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A Beginners Guide to DVD

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WHAT IS DVD?

DVD, or Digital Versatile Disc is essentially the latest and greatest in optical storage technology. It is a new kind of compact disc that holds a lot more information, and spins a lot faster than a typical (ISO 9660) compact disc. (Most DVDs spin at about the same rate as a 9X CD-ROM.) DVD is used to store movies, audio, multimedia presentations and general information.

A DVD disc looks just like a CD. It's the same size, the same width, and generally the same color. But in many important ways a DVD is different than a CD. First, it holds more—a lot more. A DVD can hold up to 20 times as much information as a CD. Second, it can be configured to play in a DVD-Video player. A DVD-Video player is a box that sits on top of your television, and looks a lot like a VCR. DVDs are currently used to store movies, audio, multimedia presentations and general information.

Why Do I Need to Know About DVD?

Whether you're talking about DVD-ROM or DVD-Video, DVD is where the world is heading. The computer and information technology industries are moving towards DVD-ROM because a DVD spins faster and holds a whole lot more stuff than a CD. This interest in DVD technology is very strong. Most computer manufacturers have announced that all new machines will come equipped with DVD-ROM drives. The entertainment industry is moving towards DVD-Video because DVDs are smaller than laser discs, easier and less expensive to replicate than VHS tapes, and offer additional interactivity that is not available with tapes. Unlike VHS tapes, DVDs offer random access, which means you can access any point on the disc instantly. If you don't think that smaller, less expensive, and more interactive are compelling reasons for a technology to grow, ask yourself how many audio cassettes and LPs you've purchased recently. Almost all of the new movies coming out of the major Hollywood studios are released on DVD as well as VHS tape. DVD is clearly a very important technology for the near future.

What Can I Use DVD For?

You can use DVD technology in many of the same ways that you use other multimedia technologies. You can use DVD for laptop sales presentations with hours of high resolution, high quality MPEG2 video that you can play in a portable DVD-Video player the size of a portable CD player. You can use DVDs to loop video for kiosks in lobby and point of purchase displays. Unlike tapes, DVDs don't degrade or wear out. Rather than setting up a computer, you can use an inexpensive, readily available consumer player to do the job. Need to store information? DVD is your tool! With up to 20 times the capacity of a CD-ROM in the same space, storage just got more compact, less expensive, and a whole lot easier.

What is the Difference Between DVD-Video and DVD-ROM?

Both DVD-Video and DVD-ROM are often called "DVDs". While they are often called by the same name, they are somewhat different formats. A DVD-ROM is essentially a replacement for CD-ROM. Like a CD-ROM, a DVD-ROM can hold virtually any kind of information. There are very few constraints regarding the file types and file formats stored on it. Likewise, there is little to no guarantee that information stored on a DVD-ROM will "play" audio, video or other multimedia files in any given system. The target system has to have the appropriate drivers and playback mechanisms (such as an MPEG2 playback card) to play audio and video properly. DVD-ROM drives are usually found in desktop computers and laptops.

DVD-Video is a special application of DVD-ROM. DVD-Video discs are designed to be played in a DVD player. A DVD player is a consumer product that is typically hooked up to a television set and surround sound stereo system. The DVD-Video format was designed by a consortium that is mostly made up of major motion picture studios and major consumer electronics companies. DVD players typically cost \$200-\$500.

So what about compatibility between DVD-ROM and DVD-Video? Most DVD-ROM drives are able to play DVD-Video discs. However many DVD-Video players will NOT play DVD-ROMs.

What's So Great About DVD?

DVD-ROM is great for two simple reasons: the discs spin faster, and the discs hold more. DVD-ROM will rapidly become as widespread as CD-ROM, and like CD-ROM, will be widely compatible and available everywhere. DVD-Video offers many features that are useful for a wide range of business and consumer applications. Obviously, not every feature is used on every disc.

However, every player must support every feature covered in the specification.

These features include:

Increased Capacity

There are many confusing "formulas" regarding exactly how many minutes of video you can fit on a DVD-Video disc. Truthfully, it depends on whether you use MPEG1 or MPEG2, whether you use constant bit rate (CBR) or variable bit rate (VBR) and how large your bit rate is overall. The other assets on your disc can also effect how much video you can fit, but the effect of audio and subpicture files is generally pretty small. As a result, the amount of video you can get on a disc varies from about 90 minutes to about 8 hours.

Basic Interactivity

DVD-Video provides for index searching for title, chapter, track and timecode. This allows the user random access to the included media.

Multiple Aspect Ratios

DVD-Video allows both 4:3 (television) and 16:9 (widescreen) aspect ratios to be displayed from a single disc. DVD-Video players also have provisions for users to choose how they wish to deal with aspect ratio choices. For example, a user viewing a widescreen-formatted movie on a 4:3 television monitor can choose to view the movie in pan and scan mode or letterbox mode.

Multitrack Audio

DVD-Video discs can accommodate up to 8 tracks of digital audio with up to 8 channels per track. This allows multiple channel audio formats including PCM, MPEG2 and Dolby Stereo. In addition, multiple channels can be used to store multiple language tracks for a single movie on a single disc.

Subtitles

DVD-Video can accommodate up to 32 subtitles or karaoke tracks. Each track could hold the lyrics for a song or a subtitle for a foreign language. The user can select among these tracks on the fly (meaning while the video continues to play).

