structure can be easily rescaled, meaning that the animation can be played at multiple resolutions without additional pixilation or related problems. Second, the resulting files tend to be much smaller and therefore consume much less bandwidth than their raster counterparts (Harrower 2004). Third, and perhaps most important, the vector structure enables the map reader to be able to interact with the map. All of the benefits of interactive mapping can be combined with map animation. For example, if several objects are in motion, the map reader could turn each of them on or off to examine individual movement patterns or perhaps relationships between a selected subset of these objects.

A major design goal in map animation is usually to develop a reasonably fluid animation. If too much change occurs too quickly, then the eye may not perceive the detail intended by the cartographer, or the map may take on a jerky appearance. Conversely, there must be enough change to warrant using animation in the first place or the map may become uninteresting. In this case, the bored map reader may actually miss the few but perhaps important changes that are happening. Thus, it is important to provide controls that allow the map reader to start, stop, back up, or fast forward the animation, loop the playback, and control the frame rate, in order to absorb the information at his or her own pace (Torguson 1997; Harrower 2003).

It is also important to revisit some of the basic map elements (discussed in Chapters 1 and 12) when creating animated maps. As with most static thematic mapping, not all elements are necessarily going to be present on every animated map. One of the most important elements in animated *thematic* maps is the legend. The legend information needs to be in fairly close proximity to the map body, and cannot change position or form if it is to serve as a visual anchor for the symbolization. For example, in the animated choropleth map depicted in Color Plate 16.1, the same legend is used for every frame in the animation. The classification is based on the lowest and highest numbers in the data set, and the class ranges stay the same (see Chapter 6 for more discussion on legend construction for animation and multiple maps).

When the animated map is temporal in nature, it is important to have some form of indicator to represent passage of time. In the same way a graphic or representative fraction is used to depict spatial map scale, the indicator is used to depict temporal scale. Peterson (1995) identifies two expressions of temporal scale that are quite common today. The first is to display the date, year, or time of day in numeric form. As the animation progresses, the numbers will change

FIGURE 16.6 TWEENING BETWEEN KEY FRAMES IN A CAST-BASED ANIMATION.
Tweening (2 and 3) occurs between key frames (1 and 4).

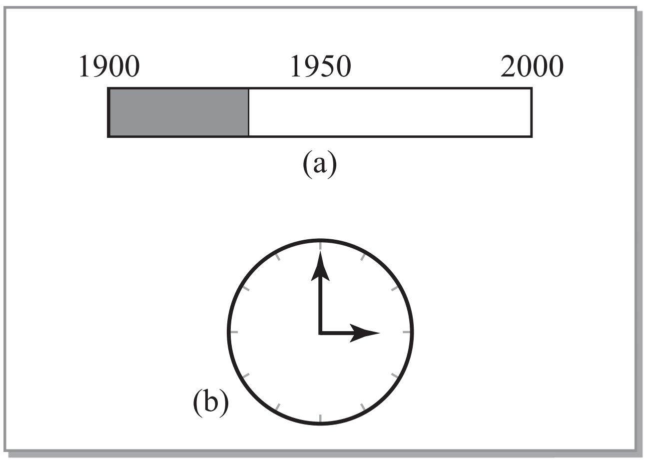


FIGURE 16.7 GRAPHIC TEMPORAL SCALES.
Using a timeline (a) and a clock (b). Source: After Kraak *et al*, 1996.

(see Color Plate 16.1). The second expression is analogous to the graphic or bar scale, and is illustrated in one of two ways (see Figure 16.7). In the timeline scale (Figure 16.7a), an indicator is included showing the location on the timeline that corresponds to the map at that moment in time. Temporal scale can also be illustrated as a clock (Figure 16.7b), which is common when the scale is measured in minutes or hours. For nontemporal maps, the animation player's built-in progress bar is usually sufficient to show how far the animation has progressed.

Finally, north arrows and inset maps are two basic elements that are commonly used in conventional cartography. Many small- and medium-scale thematic maps do not include these basic elements simply because, when the orientation is north and the map region is recognizable to the prospective map readers, they are often not necessary. However, 3-D terrain fly-throughs are often developed at relatively large scales. A small inset map can be included in the layout to show the mapped area's relative location. During the course of the fly-through, the orientation of the map may change numerous times. An animated north arrow indicating the current direction at that place in the animation should be considered.

Cybercartography

Throughout this text, we have pointed out numerous possibilities for virtual maps. And it is the exciting new and future possibilities that have given rise to a new term that encompasses both current and future prospects—**cybercartography.**

We end this chapter with a brief discussion on cybercartography, a term that was redefined by Taylor (2003), and expounded upon in his book *Cybercartography: Theory and Practice* (Taylor 2005).

