

HOW MULTIMEDIA AND HYPERMEDIA ARE CHANGING THE LOOK OF MAPS

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ABSTRACT

The ideas of what constitute the presentation format of maps have changed. We now have the opportunity to create not only maps printed on paper or displayed on a computer monitor from a digital file, but we can present them on a television screen from a digital Photo CD, an analog laserdisc, or videotape. We can even add motion, sound, and interaction to the cartographic image. This great diversity in types of media and the opportunity to integrate and link these various forms to cartographic information is changing the way we create and use maps. As cartographer's begin to explore and incorporate multimedia and hypermedia technology into their work they are confronted with a host of tools and ideas. This paper discusses a range of multimedia hardware and software available for use in cartographic displays and presents the results of a research and demonstration grant funded by the United States Department of Education to create an interactive videodisc on mapping. The videodisc contains thousands of still frame images of over 600 maps and 25 minutes of motion video, all linked to a digital database containing information about each map. Access to the map images and database are possible through an interface designed specifically for this project.

INTRODUCTION

In the not-so-distant past the sole medium for which we designed and created maps was print-on-paper. Whether the map was to be published as a single sheet; bound in an atlas, book, or journal; or destined to remain in manuscript form, the stages of map compilation, development, production, and the final product were essentially paper-based. In the 1960s automated cartography gave us a new set of tools for map creation. Cartographers were able to issue sets of commands and coordinates via a terminal or punch cards to generate output (in the form of a paper map). Recent technological advancements have created a computer desktop which has, for the most part, replaced hand-drawn, pen and ink, drafting table map production. By and large, however, the output and final form of our maps is still paper.

Multimedia has the potential to change all that. It has already made tremendous transformations in the how graphics are presented and communicated, and maps will be no exception. One only needs to pick up the latest issue of any computer trade magazine to know that motion, on-screen

presentations, sound, and color have become integral components in graphic communication.

Cartographers cannot and should not shelter maps from the changes that are taking place in graphic information capture, creation, manipulation, and presentation. We have, in fact, already started to make use of some of these tools to improve and facilitate the processes we use to create maps through mapping and illustration software and high-end image output devices. These technologies, however, offer even greater possibilities to alter cartographic practices. Not only can they be adapted to facilitate and improve traditional map creation methods, they have the potential to change the look of maps and how we communicate spatial information. It is worth restating this idea to make it clear that what is being discussed here are not merely changes in map compilation and production methods, but how these new technologies will change how maps are conceived, how they communicate spatial information, and how they will be used. The incorporation of map animations in recent electronic atlases and encyclopedias are just a few examples of cartographic ventures into this new territory.

As cartographers begin to explore and incorporate multimedia (and hypermedia) technology into their work they will be confronted with a barrage of technical information and new terminology. This paper discusses some of the multimedia and hypermedia tools that have potential for use in cartographic displays. Our intent is not to provide a comprehensive list of all the software, formats, and hardware available. Not only would such a list be enormous (if it were even possible to know the extant list of items), but it would certainly be out-of-date even before the words are entered into this document. Given the dynamic nature of multimedia and hypermedia technology, our primary goal is to present readers of this paper with a quasi-glossary of multimedia and hypermedia terms that cartographers are likely to confront in creating and displaying maps. Along with these terms we have provided descriptions of some specific items. The majority of information is applicable to the Macintosh platform, since this is the one we have the most experience with. We hope that this organizational framework and treatment provides a concise and useful way to inform cartographers of the availability and use of some tools and techniques. We caution the reader to keep in mind the "packaging date" of this information and the limited shelf-life that some of these items may have. We conclude this article with a description and discussion of a multimedia project aimed at providing hypermedia access and display of different types of maps.

MULTIMEDIA GLOSSARY

Multimedia

A 1992 issue of *PC Publishing and Presentation* states "in an industry rife with buzz-words, multimedia has become the buzziest of them all." Most simply stated, multimedia is the combined use of various media such as text, graphics, photos, video, and sound in computer presentations and/or stand alone applications.

Hypermedia

Hypermedia is a form of multimedia presentation in which associations between pieces of information or ideas are identified by predefined, user-activated links. The user activates these links by interacting with the computer

through on-screen objects such as buttons. Relationships between the various pieces of information in a hypermedia application differ from those contained in a traditional database in that hypermedia links do not identify every instance that fits a specified criteria (as in a database search), but instead identify links between the current ideas or pieces of information and some other in the application.

Animation

Animation is based on the phenomena known as the persistence of vision in which the mind retains an image for a split second after it is no longer visible to the eye. If the first image is replaced by a second relatively similar image, the illusion of motion is created. Between 16 to 24 images per second are required to create the illusion of fluid motion. Computer animation programs are not only designed to play the images (frames) that produce motion, but also to reduce the effort in creating those frames. Some programs (such as Macromind Director) are based on traditional techniques such as *cel* animation where key frames (ones that define the range of a specific motion) are created, and then *inbetween* frames are generated by the computer. Others programs (such as Swivel 3D) work with defined three dimensional objects that are then moved. Complex animations require large amounts of storage space, a relatively fast CPU and hard drive, and often an accelerated monitor. Most animation programs on the Macintosh can export files in the PICS format, or as QuickTime movies. As QuickTime movies they can be imported and played by a large number of programs including word processors.

Authoring Tools

Authoring tools are programs designed to assist in creating multimedia or hypermedia applications that range from relatively simple "slide-show" presentations (Aldus Persuasion) to sophisticated interfaces for complex interactive applications (Macromind Director). Although the distinction between authoring and more general programming tools is not entirely clear, authoring tools are optimized for linking objects of differing media (text, graphics, sound, photographs, video) into some sort of directed sequence or presentation. The more powerful authoring tools also provide predefined controls for external devices (such as videodiscs, compact discs, and videocassette recorders). The most sophisticated authoring tools allow the author to write scripts that control the course of the interaction. Scripting languages are generally based on HyperTalk, a high-level programming language that fully implements object-oriented programming principles. The majority of authoring tools that provide scripting environments also allow the scripts to call other programs external to the application itself. Examples of authoring tools include Action (Macintosh), Authorware Professional (Windows and Macintosh), HyperCard (Macintosh), Macromind Director (Macintosh), Passport Producer (Macintosh), SuperCard (Macintosh and Windows), and Toolbook (Windows).