Seamless Branching

Seamless branching allows users to select various options such as alternate endings on the fly. Seamless branching also allows for the parental lock option, which allows parents to select which movie ratings will be allowed to display on the player. For example, if a parent locks out R and NC-17 films, either the R or NC-17 scenes would be omitted or the discs simply wouldn't play at all.

Camera Angles

DVD-Video discs can support up to 9 simultaneous camera angles. The user can select among these angles as the disc is playing. If, for example, a DVD showed a famous baseball game shot with 4 angles, the user could select (on-the fly) whether she wished to view the game from home plate, first base, third base or the outfield.

Menus and Simple Interactive Controls

Most discs contain either stationary or moving menus, which allow the user the ability to hop to various sections of the disc. Generally, this interactivity is very simple, and does not allow a great deal of input from the user.

Zone Lock

The Motion Picture Industry wants to be able to control when and where movies are released in the world. Every DVD-Video player is coded with a geographical zone. DVD titles may contain a zone lock, which means that title can only be played on DVD-Video players with the matching zone numbers.

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Copy Protection

Copy protection is not readily apparent to law-abiding end users. However, copy protection affects all end users in two important ways. First, DVD developers must pay licensing fees to use the copy protection schemes. Naturally these licensing fees are passed on to end users in the form of a higher price. Second, the constant bickering over copy protection schemes among those in the DVD Consortium has set DVD-Video technology back, and has ultimately slowed the release of new titles.

HOW TO MAKE A DVD-VIDEO DISC

Making a DVD really isn't so different from making any other type of multimedia application. It requires careful planning, access to the right tools, organization, a little creative genius, and enough time and space to do the work. The steps to DVD development are planning and budgeting, audio and video development, audio and video encoding, graphics development, authoring, mastering, testing, and mastering and replication.

Planning and Budgeting

It's easy to get caught up in the technical ins and outs of DVD. But what differentiates a great DVD from a good DVD is rarely technical prowess. (Although not understanding the technology can lead to a useless DVD or mini Frisbee(r) if you can't get it to play.) A great DVD like any other artistic endeavor requires a clear sense of direction and a vision of what you want the outcome to be. This means planning, planning and more planning. Before you buy lots of equipment and commit to a huge development project, follow these steps:

1. Decide what you want to accomplish with your DVD. Do you want to increase real estate sales by 10%? Do you want to sell 5,000 copies of your title? Do you want to decrease the number of accidents on your construction site by 50%? Make sure your goals are specific and measurable.
2. Prioritize your goals. Decide what is most important to you or your client.
3. Storyboard (or flowboard) your project.
4. Set your budget and timeline.

Audio and Video Acquisition and Editing

There are many ways to acquire audio and video. In general, you should use the very best tools you can afford. While a lot can be done to compensate for bad audio and video source materials, the computer industry adage "garbage in, garbage out" holds true for DVD development. If you plan to use MPEG2 compressed video for your final application, it is especially important to shoot your video in the highest possible resolution. You should use D1, Digital Betacam, Betacam SP, or DV formats. Even if you plan to use MPEG1 video, you should use these formats if possible.

Once you've acquired all of your video, you'll need to edit it. Currently, most people edit on a computer with some sort of nonlinear editing system. Here again quality is key. The better your editing system, the better your DVD will ultimately turn out. For example, a Media 100 system or an Avid Media Composer would be a good choice for your video editing. Both of these high-end systems allow editing at high resolutions, and can be used to create a wide variety of special effects. In addition, HEURIS' MPEG Power Professional can take finished edited video directly out of these systems which leads to the next step—encoding.

Audio and Video Compression

Audio and Video compression is a very important part of utilizing the multimedia capabilities of DVD. DVD-Video, as its name suggests, was designed to hold video. Clearly, having the right compression tools is critical to the success of your DVD development project.

Why is Video Compression Really Necessary?

Simply put, uncompressed video is big. Really big. Uncompressed video runs at over 20 Megabytes per second. That means to view uncompressed video, you need a mechanism that can display 20 Megabytes every second. This is way too much to flow smoothly through a DVD player, even *with* its greatly increased speed and bandwidth capabilities. (ADVD-Video player can only sustain about 1/20th of that size.) And even with DVD-Video's large storage capacity, you wouldn't fit very much video onto a disc at 20 Megabytes per second. MPEG2 video files are typically compressed about 30:1 (or 30 times) for DVD-Video applications.

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30:1 Compression! Doesn't that Look Bad?

Sometimes MPEG compression does look bad. MPEG is what is called a lossy algorithm, which means it permanently discards some information as it encodes. The MPEG algorithm is designed to only discard information that the human eye can't easily detect. Sometimes MPEG works pretty well, and sometimes it doesn't. There are many, many factors that can affect the ultimate image quality.

How to Get the Best MPEG Image Quality

In general, there are several overriding factors that influence whether your MPEG encoded files look really good or really bad:

The Quality of Your Source

Keep in mind the computer industry adage, "Garbage in, garbage out". MPEG is a lossy algorithm. Your MPEG encoded files will not look any better than your source. And if your source files are grainy, noisy or low resolution, your MPEG files will look a lot worse.

