Disc Manufacturing, Inc.
A QUIXOTE COMPANY

AN OVERVIEW TO MULTIMEDIA

CD-ROM PRODUCTION

Acknowledgment

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WHO IS DMI?

Disc Manufacturing, Inc. (DMI) manufactures all compact disc formats (i.e., CD-Audio, CD-ROM, CD-ROM XA, CDI, PHOTO CD, 3DO, KARAOKE, etc.) at two plant sites in the U.S.; Huntsville, AL, and Anaheim, CA. To help you, DMI has one of the largest Product Engineering/Technical Support staff and sales force dedicated solely to CD-ROM in the industry.

The company has had a long term commitment to optical disc technology and has performed developmental work and manufactured (laser) optical discs of various types since 1981. In 1983, DMI manufactured the first compact disc in the United States. DMI has developed extensive mastering expertise during this time and is frequently called upon by other companies to provide special mastering services for products in development.

In August 1991, DMI purchased the U.S. CD-ROM business from the Philips and Du Pont Optical Company (PDO). PDO employees in sales, marketing and technical services were retained.

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AN OVERVIEW TO MULTIMEDIA CD-ROM PRODUCTION

If you're like many people, you're no doubt fascinated by the recent advances you've seen or heard about in compact disc technology.

For many, the excitement of combining moving images and sound on a single compact disc is exceeded only by the thrill of a new -- and enormous -- profit opportunity. Imagine, for example, an encyclopedia presentation of a space shuttle lift-off, complete with a streaking trail of fire and thundering roar. Or a discussion of the Amazon jungle brought to life by jumping chimps and chants from exotic birds. Few would argue, this is not a visionary's dream. It is here. And it will soon be as common as the home computer.

While digital imaging has given the world a new profit frontier, it has also created more than its fair share of confusion. Anyone who has taken a step toward CD-ROM publishing -- and particularly toward multi-media CD-ROM -- knows the path can be rocky. There are dozens of strange sounding names and concepts to learn. There are a host of considerations that have to be made . . . considerations that do not exist in the world of print. So it's understandable, developers and producers sometimes feel a little apprehensive as they try to move forward.

If you're interested in producing a multi-media CD-ROM disc but need some guidance to avoid false-starts and unnecessary expense, this paper should provide help. It is intended to demystify the process and make your transition to digital publishing go as smoothly as possible. In it, we will be introducing you to CD-ROM terminology and offering tips on data selection and preparation. We will also discuss such things as audio timing, sound effects, animation, and cost issues associated with the various production techniques. And finally, there is a discussion on computer platforms and practical advice on testing your world. Let's begin with a definition of CD-ROM.

CD-ROM stands for "Compact Disc-Read Only Memory." The vast majority of today's CD-ROMs include only text and still graphics. While all printed materials are based on text and still graphics, the CD-ROM allows for more creative ways to present data to the user. The CD-ROM's ability to store text, still and motion graphics, as well

as audio on the same disc provides new and exciting opportunities to add value to existing data as well as create new applications.

The creation of a mixed mode disc must start with design. The following items will help you define your product:

- The types of data to be used.
- The equipment and/or services needed to create/capture the data.
- The computer platform required to use the product.
- The amount and order in which the data is presented.
- The selection of the data.
- The retrieval software to index and present the data.
- Testing methods before a product is shipped.
- Costs. (The importance of this is on a case by case basis.)

TYPES OF DATA

Text Data

Text is often the most used form of data in an application. The amount of information available in digital form is growing every hour. Billions of dollars are spent each year by industry, government and education to convert text into computer readable formats. This information is most often viewed by users on a computer display. Only the most specialized application will be void of text.

Data capture is required in order to proceed on the development path. Often the data required is in paper form. Text can be captured by several methods; the most common are:

- Re-keying - This is mostly done off-shore. The page is keyed by two different people. A computer program then brings any page that has a discrepancy in it to a third terminal where an "Editor" makes the final decision.