Authorware Professional. Authorware began as an authoring program oriented toward computer-based training. It utilizes icons that are programmed to perform predetermined functions such as animating objects, displaying graphics, pausing the flow of the program, creating decision paths, establishing interactions that wait for user responses, and performing calculations. These icons provide the ability to create relatively sophisticated interactive multimedia

applications without writing scripts or programming code. Authorware also provides the ability to access routines that reside external to it. These routines are written in languages such as Pascal, C, and HyperTalk (including most HyperCard XCMDs) and can be used to access databases, or control devices such as CD-ROM drives. Authorware has built in videodisc controls, and can import QuickTime movies and animations created in Macromind Director. One of its main strengths is its ability to track user activities and record responses to questions, both of which are extremely important when working with computer-based-training. Authorware, however, lacks its own scripting language which can complicate matters when additional functions need to be programmed into the icons.

Authorware supports cross-platform development. The Windows version is a stand alone application that can be used to author directly on the Windows platform. Applications developed on the Macintosh can be converted for playback in Windows.

HyperCard. HyperCard was one of the first hypertext authoring tools to be widely distributed. HyperCard is based on a card and stack metaphor, a model which has strongly influenced the design of hypermedia applications. Its scripting language, HyperTalk, is still the standard against which others are evaluated. It is a high level object-oriented programming language which can be extended with XCMDs (external commands) and XFCNs (external functions). Although HyperTalk is powerful, it is relatively easy to learn. Overall, HyperCard presents a strong scripting environment for authoring hypermedia applications, however, it is severely limited by its current lack of support for color.

Macromind Director. Director was originally developed as an animation program and continues to be one of the most powerful animation tools available on the desktop. With the addition of Lingo, a HyperTalk-like scripting language, Director has also moved to the forefront of multimedia authoring. Lingo is a high-level object oriented programming language that can be used (in combination with Director's animation tools) to create highly complex interactive applications. Like HyperCard, Lingo cannot directly control external devices, but instead calls external routines, known as Xobjects, for this purpose. Lingo can access external routines written in languages such as Pascal, C, and HyperTalk, including most XCMDs. This ability to reach outside of its native programming language lets authors extend Director's capabilities to include access to relational databases and complex on-screen devices for controlling interactions. Director also includes a reasonably good 32 bit paint program and a very basic set of object-oriented drawing tools (no bezier curves or free-hand line tools).

Director provides relatively sophisticated control over sound, allowing two separate channels to be accessed and controlled independently, but played simultaneously. Sounds can be imported as digitized sound files, or lingo can be used to access and control MIDI (Musical Instrument Digital Interface) sequences. It can also import and play QuickTime movies. One of its greatest weaknesses however, is its text handling ability. This is especially apparent when a lingo script is used to load the contents of the text field. Director provides good support for cross-platform development, however in Director's case, the application must be developed on the Macintosh and then converted using the Director Player for Windows. The Windows Player supports Lingo so interactive movies can be distributed cross-platform.

Digital Sound

Sound is an element previously not part of the cartographer's repertoire, however, cartographers are now beginning to look at how sound can be added to maps to enhance and increase the map's message. Sound is analog information. In digitizing it, sound (or more accurately sound waves) are sampled periodically. Each sample is like a snapshot of the sound at that moment. The frequency at which the samples are taken determines the quality of the sound, in much the same way that the number of frames per second used in recording and playing back motion video affects the quality of an image. The minimum sampling rate necessary to reproduce most musical instruments accurately is 40,000 per second, or 40 kilohertz (40 kHz). For audio Compact Discs waves are sampled at a rate of 44 kHz. Digital Audio Tape (DAT) uses a sampling rate of 48 kHz, a Macintosh samples at 22 kHz, and the lowest recommended rate for quality speech is 7 kHz.

Digital audio can require a tremendous amount of storage space, and the higher the sampling rate, the larger the file. For example, one minute of digital audio sampled at 48 kHz uses 2,813K, sampled at 22 kHz it would require 1,304K, and at 7 kHz it would need 435K. Many multimedia authoring tools can incorporate sound into a presentation or application, however, the sheer size of the files can often create sluggish performance. As an alternative to digital sound, some applications (e.g. Director) can access Musical Instrument Digital Interface (MIDI) sequencers. Sequencers are programs that store sets of instructions that are used to produce sound on synthesizers residing external to the computer. Since the sequencer stores only the instructions to make sound, and not the actual digitized sounds themselves, the files are minuscule in comparison.

Graphics and Compression File Formats

Most cartographers have dealt with vector based drawing programs and PostScript or EPS graphics file formats. However, as cartographers begin to work with multimedia they will be confronted with a bewildering number of raster-based formats that are often incompatible. There are two types of programs that can help with this: paint/photo-editing and graphics file translation.

Paint programs work primarily with bit maps and give you pixel by pixel control over the size, resolution and look of the image (although some such as Adobe Photoshop, allow you to work with vector drawing channels that are eventually converted to bit maps). With a program like Photoshop you can import a file in one of several formats; resize it; change its resolution; change its bit depth; crop, retouch or alter sections of it; then save it in one of several different formats and compression schemes for importing into for example, an animation or authoring program.