Bit Rate

Generally, the higher the bit rate, the higher the quality. You should try to use the highest bit rate you can, based on the limitations of your playback technology, and the amount of space you have to pack everything in. Variable Bit Rate (VBR) encoding allows you to get higher visual quality at a lower average bit rate, because it allows you to allocate more bits to the complex scenes and less to the simple scenes that are easy to encode.

Generation Loss

Every time you re-copy or re-digitize video, it loses quality. That's why you should go digital early in the production process, and stay digital all the way through. For best quality, shoot in a digital format such as Digital Betacam, and then pull those digital files directly into a high-quality nonlinear editing system such as an Avid or Media 100 system. Then pull those digital files directly out of the nonlinear editing system and drop them into HEURIS' MPEG Power Professional. Convert the files to MPEG, and then pull those files right into your high quality DVD authoring system such as Spruce DVD Maestro or Daikin Scenarist. This is really your best path from NLE to DVD.

How Smart is your Encoder?

In order for an encoder to comply with the MPEG standard, it must simply produce a stream that can be read by the Standard Target Decoder (STD). This means that the MPEG algorithm can be implemented in many, many different ways, some of which produce better looking MPEG than others. (HEURIS has over nine years experience working with the MPEG algorithm. This experience and expertise ensures that HEURIS' implementation of the MPEG algorithm produces great looking results.) Consider your encoder purchase carefully. Has the encoder manufacturer been around for a while? Do they have a reputation for high quality encoders? Make sure you also take a look at some samples created with the encoder.

Preprocessing and Filtering

This is the part of the encoding process that is often seen as a "black art". There are two kinds of preprocessing and filtering. Manual filtering is controlled by the end user. Automatic filtering is controlled by the computer. In automatic preprocessing and filtering, the computer looks at the video coming up, analyzes it, and chooses the filters and options that would seem to produce the "best" looking video. In manual preprocessing and filtering, a real live person looks at the video, and makes choices about which filtering and other options will produce the best looking video. Obviously, the more expertise this person has, the better the video will look.

An ideal MPEG encoding system will allow both automatic and manual preprocessing and filtering. It will offer very smart automatic analysis and a wide range of well designed filters at the touch of a button. But a good MPEG encoding system will also allow the human operator to tweak all the settings on a frame by frame basis. Naturally, MPEG Power Professional offers both manual and automatic preprocessing and filtering.

Fine Tuning

To get really great visual quality, sometimes you need to go down to a frame by frame basis and tweak things. With a highly intelligent encoder, you won't need to do this very often, but it's important to have the capability available when you need it. Some very important tweaking options include frame by frame control of:

- I-frame detection and placement.
- Search Distances—This is how far the encoder looks for similarities between the frames.
- Search Techniques—This is how the encoder looks for similarities between the frames.
- Filters—This is how you control how heavy the filters are, and turn them on and off on a frame by frame basis.
- Inverse Telecine Phase Changes—If you do 3:2 pulldown, you want to be able to control exactly where the phase changes fall.
- Half-pel Searches—This allows very fine searches, even to 1/2 of one pixel.
- Variable Bit Rate Allocation—For best quality, you should be able to hand tweak where bits are allocated in a variable bit rate sequence.

Open and Closed GOPs

A Group of Pictures (GOP) is the segment of frames in an MPEG sequence between one I-frame and the next I-frame. For example a GOP might look like this:

IB BPBB PB BPBB PBB

There are two different kinds of GOPs. In an open GOP, P and B frames may be constructed of data from frames from another GOP. In a closed GOP, P and B frames only reference frames within that single GOP.

Since closed GOPs are required for multiangle DVD playback, it is very important that your MPEG encoder offer that option. However, open GOPs often produce higher visual quality than closed GOPs. Ideally, your MPEG encoder would allow you to choose between open and closed GOPs.

Not Constrained to Real Time

Fastest is not always best when it comes to quality. For the very best quality, an MPEG encoder should be able to grind away as long as it takes to make a scene look its best. If the encoder insists that you do every encode in real time, important concessions in image quality may occur.

Inverse Telecine

If your footage originated on film, but was transferred to video, it went through a process called Telecine. Film is displayed at 24 frames per second (fps), and video is displayed at 30 frames (or 60 half-frames or fields) per second. The Telecine process is used to add 6 extra frames (or 12 fields) to every second of film to make it meet the 30 fps requirements for video display. However, MPEG can play back just fine at 24 fps. If the bit rate remains the same, but the number of frames per second is reduced, there are more bits allocated to each frame and the video looks better. Inverse Telecine simply takes the extra frames added in the Telecine process back out again. By removing these "extra" frames, the resulting video quality is higher for a given bit rate.

MPEG Power Professional and Image Quality

Naturally, MPEG Power Professional offers all of these powerful encoding features and much more. MPEG Power Professional is quite simply, the most comprehensive and sophisticated MPEG encoding software on the market. It offers frame-by-frame controls of I-frame placement, filters, searches, variable bit rate allocation, inverse Telecine phase changes and much more. MPEG Power Professional also offers built-in templates that allow you to create fully compliant, application specific MPEG streams in just a few simple clicks. And with the latest update, MPEG Power Professional offers better image quality and is faster than ever before. Now, it accepts even more of the professional digital video file formats that you use every day such as all the latest OMF file formats. As always, MPEG Power Professional accepts digital files directly from your nonlinear editing system, providing your best path from NLE to DVD.