- OCR - Each page is fed into a scanner. The scanned page is processed by OCR, Optical Character Recognition, software and spelling checked by computer and human means.

Graphical Data

Images sway a consumer to purchase products. Images portrayed as graphics come in many formats (the word "Format" refers to the way logical structure is contained in a stored graphic file) and the format(s) chosen are important. There are many choices of file formats:

Computer Raster - This form of graphic is generated by paint programs and is stored as bit-maps of the colors displayed on the screen. Bit-mapped graphics, are like TV images, where the picture is made up of dots (pixels). Painted objects are created in a reserved area of memory called a bit-map, with some number of bits corresponding to each dot. In the simplest monochrome systems, one bit is turned on or off. For gray scale, several bits create the shade number for each dot. For color, more bits are required to hold a number for each intensity of red, green and blue in the dot.

Once a raster image is created, it is locked into a given size and resolution. Changing the screen size or resolution of a raster image requires special image processing software. The amount of storage required for a raster image file depends on the size of the image, the number of colors in the image, the type of file format used, and the compression used on the image. The same graphic will have different file sizes for each format and resolution used. A comparison table is shown below:

Image Size (Pixels)	Format	# of Colors	Size of file
640x440	Bit Map(BMP)	16	141KB
640x440	Bit Map(BMP)	256	283KB
640x440	Bit Map(BMP)	16 Million	845KB
640x440	PCX	16	31KB
640x440	TIFF	16 Million	845KB
640x440	TIFF	16	141KB
640x440	GIF	16	9KB
640x440	GIF	256	10KB

Computer Vector - Images of this type are created using CAD or draw programs. Images are created by connecting several lines called vectors, into a shape. Each shape can be assigned a specific color value. These vectors and color values are stored in a file. Vector images can take less storage space but may take longer to display on the screen. The size for storing a

vector image file depends on the size of the image, the complexity of the image, and the type of file format used.

Scanned Images - Images that are created on paper or 3-D items represented in two dimension can be converted into digital form using a scanner. The scanner and software takes and creates a digital picture of the image and creates a raster image (see above) to be stored in the computer. Some scanning software will also make vector images of black and white line art. Scanners range in price, features and quality and come in several forms: hand held, flat bed, sheet feeding, video stand and slide scanners to name a few. One should see a sample image created on each scanner before making a purchase to assess the quality of the image. Make sure the scanner(s) selected have the features and quality required, such as high scan resolution (measured in dots per inch(dpi)), color or black and white only, and speed (measured in pages per minute).

Video Frame Capture - Most homes today have a TV, many have a VCR, and some even have a CamCorder. Video is available in abundance and is relatively easy to digitize with a video frame grabber. Like a scanner, the video frame grabber is a piece of hardware that works with software. The images can be quite good if you use quality equipment and input video. Video frames are stored in raster format and require hundreds of megabytes of storage during the capture of the image. The reason for such large storage is the images are being stored in the computer at 30 full images per second. That means, if each frame is only 1.1M Bytes each (decompressed), one second will need 33MB of storage room.

High quality video requires high quality input video and high speed/high quality capture equipment. Image quality is determined by equipment that can store images at high speed without losing or distorting part of the picture. Lower quality equipment will give disappointing results. It is best to capture more frames per second than is intended to be used; with the extra data selection available, you can select from the best frames and add clarity to the video sequences.

Still Graphics

Many file formats are available: TIFF, PCX, GIF, PICT/PICT2, HPGL, LBM/IFF, JPEG, TARGA, RIFF, EPS, DXF, and CGM are only a few of the most common. Each have benefits and limits, some require less storage and others can store more complicated images. Images take much more storage space per screen than text does. This entire paper is less than 30K Bytes in size while a simple 16 color screen size image is over 150K Bytes. It is best to test the file size of the selected format before making a decision, as each file format has its own storage space requirements. The technical specifications for each file format are detailed and developers should refer to texts on graphics before selecting a given format. It is very time consuming and expensive to convert graphics from one format to another. The images will double in size during the conversion, one file for the original and one file for the converted image. One of the many image storage formats that should be looked at is JPEG (Joint Photographic Experts Group). JPEG compresses images up to 20:1 and while it is a lossy compression (lossy: unneeded color information is discarded), it provides excellent image reproduction.