Graphics file translation programs literally take files in one format and translate them into another. One, Equalibrium Technologies' DeBabelizer, goes a step further. It not only translates virtually every bit map file format available on the Macintosh, DOS/Windows, UNIX, Atari, Amiga, SCI, and Apple II platforms, it also offers scriptable batch processing and 8 bit custom palette creation. Custom palette creation can be especially valuable in multimedia because it allows images at an 8 bit color depth to appear on the monitor at, or close to, 24 bit quality. Since the images are only stored at 8 bits, the quality of the image is preserved on a large number of systems (i.e. does not require a 24

bit monitor card), and the speed of interactive, animated presentations is dramatically increased.

Usually a number of different application programs are used in creating a multimedia presentation, and often each application can create, import and export only a limited number of file formats. Bit mapped or raster based graphics formats are the predominant file format in multimedia. Since bit map graphics store information inefficiently relative to postscript, image compression (making file sizes smaller) becomes a concern. Different file formats support different algorithms for compression. Finding the formats and compression schemes that will be compatible with all the necessary programs can be tricky, especially if the presentation is intended to be delivered cross-platform.

Joint Photographic Experts Group (JPEG). Developed by the Joint Photographic Experts Group, JPEG is a compressed bit map file format that is predicted to soon become the dominant format for storing scanned photographs. JPEG is a lossy encoding system, in other words the decompressed image will not be identical to the original. However, the reconstructed image often equals or exceeds the representations offered by other exchangeable file formats. Rather than storing specific color information for each pixel, JPEG stores information on color changes. By replicating accurately these changes, the reconstructed image appears to be visually similar to the original. Using this approach, JPEG can achieve extremely high compression ratios (around 24:1) without noticeable degradation of the image. In other words, an image that was originally stored using 24 bits per pixel can be compressed down to about 1 bit per pixel or less. Compression ratios as high as 100:1 are possible depending on the image. This can be very useful when files are transferred over a network, or in multimedia applications distributed on media such as CD-ROM where data transfer rates are still desperately slow. The file is transferred in its compressed form, thereby reducing the transfer rate by roughly the amount of the compression (for example, 24:1). JPEG is supported by PICT, QuickTime, NEXTstep 2.0, variations of GIF, and it is proposed that it be included in the next release of TIFF (6.0). Its primary disadvantage is that as a software compression and decompression scheme, it is relatively slow. However, the speed is continually being improved and performance can be dramatically increased by adding NuBus boards dedicated to performing the JPEG algorithms.

LZW. Built on work done by Lempel and Ziv, T.A. Welch developed an algorithm that works on the principle of substituting more efficient codes for data. A binary code is assigned to each unique value in the file, the shortest codes are assigned to the most frequently occurring values. These code assignments are stored in a conversion table that is accessed by the decoding software. LZW achieves modest compression ratios relative to JPEG, ranging from 1:1 to 3:1. However, since each value in the original file is represented in the table, the original file can be reconstructed exactly. Consequently, LZW is considered a lossless compression scheme. It is supported primarily by GIF and TIFF file formats.

Motion Picture Experts Group (MPEG). MPEG is a standard related to JPEG that is used to compress and store digital video. In effect, an MPEG file contains series of JPEG-like frames along with information that assists decompression software, such as Apple's QuickTime, to interpolate the individual frames.

Graphics Interchange Format (GIF). Developed by CompuServe, GIF is a file format that is used for the exchange of bit map graphics files between different systems on the CompuServe network. It is generally not the primary format for any computer graphics programs. It is limited to 8 bit graphics, but can create custom 8 bit palettes for 24 bit images. GIF can not store CMYK or HSI color model data, color correction or grayscale data. Nevertheless, it is a very useful format for exchanging files across different platforms as it is supported by most desktop computers and UNIX-based workstations.

PCX. Originally developed as a proprietary format for ZSOFT's PC Paintbrush program, PCX is now widely supported by DOS and Windows applications, including most scanners. PCX can support files containing up to 24 bits of information per pixel.

Microsoft Windows Formats. As part of the strategy to develop multimedia on the Windows platform, a relatively new bit map format has emerged: the Microsoft Windows Device Independent Bitmap (BMP/DIB). This format, similar in structure to PCX, is intended to introduce to Windows applications the kind of interconnectivity provided by the PICT file format on the Macintosh. It is capable of supporting bit maps with up to 24 bits per pixel.

PhotoCD. PhotoCD is the proprietary bit mapped image format and compression system used in the Kodak Photo CD system which incorporates a dedicated 35mm slide scanner, computer system and multisession CD-ROM pressing drive. Slides are scanned, color corrected, compressed using Kodak's proprietary YCC compression, and recorded to the CD-ROM in one operation. Each single session Photo CD can hold approximately 100 slides. However, because Photo CD pressing drives are multisession, fewer slides can be scanned in the initial session and additional slides can be added later to the same CD. Multisession Photo CDs hold slightly fewer slides depending on the number of sessions. Kodak is planning to release five different formats of Photo CD: Photo CD Master, Pro Photo CD, Photo CD Portfolio, Photo CD Catalog, and Photo CD Medical. At present, only Photo CD Master is available. In this format, each slide is scanned and stored in 5 different resolutions. Photo CD is supported on both the Macintosh and Windows platforms, and when used with a special Photo CD player, the images can be viewed (with limited pan and zoom features) on a standard video (television) monitor.

PICS. PICS is a file format used primarily on the Macintosh platform for storing and exchanging animations. It is a sequence of PICT images that begins with the first frame or image area of the animation and continues through the changes to that area. Although a PICS file contains all the individual frames of an animation, the frames are not stored as separate files. Many programs, such as Macromind Director, Authorware Professional, Aldus SuperCard, and Swivel 3D can export and import animations in PICS format. Consequently, it is becoming the defacto standard for transferring animation files on the Macintosh.

QuickDraw Picture Format (PICT). PICT was originally developed by Apple Computer, Inc. as a standard for interchanging QuickDraw pictures between Macintosh programs. However, many DOS based multimedia applications have begun to support PICT. As such, PICT is emerging as a viable cross-platform file format. PICT supports vector and bit mapped graphics, as well as binary page description. In addition, it supports 32 bit color graphics files and JPEG compression. In turn, PICT and JPEG are both supported by QuickTime and QuickTime for Windows. This combination makes PICT a versatile format that is especially useful for distributing multimedia applications on both the

Macintosh and DOS platforms. Both Macromind Director and Authorware Professional use PICT as their primary graphics file format, and it is the only format that they can import.