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MPEG Encoding for Multiangle Applications

DVD-Video's multiangle feature allows the end user to view video subjects from different vantage points. For example, an exercise DVD might allow the end user to view the instructor from the front (and mirror the instructor's movements), or push the angle button to switch to viewing the instructor from the back. In order to allow this switching of angles on the fly, multiangle video must be prepared in a very specific way:

1. Angle sequences must be EXACTLY the same length.
2. Angle sequences must share the exact same audio track.
3. This audio track must be in sync with both sequences.
4. The video for the sequences must be MPEG encoded with closed GOPs.

Don't Multiplex Just Yet

In many types of multimedia development, you multiplex your audio and video together during the encoding process. However, in DVD-Video development, the audio and video are multiplexed within your authoring system during the mastering stage.

Graphics Creation

Generally graphics in DVD are used for menus, buttons, subtitles, karaoke song lyrics and still pictures. Song lyrics and subtitles are usually entered directly into the authoring system using the computer keyboard. (They are usually in a generic sans serif typeface.) Still pictures can be either a single frame of video or graphics files created with a popular graphics program such as Adobe PhotoShop(tm) or Adobe Illustrator(tm).

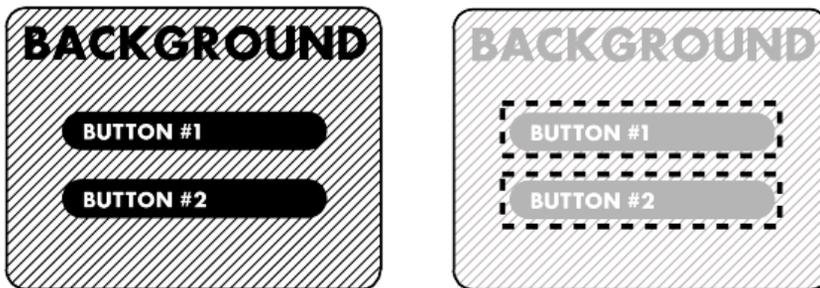
These graphics also have limitations including:

- Should be in BMP, TIFF, or PICT format. Usually TIFF files will provide the best overall image quality.
- Resolution should not exceed 720x480 (NTSC) or 720x576 (PAL).

Menus

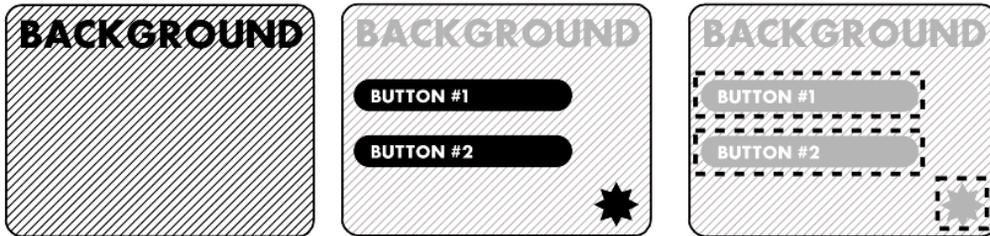
You will often use the graphics you import to create menus. Menus in DVD-Video are developed in layers, just like a sandwich. (If you've created a CDi or Video CD, you're probably familiar with this process.) For the most part, you'll want to work in a dedicated graphics program like Adobe PhotoShop. You'll also want to know that the graphics choices available to you in the button highlight or subpicture level are going to be very limited. The DVD specification only allows you to choose 4 colors from a 16-color palette.

Most menus are composed of two or three layers. The background layer is usually created in PhotoShop and then pulled into the authoring package as a TIFF file. The button activation layer allows you to highlight certain areas of the screen based on the level of activity. For example: let's say you brought in a background layer with buttons drawn on it. You could use the button layer to draw a box around those buttons. Then, when user moves the pointer to that button in the application, the button layer would overlay a color in that area. Finally when the user selects the button within the application, it would overlay another color.



Background Layer and Button Activation Layer

This overlay color can be one of four colors from a sixteen-color palette. The authoring system will also allow you to control the opacity of the overlay. But what if your button isn't rectangular, or if you want to merely change the color of the text on the button, or create a halo around the text on the button? That's where the subpicture layer comes in.



Background Layer, Subpicture Layer and Button Activation Layer

In this scenario, the color would change when a button receives emphasis or is selected. But instead of layering color OVER the button, the graphics included in the subpicture layer would change color. So if the text were in your subpicture layer, the text would change color. And if you had a star shaped button in the subpicture layer, that star shaped button would change color.

Clearly in preparing your graphics for DVD-Video menus, you'll need to decide whether you plan on using simple button overlays with stationary backgrounds, subpicture layers with text or buttons changing colors or motion menus.

DVD-Video Authoring—Putting it All Together

Now you're finally ready to put everything together. You will put everything together with a powerful product called an authoring system. This system helps you organize everything and precisely format it so that a DVD-Video player can read it.

Once you have your authoring system set up, and you've prepared all your media assets, it's time to bring everything in. With most authoring systems, this process is very simple. You simply select your media files, and drag and drop them into the authoring system. Generally these media files are sorted into four basic categories: audio, video, subpictures and still pictures. Usually there is a separate folder for each category.