Motion Graphics

Motion graphics is commonly tied to the term "Multimedia". The source of motion graphics can be computer generated or from a video. A video frame grabber is used for the latter. The video is stored as a stream of grabbed stills that can quickly display to the screen. How fast the images are displayed to the screen is measured in frames per second (fps). This will determine how smooth or jerky the images appear to move on the screen. In the United States, television is displayed at 30 fps. In contrast, animation quality will display at 10-15 fps. At TV quality, a decompressed video display would require approximately 2 gigabytes (2,000,000,000 bytes) of storage per minute.

Several solutions for compression and playback of video are available. DVI (Digital Video Interactive) by Intel/IBM, Philips/Sony's CD-I (Compact Disc Interactive), ISO's MPEG (International Standard Organization - Motion Pictures Expert Group), Iterated Systems' fractal compression, Apple's Quicktime, and UVC's video compression all offer compression/playback solutions. DVI is a compression/decompression algorithm for full motion video and is available as an add-on board to be installed in an IBM compatible

personal computer. CD-I interleaves compressed audio with compressed video playback and decompresses during real-time playback. It is available as a TV peripheral in the consumer marketplace. C-cube has implemented the MPEG compression in a chip called the CL-550. The chip can decompress 30fps of 24-bit color video with a 50:1 compression rate.

Computer Animation

Frame rates for computer generated animations are lower than video. A rate of 10 to 15fps is generally accepted as high quality. For computer generated graphics, an animation program is frequently used to move painted objects from one part of the screen to another. A simple way of creating motion is Slide-show motion. Slide-show motion is the rapid display of images to the monitor. Storing long sequences of motion in Slide-show fashion requires a lot of storage space and produces slow play back speeds.

AUDIO WITH DATA

Audio is a requirement for a mixed-mode CD-ROM. Audio comes in several forms and is used in many ways. Music, in the form we hear on the radio, is common. Music can be used as a soundtrack, playing while other information is being viewed, such as in a movie. Music can also be a music catalog database or record selection program.

Because CD-DA on CD-ROM can be computer controlled, you have a choice of the way audio is played back. Music and sound effects are often recorded in stereo to give the full impact of the recording. They can also be recorded in mono if stereo is not available or needed. Voice information can easily be recorded in two different languages; one language placed on the left channel and the other on the right channel. Splitting the audio allows for quick switching from channel to channel. However, splitting audio channels is a very time consuming and expensive process.

For professional results, audio recording is best done in a studio environment. Silence is important as the recording equipment will pick up all sounds. If recording directly in digital form is impossible, the audio will need to be converted prior to working with it. Most recording studios can convert analog audio to digital audio. The

quality of re-recorded digital audio will only be as good as the source. Thus if the audio is recorded on a cheap tape recorder, the digital version will reflect the lower quality. Professional editing is also a option for older or poor quality audio.

Audio can be recorded at various sampling rates. Full CD-DA is recorded at 44.1KHz and requires approximately 175,200 bytes per second. A comparison of recording qualities are as follows:

Quality Level	**Sampling Rate (KHz)**	**Resolution (bit)**	**Bytes Needed to Store 1 minute of stereo audio (Mb)**
CD Audio	44.1	16	10.09
ADPCM Level A	37.8	8	4.33
ADPCM Level B	37.8	4	2.16
ADPCM Level C	18.9	4	1.08
Digitized 22 KHz	22.0	8	2.52
Digitized 11 KHz	11.0	8	1.26

An alternative to CD-DA (Red Book audio) may be ADPCM, Adaptive Pulse Code Modulation, which allows the audio to be stored as data on the CD-ROM. It is played with a sound board that is plugged into the computer.

