Using High-Resolution Digital Scans in Multimedia Cartographic Applications

David W. Tilton

David Tilton is a Research Associate in the Department of Geography at the University of Wisconsin-Milwaukee, Milwaukee, WI 53201 tilton@csd.uwm.edu

Since June of 1993, the Geography Department at the University of Wisconsin-Milwaukee has been engaged in a research project to develop the *Archive of Native American Maps on CD-ROM.* A major component of this project involves the creation of high-resolution scans of the maps in the archive. This paper discusses several issues encountered in the acquisition, manipulation and display of these scanned images. The issues include scanning resolution, file compression, palette shifts, and image tiling.

INTRODUCTION

The Geography Department at the University of Wisconsin-Milwaukee has been engaged in a research project funded by the National Endowment for the Humanities Reference Materials/Tools Division to create an archive of Native American maps on CD-ROM. A large part of the project, which is more fully described in Sona Andrews's paper (pages 31-36), involves the creation of high-resolution digital scans from 35mm slides of the maps that are being assembled for the archive. This paper discusses several issues encountered in the acquisition, manipulation, and display of these scanned images. The issues include scanning resolution, file compression, palette shifts, and image tiling.

SCANNING RESOLUTION

One of the primary goals of the archive is to provide researchers with extremely high-quality images at a resolution that achieves at least a thirty times magnification of a 35mm slide when viewed on a standard computer monitor. The first step in assessing the scanning technologies available for creating these images was to establish the resolutions that would be necessary to obtain the desired magnifications.

Digital scanning technologies replicate images by creating bit map, or raster, files in which the information used to recreate the images is stored in a table of rows and columns (see Figure 1). When the image is displayed on a computer monitor, the computer translates the table cells into picture elements (pixels for short). The bit value for each cell determines the color of that pixel. For example, for a black and white image, a cell with a value of 0 will produce a white pixel, a cell with a value of 1 will produce a black pixel. The density of the table cells, or pixels, establishes the resolution of the image,

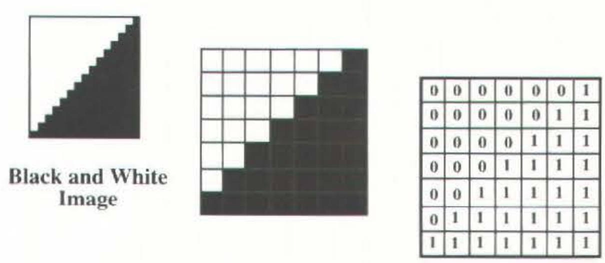

Image Type	Bits per Pixel	Colors per Pixel	Sample File Size
Line Art	1 bit	2	100 k
Gray Scale	8 bit	256	800 k
24 bit RGB Color	8 bit (R) 8 bit (G) 8 bit (B)	256 (R) 256 (G) 256 (B)	2400 k

Figure 1. Bit- map files store the information used to recreate images in a table of rows and columns. When the image is displayed on a computer monitor, the computer translates the table cells into picture elements (pixels for short). The bit value for each cell determines the color of that pixel; the number of bits per pixel determines the file size and resolution of the image.

which in turn determines how sharp the image will be when it is displayed. Most computer monitors are about 13" along the diagonal and have a grid of pixels 640 wide by 480 high for a resolution of approximately 72 pixels per inch (ppi). File sizes for gray-scale or color images are larger because more information per pixel is needed. For example, gray-scale images require 8 bits of information per pixel, whereas photo realistic color requires 24 bits of information per pixel.

For multimedia, images are generally scanned at low resolutions so that the full image can be displayed at sizes up to 640 x 480 at 72 ppi (full screen on a standard computer monitor). This is considerably less than the resolutions needed for the archive. However, at the time that we began trying to determine the resolutions we needed, the only formulas available for high-resolution scans were those used for printed output.

For multimedia, images are generally scanned at low resolutions so that the full image can be displayed at sizes up to 640 x 480 at 72 ppi (full screen on a standard computer monitor).

The standard formula for determining the appropriate scanning resolution for a printed image is: take the halftone lines per inch and multiply them by two times the scaling of the image. For example, to print a 35 mm slide at eight by ten inches with a halftone screen of 150 lines per inch; you would scan the slide at 2175 ppi (150 x 2 x 7.25 = 2175 ppi). With this formula, an increase in scanning resolution will result in the printed output having either an increased density of the printing dots within the same area or a larger printed area. However, when scanning for output to a monitor, the only variable that can change is the size of the image since the resolution of the monitor remains constant. Consequently, the formula can be simplified considerably–the resolution of the monitor is multiplied by the amount of the desired enlargement. For example, for a 30 times magnification of a 35mm slide, you would scan the slide at 2160 ppi (72 x 30 = 2160 ppi).