After you have all of your media assets in the authoring system, it's time to create all your links and menus and buttons and hook everything together. Each authoring system works a little differently and there will be plenty of peculiarities for each product. However, there are some general steps you will follow in nearly any authoring system:

1. Import your audio, video and graphics assets.
2. Set global properties—This is where you make many choices that apply to your entire DVD such as PAL/NTSC video, copy protection, geographic zones and more.
3. Drag your audio and video files into a timeline—This is where you bring all your unmultiplexed audio and video files and line them up so they start together. You would also drag subtitles in here, or create them in this section to synchronize with your video.
4. Set properties for each of your audio, video and subtitle files—For each of your files, you will select certain options such as assigning languages to audio tracks and aspect ratios to video tracks. You'll also add chapter markers here for use by your search and playback navigation commands.
5. Assemble menus—You'll bring in your backgrounds and subpictures here. You'll also define each button highlight area as well as defining what happens visually when a button is highlighted or selected, and which order the buttons are selected in.
6. Create all the connections and links within the DVD—This is where you define all your connection points and links, including:
 - First Play—What happens when you first insert the disc? (This can be either a video auto play command or a menu.)
 - Chapter End—What happens after each chapter is finished playing? Does it connect to a menu or a particular button? Does it connect to another chapter that begins to play?
 - Timeout—Where you determine if menus simply continue to play indefinitely or if menus jump to a video segment after a certain amount of time.
 - Title Menu—For each screen or video in your DVD, what happens when you click the title button on the remote control?
 - Buttons—What happens (or where do you go?) when you click every button on every screen of the application?

7. Emulation—As you are working in the application, you will use the emulation capabilities of your authoring system to test out the decisions you are making. The DVD emulator should be able to display menus just as they will appear in the final disc and should be able to play back all your audio, video, subtitle, and subpictures correctly.

Premastering

Premastering is essentially just what it sounds like—what you do to the disc before you send it off to be mastered and replicated. If you have a Spruce or Daikin system, you'll do most of your premastering within your authoring system. Here are the basic steps:

1. Compile—In most professional DVD authoring systems, a lot of the formatting required to make your application compatible with the DVD specification will be transparent to you. Much of this formatting occurs when you compile your DVD within the authoring system. Once you've compiled your application, the compiled version can no longer be edited. (Of course, you should be able to go back to your project files, make changes and recompile if you need to.) In this stage all the multiplexing or VOB creation for your audio, video and subpicture files finally occurs.
2. Test—At least the first round of testing will occur at this point. After you've compiled your application, take a look at it within your DVD emulator. This is a good time to check that all the buttons do what they're supposed to, and everything looks good.
3. Create a Disc Image—After you've compiled your DVD and checked it in the DVD emulator, it's time to create a disc image. You will do this in your authoring system. (The DVD disc image is a UDF bridge volume, which is the same volume that is written to your final replicated disc.)
4. Test Again—Now that you've got a final (well hopefully final) disc image, it's time to test again. If you can make it fit your budget, you should burn DVD-R discs and test them in both computers and set-top players.
5. Create a DLT—A DLT is a Digital Linear Tape. It is literally the only format that you can send to a DVD replicating plant right now. You can't send DVD-R discs or any other kind of media.

What's a DLT?

DLTs are sort of like very high capacity 8mm DAT tapes. They are a different size and shape than 8mm tapes, however, (more square shaped) and they can only be created or read in a DLT drive. DLT drives are currently available from a wide range of manufacturers ranging in price from around \$2,500 to \$10,000. Capacities range from 20 to 40 GB.

Mastering and Replication - Disc Labeling and Printing

Even before you send your DLT to the replicating plant, you'll probably want to send your graphics files or film in for the disc labeling and packaging. Labeling is the printing on the disc surface itself. Please note that capabilities for disc labeling are very different for single-sided vs. double-sided DVDs. Single-sided DVDs can have labels that cover almost the entire disc surface. Double-sided DVDs only allow a thin band of printing on the disc.

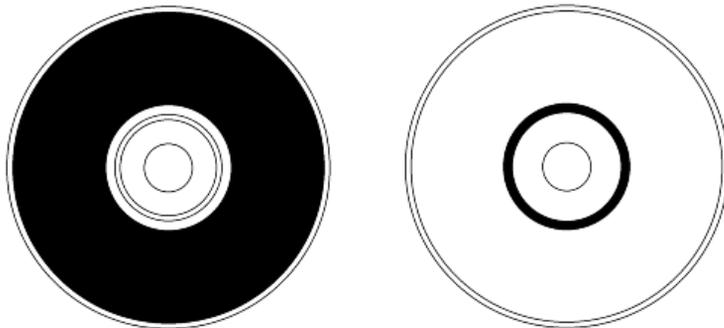


Figure shows disc label for a single sided disc on the left and a double sided disc on the right. The black area represents the label.

Generally, DVD replicating houses accept digital graphics files in common formats as well as film. Contact your specific replicating house for more information on required dimensions and accepted file formats. If you are sending digital files, allow several days during the replication process to send proofs back and forth and secure approval.

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DVDs are often packaged in plastic cases that are taller than standard CD cases to distinguish them from CDs. However, since DVD discs are the exact same size and shape as CDs, you can choose to use traditional CD packaging. Most replication houses can print and assemble your DVD packaging as well.