Cybercartography is a term that is used to define much of the current state of Web and virtual cartography and the possibilities on the horizon for virtual cartography. The term includes all of the aspects of Web mapping discussed in this chapter—and more. Taylor (2003, 407) outlines the seven major elements of cybercartography as follows:

1. *Cybercartography is multisensory, using vision, hearing, touch, and eventually, smell and taste.*
2. *Cybercartography uses multimedia formats and new telecommunication technologies, such as the World Wide Web.*
3. *Cybercartography is highly interactive and engages the user in new ways.*
4. *Cybercartography is applied to a wide rage of topics of interest to the society, not only to location finding and the physical environment.*
5. *Cybercartography is not a stand-alone product like the traditional map, but part of an information/analytical package.*
6. *Cybercartography is compiled by teams of individuals from different disciplines.*
7. *Cybercartography involves new research partnerships among academia, government, civil society, and the private sector.*

Of course, many of the items on this list are things that geographers, cartographers, and other mapping scientists already do. But the *combination* of all of these elements can serve as a framework or roadmap for things to come in Web and virtual mapping. In other words, the term that encompasses these seven elements serves to "reassert and demonstrate the importance of maps and mapping and the centrality and utility of cartography in the information era" (Taylor 2005, 6)—something that most cartographers want for their profession.

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GLOSSARY

aliasing the stair-step like appearance of nonhorizontal or nonvertical lines on a raster screen display or image

alpha channel bits in an image that are reserved for creating masks in some software, or for specifying transparency values; often the last 8 bits in a 32-bit image

animated map motion or appearance of motion in a map; in thematic cartography, often applied in cases where attributes change over time, called temporal animation

aspect ratio the ratio of the horizontal dimension to the vertical dimension in a monitor display's viewing area (typically 4:3 or 16:9) or in a raster image

bandwidth in any sort of network environment, the amount of information that can be processed at one moment in time; maps and other graphics consume more bandwidth than does text

bit depth the number of binary bits used to define color (or shade) in each pixel in the monitor or in a raster image

browser a program that allows the user to view and interact with information on the Internet; Internet Explorer, Mozilla Firefox, and Opera are examples of popular browsers

cast-based animation vector-based form of animation where objects are moved and manipulated in layers and/or with a background

color depth number of simultaneous colors that can be displayed on a display monitor at one time; see also bit depth

color palette any collection of solid colors that is a subset of a larger collection of colors; the term is usually associated with images of lower bit depths

cybercartography a view of cartography, technology, and Web in future terms; usually described as having seven elements (see text for the list)

dithering displaying alternating pixels of different hue or shade to create an impression of another color; usually associated with the use of a color palette in a raster image

dynamic rerouting Internet principle that allows packets of information to take on any one of a number of routes as information goes from the source to its destination

frame-based animation a sequence of images displayed in rapid succession, creating the illusion of motion; each image is called a frame

hypermedia like hypertext (below), links multimedia objects to other resources on the Web

hypertext text that points to other resources on the Web

hypertext markup language (HTML) language for the Web that allows for hypertext that is used to author a Web page; other languages are also used, but at present, HTML is considered the most basic and standard

image as a file format, synonymous with a raster image; in a cartographic layout, image data is sometimes associated with remotely sensed imagery or picture data

interactive map map in which the map reader can click and interact with features or layers, often in the same way that a GIS user might interact with map layers in a GIS

key frame a frame in animation in which the objects are fully designed by the cartographer; usually applies to animation in conjunction with tweening; See also tweening

lossless compression compression of a file in which no information is lost; this means no reduction in an image's quality on reduction

lossy compression compression of a file in which some information is lost; the greater the compression, the more degradation of the image's quality, but the image's file size will be smaller

metafiles files that are sets of "drawing instructions," which tell various software packages how to render and display, point, line, area, text, and raster objects; often used to transfer graphics from one program (or platform) to another

pixel smallest resolvable element on a CRT or LCD display, or in a raster image

refresh rate the rate or speed at which a CRT screen is refreshed; screens that have a refresh rate of less than 60 Hz (60 times a second) often have a noticeable flicker, and can produce eyestrain if viewed for an extended period of time

resampling changing the resolution and or number of pixels in an image (reduction is most common in Web mapping); this will alter its storage size, physical size, and clarity

resolution the number and size of the pixels on a display monitor or a raster image, often described in terms of the horizontal and vertical dimensions (in pixels) and/or pixels per inch (ppi)

static map a map that does not have animated or interactive qualities

tweening the process in animation that allows software to generate intermediate frames in between designated key frames

uniform resource locator (URL) the URL identifies the "Web address" of a particular resource; more specifically, it includes the naming scheme, the resource, and the host computer (W3C 2007)

virtual map a map that is viewable but impermanent, such as a map that is displayed on a computer monitor; virtual maps originally had several definitions, depending on the map's permanence and information storage (after Moellering 1984)