Audio Start/End Timing

A-Time is a way of calculating the start time of an audio segment from the start of the disc. The use of A-Time can lead to technical difficulties as the start of playable lead time for discs can vary. CD-ROM drives can start at slightly different locations near the beginning of a disc. A program can tell a CD-ROM drive to start playing at 10 minutes - 32 seconds and 0 frames, but the drive may actually start at a location plus or minus a few frames. An additional problem with A-Time is that any change in the size of preceding tracks will change the timing of all subsequent tracks. Any of these problems can cause audio to play out of sync. Note: A-Time frames are 75 per second and SMPTE frames are 30 per second.

Track relative time is a combination of track and A-Time. Instead of addressing the elapsed time from the beginning of the disc (like A-Time), you can address the elapsed time from the beginning of a specific track. Many mixed-mode CD-ROM's rely on track relative time addressing so if the size of the data track changes, it does not effect the audio access times.

If you have less than 98 sound segments, you can record each segment as it's own track. However this becomes cumbersome with more than 10 to 20 segments. The maximum number of tracks on a CD-ROM is 99. Thus, allowing for one track of data, only 98 audio tracks can be recorded.

The paragraphs above are only for digital sound recorded as CD-DA. If you record digitized audio and store them as files on the data track of the CD-ROM, then you will play them back using a sound board. The playback will come from speakers attached to the sound board or from the internal speaker in the computer.

Most problems with a mixed mode CD-ROM are caused by the fact that the timing of the audio is off. If an image display, slide show, animation or video sequence takes 12 seconds, you want to time the audio to last 12 seconds or less. Users accept visual data without audio but are quick to criticize when audio rambles on after the visual is gone. The best way to avoid audio without image is to make each audio segment "event driven". Event driven means:

- Audio has delays built in to allow time for graphic changes.
- The user is "locked out" of changing the screen while audio is playing.
- A still image that pertains to the audio is displayed long enough to allow the audio to finish.
- If a motion sequence is to end before the audio, it should transition to a still picture that is relevant to the audio. The still can work as a place holder for the eye.
- Have graphics change only during silence in the audio.

When recording audio for CD-ROM, consider the following:

- What formats are accepted by the mastering facilities? U-Matic (the preferred format), DAT (Digital Audio Tape), or check with Disc Manufacturing, Inc. for guidelines.

- Que sheets are required. Que sheets are used for analog recordings. Identify each track as to its start time, end time, and content on the Que sheet. This helps the audio engineer during the mastering process. A sample que sheet is shown below:

Audio Input Table

Tape #	Requested Track # or A-Time	Start Time Min: Sec: Frame	Duration Min: Sec: Frame	Description*

***Description of the desired track would be something to indicate to our audio engineers where each track begins, such as the first few words.**

- When audio is recorded in one long track, usually Track 2, it is important to leave two seconds of silence at the beginning of each audio segment. This allows the CD-ROM drive to seek to the proper area without over/under shooting the start of the recording. Standards require that each track is at least 4 seconds long.

Sound Effects

Sound effects such as glass breaking, barking dogs, jets flying or a car horn can enrich the effectiveness of a product. Sound effects are easy to record and require little time to integrate into a program. An educational database of animals will hold a young student's attention much longer if sounds from each animal were included.

MIDI

MIDI (Musical Instrument Digital Interface) can be employed to enhance a product by adding computer generated music and sound effects. MIDI music can be recorded as a digital audio track or it can be stored as a computer file in a directory on the CD-ROM. Most computers do not have MIDI hardware interfaces, so an interface card is needed if the MIDI music is not recorded in CD-DA form. MIDI data transmission requires 10 bits per byte and transmits 31,250 bits-per-second asynchronously. MIDI messages control synthesizers, drum machines, keyboards, music sequencers and other MIDI devices. The Standard MIDI file format allows compatibility regardless of hardware platforms. If creating music is not in the plans, you can purchase a wide range of public domain and commercial recordings in MIDI format. MIDI files are available from computer Bulletin Board Systems (BBS) and recording studios. Music magazines are a great source of advertisements for MIDI music for sale.