This may seem like the last step, but it rarely is. Not all DVD-Video players can read DVD-R discs, so you'll probably want to have your replicating house run a few test discs before you do your full replication run. You can test these discs yourself (in absolutely every player you can get your hands on), or send your discs to a disc testing facility. Once you're through this final testing phase, the replicating plant will make many copies of your DVD, print labels on them, package them, and ship them.

MAKING A DVD WITH HEURIS MPEG POWER PROFESSIONAL-DVD

Making a DVD with HEURIS MPEG Power Professional is easy! Simply import files from your nonlinear editing system, encode with MPEG Power Professional, and import your files into an authoring software package. MPEG Power Professional is powerful and flexible allowing you to make everything from simple non-interactive DVD discs to full-blown, multi-angle, Hollywood blowout DVDs. MPEG Power Professional is so direct and easy to use, it's really your best path from NLE to DVD:

- MPEG Power Professional accepts files directly from all popular nonlinear editing systems including Avid, Media 100, Apple and Adobe systems. No need to render to another file format or make a quality draining move back to tape, just drop in your edited files and go!
- MPEG Power Professional's built-in template ensures fully compatible MPEG files with just one click. Just click the DVD template button and all the MPEG encoding options are selected for you.
- If you simply want to put video files on a DVD disc for linear playback, you no longer need an authoring system. Simply use MPEG Power Professional's VOB feature to create VOBs right within the encoder. Then you can use a burning package such as Adaptec Toast DVD to burn your files to DVD-R.

- If you do need to use an authoring system, MPEG Power Professional is ready. HEURIS has already tested the encoder with all the popular authoring systems out there. Just pull your MPEG encoded audio and video files out and line them up in your authoring system. With MPEG Power Professional, you can be confident that your streams are correctly configured and fully compliant.

IT'S PLAYBACK TIME

Now that you've finished with your shiny new disc, you'd probably like to play it somewhere. That's often not quite as simple as it seems. Simply put, you've got to have the right stuff.

Playing a DVD-ROM on a Computer

The first thing you'll need to play a DVD on a computer is a DVD-ROM drive. A DVD drive generally spins as fast as an 8x or 9x CD-ROM drive. Sometimes, if your CD-ROM drive is fast enough, you can convert it to a DVD drive with a DVD upgrade kit.

The next step is to check what kind of DVD you have. If you have a DVD-ROM disc, you can read it in any DVD-ROM drive. But if that DVD-ROM contains audio or video, you'll need the appropriate audio and video decoding hardware or software as well as enough CPU horsepower and RAM to make it go. For example, if your DVD-ROM contains MPEG2 video, you'll need an MPEG2 hardware or software decoder and some sort of sound card and speaker system to hear the audio. If you are using an MPEG2 software decoder, you'll also need to be sure that your CPU is fast enough and you have enough RAM for smooth playback.

NOTE: All DVD-ROM drives also play CD-ROMs and CD-R discs as well as most CD-RW discs.

Playing a DVD-Video disc on a Computer

Most computers with DVD-ROM drives also have the ability to play DVD-Video discs. On PCs, most DVD player applications allow you to specify which volume to play back from. Microsoft Direct Show in particular, looks for the VIDEO_TS directory in the root, starting with the volume in drive D (if no drive is specified). On the PC side, you can read DVD-Video data from drives other than the DVD-ROM drive. DVD-Video discs can only be read from the DVD-ROM drives on Macintosh G3 and G4 systems.

Your computer will naturally require MPEG audio and video playback in order to read a DVD-Video disc. Most of the hardware playback options, such as the Sigma Designs Hollywood Plus card and the Margi Systems DVD-To-Go PCMCIA card work quite well. The software products for DVD playback offer highly variable results depending on the speed and memory of your computer system. Many new DVD-Video discs have a software DVD decoder on the disc along with the application.

Other DVD-Video Data on Computers

You can put a DVD-Video application on virtually any media on the PC side (Zip(tm) disc, CD-ROM or even floppy) and be relatively sure it will play. However, in order to ensure smooth playback from that other media, the storage device must move data at sufficient speeds to meet the peak data rate of your content. (For example, if you are playing an MPEG2 file from a Zip disc, and the top data rate is 9.8 MBPS, your Zip disc must be able to move 9.8 MBPS. Otherwise playback will be choppy or stop altogether).

Again, on all shipping Macintosh systems, DVD-Video titles can only be played from the DVD-ROM drive. In fact, if you're planning on using the G4's built-in software for decoding, all MPEG2 files can only be read from the DVD-ROM drive.

DVD-Video Players

A DVD-Video player is generally an inexpensive consumer electronics component that is hooked up to a television. (There are also professional DVD players that are used in kiosks and video

walls.) It is approximately the same size and shape as a traditional audio CD player. Generally this system comes with a remote control for interacting with the simple controls found in most DVD-Video applications. Most DVD-Video Players can read most DVD-Video discs. However, some new discs, which implement more esoteric corners of the DVD specification, are not playable on some first generation DVD players. This will undoubtedly get better over time.

Technically a DVD-Video player is only required to read DVD-Video discs. Some first generation players do only that. However, through the assistance of outside organizations such as the Optical Storage Technology Association (OSTA) efforts have been made to ensure that DVD-Video players can read discs in other formats. Many current players have voluntarily complied with the OSTA MultiRead specification and can read CD-DA, CD-ROM, CD-R and CD-RW formats. Some players can read Video CD and DVD-R discs. None of the players can currently read CD-R discs formatted as DVD-Video discs. Generally speaking, DVD-Video players do not read DVD-RAM or DVD-RW discs, but there is a movement towards ensuring compatibility with these formats as well.