QuickTime. Technically, QuickTime (developed by Apple Computer, Inc.) is not a file format, it is a system software extension for both the Macintosh and Windows platforms. Nevertheless, it presents a standard "format" for creating, storing, and interchanging time-based information such as digital video, animations and sound. In effect, it is intended to do for time-based information what QuickDraw does for graphics; establish a display standard that can be accessed by all application programs. QuickTime actually consists of four major components: system software, standard data formats, compression software, and interface guidelines. The availability of a standard such as QuickTime allows the same time-based information to be shared across platforms by numerous application programs running on a wide variety of computers, and at the same time provide the user with a consistent interface for accessing that information.

Tagged Information File Format (TIFF). TIFF was developed jointly by Aldus Corporation and Microsoft Corporation as a file format for bit mapped graphics. It can accommodate black and white, grayscale and 32 bit color, and is generally considered one of the best formats for storing scanned photographs. It supports LZW compression and is widely accepted on the Macintosh, DOS and UNIX platforms.

Truevision Targa. Targa is a format developed by Truevision, Inc. It was one of the earlier formats for storing 24 bit image files and consequently, is widely supported on the DOS and Macintosh platforms.

Scanning

Scanning is a common way to convert analog images into digital information. In cartography this is most often done when information from a paper basemap is needed in digital form. The scanned image is affected by how a scanner senses light, color, and resolution.

Charge-Coupled Device (CCD). The chips that sense light reflected or transmitted from the image being scanned are called charge-coupled devices (CCDs) and are usually combined into linear arrays. The more CCDs in the array, the higher the linear resolution of the scanner. In most scanners, the array is moved over the image line by line (the width of one sensor). However, with scanners such as sheetfed scanners, the image is passed in front of the array. Each CCD element captures information for one picture element (pixel), one line at a time, in color bit depth resolutions ranging from 1 to 48.

Color Bit Depth. The amount of information (the number of bits) that is sampled by the CCD element for each pixel is referred to as the bit depth. For example, black and white scanners sample each pixel of the image and based on a predetermined threshold, assign a value of either 1 (white) or 0 (black). Black and white scans are said to have a bit depth of 1. Most scanners are capable of scanning at least 8 bits per pixel. In binary this yields a range of 0-255 which can be used to record one of up to 256 possible values for each pixel. This is more than sufficient for representing gray scale information. Almost all color scanners are based on an RGB (Red, Green, and Blue) color model and sample data for each of the Red, Green, and Blue channels. In order to represent continuous tones for RGB then, the scanner must sample at 8 bits per channel, or a bit depth of 24. This produces up to 16.7 million binary combinations and

consequently, each pixel can be assigned one of 16.7 million different colors. Although computer systems generally cannot use image files containing more than 24 bits per pixel,¹ scanners that collect more information per pixel (10 to 16 bits per channel or 30 to 48 bits per pixel) generally interpret the data and output a file that contains only the most useful 24 bits. This additional information is especially helpful for bringing out the details in shadows as in the case when lettering crosses line work on old maps.

Scanning resolutions. The true resolution of a scanner is determined by its CCD array. For example, a typical 8.5 inch long array uses 2550 CCD elements to achieve a true resolution of 300 pixels per inch ($2550 \div 8.5 = 300$ ppi). To increase this resolution, more elements must be added to the array, thereby increasing the cost of the scanner. Many lower cost scanners boost the "resolution" without adding additional elements by means of software interpolation. The software, in effect, creates additional pixels by taking each sampled pixel and dividing it into two or more smaller ones. For example, a 300 ppi scan can be boosted to 600 ppi by taking each sampled pixel and dividing it in two. The values given to these created pixels is determined by interpolating the values for the surrounding sampled pixels. Although interpolation can often increase the sharpness of a scan by reducing the jaggies, it does not achieve the level of detail captured by an equivalent number of CCD elements. Consequently, for images that are primarily line art (often the case with maps) interpolation can significantly improve the resolution of the scan, however, for continuous tone images, interpolation may improve the scan only slightly.

One of the most important questions concerning resolution is "How much is enough?" Traditionally, scanning resolutions have been determined by using a formula driven by the desired screen resolution, given in lines per inch (lpi), that will be used in printing. These formulas, however, are of little use for determining resolutions for scans to be incorporated into multimedia productions. In multimedia, the output device will generally be a computer or television. Most computer monitors (e.g. the Macintosh 13" RGB, and SVGA monitors) have a screen resolution of 640 pixels (approximately 9" horizontal) by 480 pixels (approximately 6.5" vertical) at a color depth of 8 bits per pixel. This works out to approximately 72 ppi. For a 100% enlargement then, the scan need only be made at 72 ppi.

Scanners

A variety of types and forms of scanners are available. The decision to use one over another is based on cost, size of the image being scanned, medium of the original, color, and resolution.

Hand-Held. Generally, the least expensive are small hand-held devices typically with a horizontal scanning width of about four inches. Hand-held scanners are of limited value because the scans are made by dragging the device (the linear CCD array) over an image, often resulting in uneven, poorly registered scans. Also, the limited width of the linear CCD array requires two or more passes for images wider than about four inches. The two or more resulting digital files then need to be "sewn" together or edge matched, a cumbersome process that can be especially frustrating with line work such as maps.