Voice

Voice is a valuable form of audio for a mixed-mode CD-ROM. In some instances, the human voice can explain concepts better than written word or a graphic diagram. Written words can be distracting, proven by a movie that has subtitles. Adding voice to a dictionary increases its usefulness to users that are not familiar with the language or do not understand the rules of pronunciation.

COMPUTER PLATFORMS

Choosing a computer platform is very important. The computer market is divided into three main segments: DOS 80x86 computers, Apple Macintosh, and UNIX based computers. Once a system is selected, based on target market and research, it is important to take into consideration the unique factors each present.

DOS Computers

DOS is the computer platform most often designed for, as it has the greatest number of users. With a common operating system and executable command set, the selection of a system is a matter of screen quality, possible memory available, and maximum CPU (Central Processing Unit) speed. Before doing a Multimedia CD-ROM, one should check the latest standards issued by groups such as the Software Publishing Association (SPA) or the Multimedia PC Marketing Council (MPC).

There are program specific questions that need to be answered. If the application is math intensive (i.e. performing numerous floating-point calculations as in finance databases), will it require a math co-processor to operate at acceptable speeds? Will the program be operating under a GUI (Graphical User Interface)? Will the program be written as a custom application or will it be created using a commercially available index/retrieval program?

The pros and cons of developing a custom program versus using off-the-shelf software are many. Time to market, cost to develop, talents of the producer/company and after-market support are just a few of the factors to think about. The answers to these questions and the selection of any software program should be tied to the programs ability to control access to the audio and video on multimedia CD-ROM. It will serve no useful purpose to have a program that cannot make use of all the data, video, and audio available.

Macintosh Computers

The Apple Macintosh is an excellent computer for the integration of text, sound, and graphics. The Mac has had a graphical user interface from its introduction. It works well with sound and is easy to use and program. All these features make the Mac friendly to multimedia developers. The decisions for the design of a Mac mixed mode CD-ROM fall into the areas of supporting color and how much speed is required to display images. The less expensive Mac Plus, Classic, and SE series display only black and white images. Authoring systems and automated tools to create applications are plentiful for the Mac. The list includes: HyperCard and HyperCard clones like SuperCard and Plus, Macromind's Director, Authorware and many others. There are tools to speed access to CD-ROM data in

most of these authoring applications. If you write your own custom application, Apple provides excellent developer support services.

UNIX Computers

UNIX systems are becoming more important in the CD-ROM world. As with any other system, UNIX applications benefit from the addition of CD-DA to the applications. In addition to the common requirements of any mixed mode CD-ROM, the UNIX world has CPU dependencies and operating systems (OS) version dependencies. Each vendor of UNIX workstations have specific programming requirements, (i.e. a UNIX program written for the SPARC CPU will not work on an Intel CPU based UNIX computer. If the user-interface is written in one style (Open-Look), it may not work with another style (Motif) user-interface). Once the selection of CPU's and OS versions are made, the key issue is getting the CD-ROM drive next to the user that is running the application. In most workstation offices, the only CD-ROM drive is the one they use to load releases of software from the manufacturers. This is changing as more workstations get CD-ROM drives. Presently, it is important that the application ask the user if they have speakers turned on and they can hear the audio playing. The question is necessary because the audio from a CD-ROM drive comes from speakers attached to the CD-ROM drive and not from the speaker in the computer.

SELECTING DATA

After selecting the data types and platform, decisions need to be made on what data is to be used and the order in which it is to be presented. When using sound to augment text data with short sound-bytes, such as sound effects or short sentences, the selection of what audio to be used is directly related to the other data selected. A dictionary containing 30,000 words should have 30,000 samples of the spoken word. It makes no sense to make a user guess when or where they will get audio.