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MPEG - The Big Squeeze

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Why do I need to Know About MPEG?

You may have heard of MPEG and wondered what it is. Or you may know what MPEG is, and wonder why you should care. Well here's the straight scoop. If you work with multimedia in any way, shape, or form, and you want your applications to look new, hip, and powerful, you'll want to incorporate video. If you incorporate video into your applications, you'll need some form of video compression. The only form of video compression that is both cross platform and accepted as an international standard is MPEG. So, if you are a multimedia developer, or work with multimedia in any way, you really need to know MPEG.

What is MPEG?

MPEG (pronounced EM-peg) is an international standard for audio and video compression, multiplexing (or joining together audio and video) and decompression. The reason MPEG is needed is that audio and video files are VERY LARGE. Uncompressed video files run about 27 Megabytes per second. This means you can get only a few seconds of uncompressed video onto a CD-ROM. That's where MPEG comes in. With MPEG your audio and video can be compressed to 1/20th of its original size, yet still look great.

What is the Official Definition of MPEG?

MPEG is an acronym for Moving Pictures Expert Group, which commonly refers to the international standard for digital video and audio compression. The official name of the MPEG1 standard is "Coding of Moving Pictures and Associated Audio for Digital Studio Media at up to about 1.5 MBPS". It is sometimes referred to by its ISO/IEC project number, 11172 parts 1 through 5. However, this standard is usually just called "MPEG".

Just as Norton Utilities is a collection of tools for maintaining computers, MPEG is a collection of tools for compressing and decompressing audio and video. MPEG does not specify how to perform this compression. It does, however, describe a set of minimum requirements that the MPEG decoder must live up to. (An MPEG decoder is the device which plays back the compressed audio and video.) In particular, it defines a fictitious MPEG decoder, which incorporates the minimum requirements that determine whether something is MPEG or not.

This theoretical decoder is called the STD (Standard Target Decoder) model:

- If a product is a MPEG decoder, then it must minimally have the same functionality as the STD model.
- If a product is a MPEG encoder, then any streams it generates must be decodable by the STD model.

(For more information on the MPEG standardization process please see the Details, Details White Paper.)

The Many Flavors of MPEG:

There are currently two MPEG standards in existence, MPEG1 and MPEG2. There is no MPEG3 (it was rolled into the MPEG-2 standard). New standards called MPEG4 and MPEG7 are coming on the scene. MPEG4 is currently under development, but is not expected to be finalized for at least another year. MPEG7 is just getting underway, and is not expected to be finalized until 2002.

There has been a lot of confusion in the industry and the media about the differences between MPEG1 and MPEG2. Contrary to what many people think, MPEG1 and MPEG2 are not competitors to one another, and MPEG2 is not an improved version of MPEG1.

MPEG1 was, in fact, designed specifically for delivering video from a single speed CD-ROM drive or T1 data stream. MPEG2 is a completely different standard from MPEG1, and is designed for different purposes. MPEG2 is specifically targeted at digital transmission or broadcast of video signals, and supports a much wider range of resolutions and bit rates than the MPEG1 standard. It supports these resolutions and bit rates in its various "profiles and levels". MPEG2 is used in DVD-Video discs, and MPEG2 has been chosen as the standard on which US HDTV systems are based. The following chart indicates some of the different "flavors" of MPEG.

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| Name | Resolution/Target Bit rate | Common Applications |
|-------------|---|--|
| MPEG1 | SIF resolution: 352 x 240/ 1.152 MBPS QSIF resolution: 176 x 120. | Internet, CD-ROM, Video CD, CDi, sales presentations, kiosks, DVD, DBS |
| MPEG2 | 1/2 D1 MPEG-2: 352x480/~3-5 MBPS Full D1 MPEG-2: 704x480/ 4-10 MBPS | DVD, DBS, kiosks, sales presentations |
| MPEG4 | Very low bit rate, very low resolution | Internet, games, teleconferencing |
| MPEG7 | Cataloging and searching standard for maintaining databases of media objects. | games, CD-ROMS, DVDs, virtual reality applications, media editing and cataloging |

(For more technical information about the MPEG standard, please see the Details, Details White Paper.)

Which MPEG Do I Need?

Generally speaking, which MPEG you need relates to what you are trying to do. MPEG2 is higher resolution and generally has higher visual quality. However, MPEG2 also takes up more space on your media, and is playable on a somewhat smaller number of machines than MPEG1.

Generally speaking, if you need to fit in a smaller space, or you need to play back on a wide variety of computers with a wide variety of configurations, you should use MPEG1. If image quality is your primary concern, and you know that your target playback systems will have MPEG2 capabilities, you should use MPEG2. MPEG4 is still being finalized in the International Standards Organization. You may see some machines as early as 2000 with MPEG4 capabilities.

In general, this is an area to keep an eye on. However, it's probably not too prudent to make design plans based on MPEG4 until things sort themselves out a little more.

Why Use MPEG?