With this formula in hand, we were in a position to evaluate and test the available scanning technologies–two of which are mentioned here. One that seemed promising at first was Kodak's Photo CD. With Photo CD, the slides are scanned at a reasonable cost ($2.00-$5.00 a slide) and returned at five different resolutions on a CD-ROM (see Figure 2 below). While Photo CD looks promising for many applications, its highest resolution is only capable of producing a magnification slightly over the minimum we were hoping to achieve, and after running a number of tests, we decided that this wasn't quite high enough for many of the detailed maps in the archive. As a result, a Nikon LS 3510-AF slide scanner that could achieve magnifications of slightly over 44 times was purchased. Figure 2 compares the five resolutions of Photo CD with the resolution produced by the Nikon scanner. Figure 3 (page 37) compares a portion of a map, scanned at the highest Photo CD resolution, with the same area scanned on the Nikon.

One of the design criterion for the archive stipulated that it should be able to be used on a standard multimedia computer system. However, presenting high-quality images at the resolutions used in the Archive raised a number of issues for meeting this criterion. One issue was that some form of image compression would be needed so that all 400 or so images could fit on one CD-ROM. The second concerned whether the images would be viewed in 8 bit,

System	Image Size (in pixels)	Image Size (in bytes)	Enlargement
Kodak Photo CD	192 x 128 384 x 256 768 x 512 1536 x 1024 3072 x 2048	72 K 288 K 1.1 MB 4.5 MB 18.0 MB	1.9 x 3.9 x 7.8 x 15.5 x 31.0 x
Nikon LS-3510-AF	4257 x 2881	35.1 MB	44.1 x

Figure 2. Comparison of the five 35mm scan resolutions from Kodak's Photo CD process with the maximum resolution for a 35mm slide from a Nikon LS-3510AF transparency scanner.

16 bit, or 24 bit color. A third issue was that some form of memory management system would be needed so that the images could be viewed from within the archive application.

COMPRESSION

Compression algorithms fall into two general categories: lossless and lossy. Ones that are lossless retain all information from the original file but store it more efficiently by eliminating duplications in the pixel information (i.e. they create a more efficient table structure). The original file can be replicated exactly without any loss to image quality, and changes made to a decompressed file can be saved and compressed again without degrading the image. The drawback is that only moderate savings in file size can be achieved. Lossy compression algorithms, on the other hand, can compress files by ratios as high as 100 to 1. However, they achieve these ratios by throwing away information from the original file that is perceptually less critical. This means that, although a decompressed file is visually similar to the original, it is not identical. Consequently, once a file is compressed, it can be decompressed and viewed, but it cannot be edited and resaved without incurring generational image quality loss.

Figure 4 shows the effect of moderate and high JPEG compression applied to one of the images from the archive. JPEG is a standard established by the Joint Photographic Experts Group for developing lossy compression algorithms. The image on the left is not compressed, the image in the middle has been compressed moderately, and the image on the right has been subjected to high compression. The severe pixelization that appears in the image on the right results from compression artifacts that are indicative of high JPEG compression. We have found that, with the maps in the archive, we can consistently achieve a compression ratio of about 30 to 1 without noticeable image quality degradation. This ratio allows all of the images to fit onto one CD-ROM and still have space to accommodate the text database and application.

One drawback to the use of image compression is that the time needed to decompress the images as they are called into the archive program can result in sluggish performance. In order to speed this process, we employ a software decompression accelerator that reduces decompression times by a factor of five. This essentially allows the images to be decompressed and read into the program as quickly as the CD-ROM drive can read the data.

COLOR BIT DEPTH

The color bit depth at which the images in the archive are displayed has a tremendous impact on image quality. Systems that use 24 bits draw from a palette of millions of colors to display an image, while 16 bit systems draw from a palette of thousands of colors. However, 8 bit systems draw from a palette of only 256 colors, and in the process of reducing the thousands or millions of colors used to display an image down to a standardized palette of 256, image quality is substantially degraded.[1] When viewed in 8 bit color, the usefulness of many of the images, especially the detailed low-contrast images that make up a substantial portion of the archive, was considerably reduced.