Flatbed. Although flatbed scanners range in linear resolution from 300 to

¹ Actually computer systems can work with up to 32 bits of information, but 8 bits are reserved for an alpha channel. The remaining 24 bits are used for the color information.

over 1200 ppi at bit depths from 8 to 30, the ones under \$10,000 generally range from 300 to 800 ppi at 8 to 24 bits. In most flatbed scanners, the artwork is placed face down on glass and the CCD array and light source are passed underneath, much like the typical photocopy machine. The quality of the scanner is determined by the precision with which the array and light source are moved, the resolution of the CCD array, and the software that interprets the information. Almost all flatbed scanners capture color information using the RGB color model. Newer models capture all three channels in one pass by using three light sources (one red, one green, one blue) during the scan. However, many of the older models use only one light source and pass the array over the image three times, once each with a red, green or blue filter in place. Most flatbeds can scan originals up to 8.5 by 11 inches, some high-end models can scan up to 11.7 by 17 inches. In general, flatbed scanners provide a relatively high quality scan at a reasonable price. Flatbed and Sheetfed scanners are usually used for Optical Character Recognition (OCR) scanning.

Sheetfed. Sheetfed scanners are similar to fax machines where rollers draw the image into the scanner and past the CCD array and light source.

Overhead. Overhead scanners suspend the CCD array above the image or object to be scanned. This allows objects to be captured in 3D, however, because the light source is projected onto the object, the quality of the scan is diminished.

Slide/Transparency. Slide/Transparency scanners project light through the film to be scanned and into the CCD array as it is moved across the film. The projected light provides more saturated colors and greater detail than is achieved with reflected light. Some flatbed scanners can be fitted with a transparency option, however, they tend to produce lower quality results and generally cost as much or more than dedicated slide scanners. Dedicated scanners provide resolutions ranging from 1000 to 6000 ppi at bit depths of 24 to 48.

Drum. Drum scanners represent the high end. Not only do they produce the highest quality scans, they are also the most expensive (generally over \$70,000 but recently as low as \$40,000). With these scanners, the image or film is mounted on a scanning drum and a focused beam of light is moved across the image. The light can be used to expose photographic film mounted on an exposing drum, or to create a digital file. The level of precision at which the focused light source is moved yields extremely high quality scans.

Storage Media

Storage media can be distinguished based on its capability, receptivity (magnetic or optical), and capacity. Magnetic drives use disks which store information coated with a material that is receptive to magnetic encoding. Optical disc² drives use discs which store information of extremely high density in the form of pits that are written and read by a laser beam. Some optical drive mechanisms are used to record analog data to the discs, others record digitally encoded data. A variety of both magnetic and optical storage devices are available.

CD-ROM Drives. CD-ROM (Compact Disc-Read Only Memory) drives utilize the same basic technology originally developed for audio compact discs.

² Typically a spelling distinction is made between the storage devices of magnetic and optical media. Magnetic disks are spelled with a "k," whereas optical discs are spelled with a "c."

In fact, CD-ROM drives can play standard audio CDs, or CD quality audio tracks encoded onto CD-ROM data discs. A CD-ROM disc is only slightly larger than a high-density floppy disk, but can hold over 450 times more information depending on the format used in mastering the CD. Most CD-ROM drives can read discs mastered for slightly over 650 megabytes, others can only read discs that have been mastered for about 580 MB. CD-ROM discs are Read Only Memory and cannot be written to or created without specialized equipment which, until recently, was cost prohibitive except for large dedicated pressing facilities. However, recent advances in CD-ROM pressing technologies have brought down the cost of creating single copies of CD-ROMs (one-offs) to where they provide an extremely competitive solution for back-up and distribution of large quantities of data to a single location.

Hard Disk Drives. The drive mechanism of a hard disk drive consists of one or more non-flexible fixed disks, two magnetic read/write heads per disk (one for each side), a housing, and an electronic interface for connecting to the computer (ST-506, SCSI, ESDI, or IDE). Drive capacities range from 10 MB to 3,000 MB with access times ranging from 10 to 50 milliseconds. The read/write heads float on a cushion of air over the disks that spin at 3600 rpm. Electronic signals received from the computer (via the interface) activate motors (either stepper or voice coil) that position the heads for either reading from or writing to a specific address (location) on the disk.

Removable Cartridge Drives. These drives are essentially 5 1/4" magnetic, hard disk drive mechanisms that allow the disk (housed in a plastic or metal cartridge) to be inserted and removed like a floppy disk. Disk capacities range from 20 MB to 150 MB, although the most common are 44 MB and 88 MB. Drives tend to be only slightly slower than fixed platter drives. Generally, cartridges can be interchanged among drive mechanisms of the same format and manufacturer, thus making the transportation of large files (generally the case in multimedia applications) between computers with compatible cartridge drives quite easy. Some drive mechanisms such as the Syquest 88c or the Bernoulli MultiDisk 150 can read and write to more than one capacity of cartridge.

Removable Optical Drive. Removable Optical Drives have storage capacities of up to one gigabyte that allow the same area of an optical disc to be recorded to and erased multiple times. This brings to optical drives the convenience and flexibility of magnetic hard drives, however, optical drives tend to be much slower. Recently, removable 3.5 inch cartridge drives have gained popularity. Depending on the drive mechanism, they can read and write to cartridges of either 128 MB or 256 MB. These cartridges can then be interchanged with other removable drives, making them convenient for transporting large files to and from locations such as service bureaus.

Write Once Read Many (WORM). Unlike CD-ROMs which require pre-mastering and mastering before usable copies can be made, WORM drives allow one time recording of data directly from the computer. Once the data is written to the disc (which can occur over multiple sessions), the drive becomes read-only storage media. Worm drives can have storage capacities up to 1 terabyte. However, with the recent advance of a number Compact Disc Recordable (CD-R) drives for under \$5000, the popularity of traditional WORM drives has diminished. CD-R is in reality a cross between CD-ROM and WORM technology. The advantage of CD-R is that it records to standard CD-ROM discs which can be used on most CD-ROM drives, thereby greatly increasing the distribution potential.

Video

Video has traditionally meant the picture phase for television broadcasting and has been distinguished from audio which deals with sound. Multimedia makes use of both analog video (traditional video) and digital video.