Remember the audio should be in sync with the screen. If a CD-ROM has animations or video, then the audio should run in sync with the video. It is awkward to hear an audio segment run beyond the motion, so select the audio to fit the motion.

The quality of the data used is important, but the target market may not require the highest level. This is not to say the data will be of poor quality or inaccurate. Selecting only the highest quality images, sound, and motion will limit the market for a product into a category of machines that have a very small percentage of the total market. Few computers can perform to that high of a standard. The project guidelines of a mixed mode CD-ROM will define the target market. The choices are greater when designing for a new system where computer performance is known, rather than with an installed base of computers where the performance is varied or unknown.

Selection of only full color, full motion video and stereo digital audio is the best of all worlds. However, the truth is that system speed, display quality and RAM storage on a typical computer system makes that unrealistic. Each developer must decide, based on input from the target market, what requirements can be put on the users of the product.

Select the resolution of images that best fit the target computer and limit the stereo audio to segments that require them. High quality animations can take megabytes of storage per second, they are RAM intensive and can cost hundreds to thousands of dollars per minute to create. The average cost of creating cartoon type animations is 2,000 to 4,000 dollars per minute. Half and quarter screen size animations/ images take much less space and require less RAM than full screen animations and can be brought to the screen much faster. When considering image resolution, a screen that can only display 75 dots per inch does not need images of print quality to work, unless you need to print the image.

If you do not capture data in high quality (i.e. 44.1KHz for audio, 1280x1024 pixels for images) and later decide to re-purpose the data (i.e. convert a CD-ROM title to a CD-I title), you will need to recapture the data. But if the data is captured in high quality, it can often be converted in bulk reducing long-term production costs.

A wise evaluation of your graphics and target audience will help ensure that you are getting the most value for your application development dollars. Few, if any, customers will buy more memory or equipment for an application.

TEST UNTIL IT HURTS

To avoid problems it is best to allow time for extensive testing. You can test mixed mode CD-ROM's by using one of several methods. Simulation systems such as the VR-Publisher or VR-Pro by Meridian Data Inc., TOPIX PC & TOPIX Mac by OMI, or CD-Simulator by Electrosun can provide simulation of a CD-ROM before you go to the pre-mastering stage of production. Creating a test CD-ROM can be even better for testing purposes. The mastering facility can provide test discs (one-offs) prior to mastering and replication of an order.

Testing should occur on the full range of computer systems defined by your project. Basic testing includes viewing each record, picture, animation and listening to all the audio. Have both programers and end-users test the CD-ROM; an end-user will often detect errors that programers will miss. More advanced testing can include creating programs to verify data and searching every record individually and in various combinations.

The CPU and CD-ROM drive speed can greatly effect the performance of mixed mode CD-ROM's, so testing many configurations before shipping a product will keep the customer from finding problems first.

Testing time of one to three weeks should be allowed for all but the simplest of mixed mode CD-ROM's. Less time spent testing will be that much more time you will spend on the technical/customer support phone line. Make sure every last file is both opened and fully read from the CD-ROM. Play all audio and check it against the original recording.

Your Next Step

We probably don't have to tell you, companies of all sizes and purposes are quickly moving to CD-ROM multi-media technology. The reasons are apparent: it is a medium offering exceptionally low costs per megabyte; it allows storage and playback of any form of digital data, including audio and motion video, and, of course, it provides enormous data capacity on a single disc. Hopefully, you too, will soon be profiting from this fast-growing technology.

We trust this discussion has been of value to you. Although we readily admit that multi-media CD-ROM can be confusing, especially to new producers, getting to a final, "flawless" disc is not nearly as difficult as most people imagine. We at Disc Manufacturing, Inc. are anxious to answer any questions you may have and to help you to take the next step in the process. Won't you give us a call?

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