This raised the dilemma of trying to maintain image quality but still making the archive accessible to a wide range of users. Although 16 bit

[1] By using customized palettes that select the best 256 colors to represent an image, 8 bit color can be significantly improved. However, this substantially reduces the amount of compression that can be achieved.

color is quickly becoming a display standard for multimedia computer systems, we had hoped to make the archive available for use on 8 bit systems as well. Initially, we had envisioned creating the images in 24 bit color and using the same images in 16 bit and 8 bit systems. This strategy works beautifully for 16 bit systems, but not for 8 bit systems. In Macromedia DIRECTOR, 24 bit images viewed in 8 bit color undergo a noticeable palette shift which further degrades the image (see Figure 5, page 37). This palette shift occurs as the result of two non-related conditions. First, Macromedia DIRECTOR, the authoring software being used, requires that the application be created to run in either 24 bit or 8 bit color. If a 24 bit application is run in 8 bit, it results in the palette shift. This can be resolved by creating a separate 8 bit version of the archive. However, the second condition complicates this solution. The decompression accelerator used in the archive creates the same palette shift when 24 bit images are displayed on an 8 bit system. Consequently, it would require the creation of a separate non-accelerated version of the archive in order for it to be viewed on 8 bit systems. Given that many of the images are of questionable value when viewed in 8 bits, it was decided that the only version of the archive that would be distributed at this time would be for 16 bit and 24 bit systems.

In Macromedia DIRECTOR, 24 bit images viewed in 8 bit color undergo a noticeable palette shift which further degrades the image.

Another issue encountered in working with image file sizes as large as those in the archive is that the computer must have enough RAM (random access memory) available to store the entire image while it is being viewed. Images of the size included in the archive would require a computer with over 30 MB of RAM–a level well above the five to six megabytes found in standard multimedia computer systems. Most image processing programs such as Adobe PHOTOSHOP or DEBABELIZER overcome this problem by using virtual memory that allows the program to use part of the hard drive as if it were RAM. However, multimedia authoring programs such as DIRECTOR generally do not have virtual memory capabilities, and consequently, alternative methods for presenting these large images in systems that have about five or six megabytes of RAM needed to be developed. After investigating several different options, a strategy in which the images are systematically cut into 320 x 240 pixel (1/4 screen) tiles was adopted.[2] Controls are provided in the archive that allow users to scroll through the tiles as if they were panning around the entire image. Each tile is only about 225 kilobytes in size and no more than four tiles (one screen's worth) are presented at any one time. As a result, less than one megabyte RAM is dedicated to displaying the tiles, and the entire archive application can run on a system with about 4 MB of free RAM.

CONCLUSION

High-resolution scans increase the complexity of multimedia development considerably, and the issues discussed briefly in this paper have taken us months of testing and research to determine. For centuries, cartographers have found themselves in a position of shaping new technologies to accommodate large, detailed graphics, and multimedia is proving to be no exception. As an industry, multimedia has, with rare exception, accepted the size of the monitor as the limit of its design space. However, as cartographers, we find ourselves having to push that limit in order to accommodate the special needs of presenting maps.

[2] The archive prototype that is available through anonymous ftp (file name archive.sea.hqx.) uses a tiling system that was developed in the early stages of the project. Instead of 1/4 sreen tiles that provide a 50% visual overlap, the prototype uses full screen tiles that incorporate only about a 25 to 20% visual overlap. For information on obtaining a copy see the *Message from the Editor* (page 1).

ACKNOWLEDGMENTS

The *Archive of Native American Map on CD-ROM* is solely funded by a National Endowment for the Humanities Reference Material/Tools Division grant (#RT-21464-93) awarded to Sona Andrews, David Tilton, and Mark Warhus. The work is being carried out in the Geography Department at the University of Wisconsin-Milwaukee. Dr. G. Malcolm Lewis at the University of Sheffield in England is working as a consultant on the project, and the project's Advisory Committee is comprised of experts in the fields of Native American History, Geography, Cartography, and Anthropology. The grant began in July of 1993 and runs through December of 1994.

EDITOR'S NOTE

This paper was presented at the 90th Annual Meeting of the Association of American Geographers, San Francisco, California on March 30, 1994.

RESUMEN

Desde junio de 1993, el Departamento de Geografía de la Universidad de Wisconsin-Milwaukee, está trabajando en un proyecto de investigación para desarrollar un archivo de mapas sobre los indios americanos en CD-ROM. Un componente importante de este proyecto es la exploración de los mapas existentes. Esta investigación trata diferentes aspectos como: la adquisición, la manipulación y la exhibición de imágenes. También incluye la exploración, la compresión de archivos, la colocación de paletas y la reproducción de mapas originales.

SOMMAIRE

Depuis juin 1993, le Département de géographie de l'université du Wisconsin à Milwaukee s'occupe d'un projet de recherche de développement de l'archivage de cartes amérindiennes sur disque optique numérique (CD-ROM). Une composante essentielle de ce projet inclut la création de balayages haute résolution des cartes des archives. Ce document discute de plusieurs problèmes rencontrés dans l'acquisition, la manipulation et l'exposition des images résultant du balayage, qui comprennent la résolution du balayage, la compression des fichiers, les décalages de palette et le quadrillage de l'image.

❑