Analog Video. Video, in the form of television and movies, is analog. The analog signal is comprised of a wave form varying in frequency. Videodiscs (12" reflective optical discs) and video tape store images in analog format.

Digital Video. Whereas analog signals vary in voltage, digital video converts analog signals to discrete bits of information. In its broadest sense, it covers a number of activities ranging from capturing still images to digitizing and editing full-motion video. Still image capture is a form of scanning that utilizes a video camera instead of a CCD array. The camera is pointed at a stationary object or image and the signal is passed through the camera to a computer program that converts the analog video signal to a single digital graphics file. A variation of this is called a frame grabber. Here individual frames from a motion video source are grabbed and digitized, thereby allowing motion video to be digitized. However until recently, most frame grabbers stored the captured frames in RAM, usually a severe limitation on the number of frames that could be digitized. Now, efficient image compression algorithms (such as the standard developed by the Joint Photographic Experts Group (JPEG)) and protocols for synchronizing time-based digital information (such as Apple's QuickTime) have begun to make the real-time digitizing and playback of motion video a reality on the desktop. A number of new frame grabbers, such as SuperMac's VideoSpigot, utilize both JPEG compression and QuickTime protocol standards to achieve acceptable recording and playback of motion video. Once the video has been digitized, editing software such as Adobe's Premiere, provide the ability to integrate the video with a additional media such as animations, photographs, graphics and sound. The resulting integrated linear segments can be played back as stand alone presentations or incorporated into documents created by applications such as word processors, charting and presentation programs, or multimedia authoring tools.

APPLYING MULTIMEDIA TO CARTOGRAPHY: THE INTERACTIVE VIDEODISC MAPPING PROJECT

The remaining portion of this paper describes the Interactive Videodisc Mapping Project carried out at the University of Wisconsin-Milwaukee. The project was funded by a grant from the United States Department of Education, College Library Technology and Cooperation Grants Program. The project had two basic objectives. The first was to use multimedia technology to create an interactive videodisc to illustrate the broad and diverse topic of mapping. Second, but no less important, was to provide access to some of the rare and valuable examples of cartography from one of the premier map libraries in the country, the American Geographical Society Collection.

Description of the Videodisc

The double-sided videodisc contains on one side, 28,900 still frame images of more than 600 maps and a four minute motion video documentary on the procedures used to create the videodisc. The second side has three short (approximately 7 minutes each) full motion narrated video segments: "Changes

Through Time" illustrates how maps can communicate information about the past as well as show trends about the future; "The Cartographer's Choice" explains how some mapping decisions are made; and "Maps, You Gotta Love Em" is a fast paced look at different types of maps and their various uses. A fourth video segment (also approximately 7 minutes) demonstrates how the videodisc images and database might be used.

All of the images on the videodisc are linked to a digital database (designed for the Macintosh) containing information about each map's title, region, scale, projection, date of publication, etc. For each map in the database there is one image of the entire map on the videodisc as well as a series of systematic enlargements (tiles) and close-up images (enlargements of selected areas of interest on the map). The images for each map are linked to information in the database by a unique object identification number. The database also links the videodisc images to other related images on the videodisc as well as to other information in the database.

The videodisc and database are designed to work together in an interactive, multimedia environment. The videodisc images are analog and played on a television (video) monitor from a videodisc player. The database information is digital and read from a floppy disk by a Macintosh computer and displayed on a computer monitor. The ideal arrangement when using the videodisc and database is to have the television and computer monitor side-by-side (or projected side-by-side) to enable viewing an image and its information at the same time. The user interface, specifically developed for this project, is what allows users to link the database information for each map to the appropriate images and permits database searches. The link is bi-directional so that images can be accessed via the database, or the database information can be accessed via the images.

Analog vs. Digital Technologies

One of the first issues in developing this multimedia tool was deciding on the appropriate technology and media for displaying images of maps. Amongst the many concerns was attaining a high quality image that would capture the rich color and detail present on maps. One option was to reproduce the maps on a CD-ROM. The map images and their data would be stored in a digital format and displayed on a computer monitor. Although this medium would have offered a number of advantages, CD-ROM technology was still in its infancy at the time the grant proposal was developed (1990). The large size of the original maps,³ restrictions on the number of images that could be placed on a CD-ROM, and concerns over image pixelization and color reproduction quality were also problematic. An added concern was how the data and map images would share screen space if they were both being played off the same media.

A second option (and the one decided on) was imaging the maps onto a videodisc and creating an accompanying digital database. Videodisc (or laserdisc) technology relies on an analog signal and displays images on a standard video monitor in an NTSC (National Television Standards Committee) display. We were encouraged by the number of successful projects that had

³ Since most of the maps intended for the project were larger than page size (in some cases as large as 4' x 6'), scans on a typical flatbed scanner would have been prohibitive and an intermediate slide or color transparency would be required.

used videodisc technology and reports and studies showed that this media was an effective way to capture and display thousands of images. The image storage capacity of a videodisc is truly exceptional. Each videodisc side is capable of storing 54,000 individual images or 30 minutes motion video (or a combination of the two). Most advantageous, however, was the high level of interactivity that could be achieved with a videodisc and the almost instantaneous access to images regardless of their position on the disc.

Selection of Map Images

The maps selected for inclusion on the videodisc were based on the following criteria:

1. A map's representativeness of a cartographic characteristic or map type. For example, a 1972 plat map by Rockford Map Publishers was used as a typical example of a map that show detailed land ownership. A 17th century Dutch atlas was selected because it was a typical example of coloring techniques used for maps during that period.

2. A map's exemplary portrayal of a cartographic characteristic of map type. For example, National Geographic Society's 1992 map of Amazonia was selected for its unique and innovative design and cartographic style that incorporates text, graphics, and maps in a single sheet.

3. A map's temporal, regional, or topic relatedness to a previously selected image. For example, we selected a 1789 plan of Naples and also a 1990 plan of the same area to illustrate how mapping styles (and the landscape that was mapped) had changed. In addition, two maps of Philadelphia, corresponding to the dates of the Naples maps, were selected to show how mapping practices and styles differ regionally.

4. A map's uniqueness as a rare map. For example, we selected Leardo's *Map a Mundi* made in 1452 because there are only three known original copies, allowing the videodisc viewer access to a map they might otherwise never be able to see in such detail.

The 600 plus maps cover every region of the world, with scales ranging from a map of the interior of a shopping mall to a map of the universe. There are over seventy different map projections represented on the videodisc. There are more than ninety map subjects ranging from maps of administrative divisions to whaling charts. There are maps published by all levels of government as well as private publications from all over the world. There are maps from atlases, newspapers, magazines, map sheets, and books. There are maps that are hand colored as well as some made by computers or satellites. There are maps of the earth during the pre-Cambrian period, maps of the exploration of the Americas, and an animated map that shows what the population of the earth might be in the future. There are maps etched on paper, printed on fabric, and even made out of cheese. In all, it is possible for a user of the videodisc to search a variety of characteristics and find a rich assortment of images to look at and study.

Map Imaging Process

The NTSC display of the standard video monitor is not capable of storing an

image of a large map at a resolution which preserves critical map details. To compensate for the low resolution, analog map images were recorded directly onto a re-writeable optical disc cartridge via a videodisc recorder and video camera. The high-resolution recording mode stores images at a video resolution in excess of 400 lines and much of the map detail was preserved by using a high quality video camera. A technique was developed whereby an image of every map was taken in its entirety and systematic enlargements (tiles) were taken at a resolution appropriate for the specific detail of the map. The tile sizes on average covered a 3 cm x 4 cm area of the map. A given map could have as many as 200 tiles or none depending on the original map dimensions and detail (the average was approximately 40 tiles per map).

The video feed to the videodisc recorder was through a Sony DXC-930 3-CCD video camera with a 12 to 1 zoom lens. The camera and lens configuration provide sharp images through three .5" IT Hyper HAD CCD's, each with 380,000 effective picture elements with a resolution of 720 TV lines. The camera signal also provided a feed to a video monitor in order for the camera operator to preview what was to be recorded on the optical disc cartridge.

The imaging process involved moving the maps under a vertically mounted camera rather than moving the camera. The maps were laid flat on an imaging platform that was attached to a motor driven wheeled apparatus which allowed four feet of movement in the "Y" direction and six feet of movement in the "X" direction. The map was centered under the camera and a picture of the whole map was recorded onto the re-writeable optical disc cartridge. The tiles and close-up images required precise and accurate positioning under the camera and zoom control of the lens. Computer controlled stepper motors dictated the movement of the imaging platform in both the X and Y direction (to within one millimeter) to position the map under the camera for the tiles and pieces. When each tile position was reached a signal was automatically sent back to the videodisc recorder to record the image before the imaging platform moved to the next tile.

The User Interface

As with any multimedia application, the user interface is a critical aspect of the planning and development. The primary function of the interface for the videodisc was to link images on the videodisc with the information about the map it belongs to in the database. This is a bi-directional link that allows images to be accessed via the database, and the database to be accessed via the images. The initial proposal envisioned development of a cross-platform interface for use on both a Macintosh and DOS platform. Despite the claims of dual platform authoring software, we found the task impractical given the time and budget constraints.⁵

The interface was structured around four display environments:

- **Map Information Display:** This environment allows users to view information for individual map records and access videodisc images that correspond to that information.

⁵ The primary problem was the lack of existing external commands (XCMDs) to implement specialized videodisc controls on a dual platform. This was further complicated by the need to integrate authoring software with the relational database program.

- **Image Browsing:** This environment permits users to browse images on the videodisc and place the images on a Request List that they can name and save to their own floppy disk.
- **Database Search:** This environment provides the ability to search for maps with specific characteristics, obtain lists of all the maps on the videodisc that have that attribute; view one, any, or all of those maps; and save their titles to a Request List.
- **Supplemental Information Display:** This environment contains a dictionary of terms, chapters on specific map subjects, and digital illustrations to enhance explanations.

The user is presented with a choice of three activities when they start the interface videodisc program. They can *Browse Images* on the videodisc, *Search the Database* for specific characteristics to yield a list of all the maps on the videodisc with those characteristics, or *Browse a Collection* containing prescribed subsets of maps with a coherent theme that we have created.

If they select *Search the Database* they are presented with a finder similar to the Macintosh System 7 finder. The finder is designed to allow the user to query the database by asking it questions. By clicking on the left hand entry field of the finder, all the categories of map characteristics in the database are listed. If the user was looking for *Spanish Language* maps made before 1600 they could choose *Language* from the available map characteristics. This would configure the appropriate operator (*contains*), then they would choose *Spanish* from the pull down menu of choices to the right. They could continue with the second parameter in the same fashion by selecting *date* on the second line, using the operator *before*, and typing in the date 1600. In all, four parameters can be searched at one time with designators of 'and' or 'or' and with characteristic operators such as *contains, is, is not, does not contain, before, after*, etc.

When the designated parameters have been specified the user would click on the *Find* button and the screen would change to one displaying all titles of all the maps that fit their search criteria in a window on the left and the ability to create a Request List as a subset of the maps if they chose to do so. The user could click on any of the map titles and view the videodisc picture of that map on the television monitor. They could also double click on one, many, or all the map titles to place them on a Request List. The request list can be named, saved on a personal floppy disk, and used at anytime to recall and access the maps on it. Double clicking on any title once it is in a Request List will bring up the Map Information Display environment containing all of the information for that specific map.

This display environment allows users to view information for individual map records and access videodisc images that correspond to that information (see Figure 1). The primary components of this screen are the Tile Access Grid (upper left), the Close-ups Listing (middle left), Buttons for accessing the primary map record information (bottom), and a screen area for displaying that information (text area on right). Also included are the abbreviated map title (upper right), the map's database Object Number, and the Frame Number for the current videodisc image (upper left). A Menu Bar along the top of the screen provides access to *File* and *Edit* functions; *Search* (access to the *Image Browser* and *Database Search* environments); a *Dictionary*; *Request Lists*; *Links* (links

between this and other map images and related information); and an *Activity Log* (that monitors images accessed).

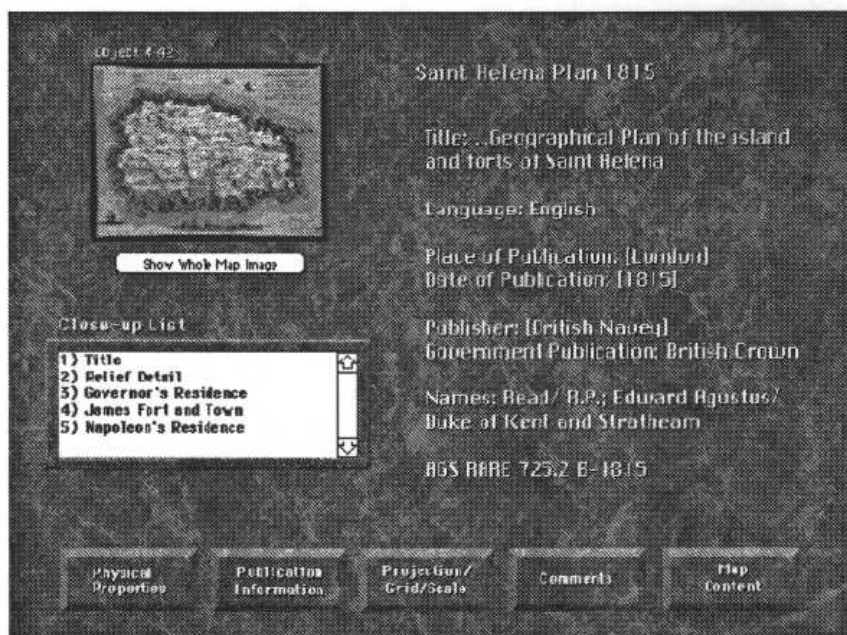


Figure 1. The Map Information Display environment showing the *Publication Information* for St. Helena Plan of 1815.

The database information for the primary map is divided into five general categories and accessed by the buttons. Users can access the information for each of these categories by clicking the appropriately labeled button. *Physical Properties* includes the color scheme, execution, medium, and original map dimensions. *Publication Information* includes the map title, edition, language, place of publication, publisher, date of publication, whether it is a government or other type of publication, the authorities involved in the map, if it is from an atlas or book, its AGSC call number, and its OCLC number if it has one. *Projection, Grid & Scale* information includes the map scale, grid designation, its Prime Meridian, and projection. Each map record contains *Comments* that provide a brief written narrative about the map when appropriate, or refers the user to other images on the videodisc or other sources of information. *Map Content* includes the region covered on the map, its latitude and longitude extent, date of situation, subject, mode of representation, and cartographic themes that we have chosen to highlight.

The Tile Access Grid has a coarse digital background image of the map overlain by a grid. The grid indicates the number and location of the tiles available for that map. The user can access videodisc tiles by placing the mouse pointer over the Tile Access Grid. Pressing the mouse button and positioning the pointer over a tile in the grid brings up the corresponding image from the

videodisc onto the television monitor. Pressing the mouse button and moving the pointer over the grid simulates panning the map and the speed at which the videodisc displays the corresponding image is directly related to the speed the mouse is moved. What makes the Tile Access Grid work is that the number of tiles for each map, the videodisc frame number for each tile, and the centroid coordinate for each tile are in the database. This data is generated before the map is ever imaged. It is the same data that controls the movement of the imaging platform.

In addition to its tile access function, the Tile Access Grid shows the size and position of each close-up with a rectangular symbol labeled with numbers that correspond to the Close-up Listing. The Close-ups Listing is a scrolling window that lists the number and short description for each close-up. The user can click on the description and the information for that close-up is displayed in the information display area and the close-up image is displayed on the television monitor.

Users also have access to an *Activity Log* that records the date, time, and title for every map or image accessed in a single session. If a user wanted to look at a previously viewed map they can access the activity logger, click on the map title of the map they wish to see and it is automatically displayed on the television monitor.

CONCLUDING REMARKS

We have attempted to provide readers of this paper with an example of a multimedia, cartography application and a glossary of some multimedia terms. The following concluding remarks, though brief, warrant attention by cartographers.

Much of what is driving the development of multimedia tools is the idea that graphics are an extremely effective and powerful way to communicate information. This is not something new to cartography—in fact, it is mainly for this reason that multimedia lends itself so well to communicating cartographic information. Multimedia offers cartographers exciting opportunities to work with graphics in new and different ways. As we begin to experiment and understand these new tools we should keep in mind that not only are they beneficial for improving the methods and processes we already employ, but that they have great potential to change the way we conceive of maps.

We should look to multimedia for mapping solutions that not only enhance the way map information is communicated, but for the ways in which it can change the look of maps. This requires moving beyond the use of multimedia components individually. Instead, these components should be harmoniously integrated to communicate information in new and different ways. For example, instead of simply using animation to show spatio-temporal change (animating a series of static maps), animation can be combined with sound and interaction to change the basic nature of how relationships are communicated. It will be through this type of integration that maps and the communication of spatial information will reap the greatest benefits.

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Authorware Professional, Macromedia, Inc., San Francisco, CA (415-442-0200)
Macromind Director, Macromedia, Inc., San Francisco, CA (415-442-0200)
Debabelizer, Equilibrium Technologies, Sausalito, CA (415-332-4343)
HyperCard, Claris Corp., Santa Clara, CA (408-727-8227)
QuickTime, Apple Computer Inc., Cupertino, CA (408-996-1010)

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