There are at least three ways in which MPEG is superior to other types of video compression:

1. **Image Quality:** MPEG is the only current internationally standardized, cost-effective way to get one hour of VHS quality video on a CD-ROM or over 2 hours of high resolution video on a DVD.
2. **Compatibility:** MPEG was designed as an international, open standard in order to ensure compatibility. MPEG gives you more choices than other video compression schemes, especially when it comes to playback.
3. **Compression Ratio:** MPEG1 frequently offers data compression ratios of up to 200:1 yet still offers VHS quality playback. MPEG2 offers compression ratios up to 50:1 yet still allows Betacam quality playback. You won't find that anywhere else.

What Can I Do With MPEG?

Besides thinking up new words to go with the acronym (Multimedia Projects Ensure Gastritis for example), there are lots of things you can do with MPEG. The high output quality and incredible compression power of the MPEG algorithm makes video accessible for a wide variety of users:

- Developers of full-length motion picture titles for playback from DVD movie players.
- Developers of interactive software packages for DVD-ROM.
- Interactive television producers who wish to encode advertising and services and movies for satellite broadcast and "video on demand".
- Developers of full length motion pictures on CD for Interactive Compact Disc machines.
- Developers of software packages for the Interactive Compact Disc machines like Philips CDi.
- Corporations-- for use in training videos.
- Software Developers-- for a wide variety of uses including video help screens.
- Game Developers-- add full motion video to interactive games.
- Marketing--to add spice to that important presentation.

MPEG opens up whole new worlds in multimedia. You can encode full-length movies to compact discs or DVDs, create interactive video training applications, develop kiosks, send video over phone lines, and do a whole host of other projects. MPEG offers better image quality at a smaller bit rate than any other compression method. So if you want the most bang for your byte, MPEG is the method for you.

How to Play an MPEG File

In order to play an MPEG file you'll need some kind of MPEG playback device. These devices may include software MPEG players for your computer, hybrid software/hardware players for your computer, hardware players for your computer and dedicated playback devices. Each of these players has advantages and disadvantages.

Software Only Players on your Computer

Software MPEG playback on your computer has two obstacles to overcome. First, it must use your CPU to decode the MPEG file. Then it needs to draw 30 frames per second on your screen. How fast it can decode the MPEG file depends on your processor speed. How fast it can display the frames of the video depends on your video card as well as your processor speed. Therefore, the quality you can expect is dependent on how fast your computer and your video card are.

MPEG1 playback in software is quite commonplace at this time. Most new computers come bundled with some sort of MPEG playback software capable of real-time full frame playback. Generally if your computer is equipped with one of these software decoders, at least a Pentium level CPU, and over 32 Mb of RAM, you should be home free.

Microsoft's ActiveMovie Control is available free of charge from Microsoft, and enables Windows 95 and Windows NT 4.0 users to play back from MPEG1 files without installing additional hardware. If you have recently upgraded your system, chances are good that you already have ActiveMovie installed. From the Windows Start Menu, select Programs/Accessories/Multimedia and look for "Active Movie Control".

Playing back MPEG files on the Macintosh has historically been rather difficult. QuickTime 4 will allow you to play back MPEG1 files without any trouble. Earlier versions of QuickTime are less reliable for MPEG playback. The same issues with other software MPEG playback devices are also relevant with the MPEG player in QuickTime. The MPEG player plug-in can be found at the QuickTime Home Page.

While MPEG1 playback in software is quite common, MPEG2 playback in software is another story. The higher resolution and bandwidth of MPEG2 make playback in software much more difficult. You can decode MPEG2 files on the PC side via Microsoft's Active Movie. But you probably shouldn't expect reasonable results unless you have a 266 MHz machine or better. The new G4 systems from Apple come bundled with an MPEG2 software decoder. However, this decoder can *only* read MPEG2 files from the DVD drive, and those DVD files **MUST** be written in the form

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of a VOB. (A VOB is a special type of multiplexing for DVD. You can create VOBs in a DVD authoring system or in HEURIS' MPEG Power Professional-DVD.) MPEG2 playback in software should continue to become better and more widely available.

Combination Hardware/Software Solutions

Some video cards being sold now come with MPEG playback software that can link directly into the accelerated drawing features on the video card. This way, they can deal with displaying all 30 frames per second very well. This method of playback still needs a powerful CPU to decode the data but it will display the video more smoothly. Companies like ATI and Diamond include MPEG playback software like this with their video cards.

Hardware Players for your Computer

The most effective way to play MPEG on your computer is through a hardware decoder. This MPEG playback hardware is often a card that you plug into your computer, but several computer manufacturers are incorporating the hardware directly into their newer systems. The hardware does all of the decoding of the data and overlays the frames on the video signal. This way, you can get full screen, full color 30 frames per second video on your computer. Some computers from IBM and Compaq incorporate MPEG1 and MPEG2 playback hardware, and Sigma Designs makes some of the better add-on hardware cards for your computer. Wired Inc. makes the only currently available hardware MPEG1 and MPEG2 decoders for the Macintosh platform.

Dedicated Hardware Playback Systems

Dedicated hardware playback systems include systems like CDi, Video CD and DVD-Video Players. These are basically CD-ROM or DVD players with MPEG playback hardware capable of playing back on a television monitor. These are designed largely as consumer level items. They are relatively inexpensive compared to computers with playback devices. For example, CDi or Video CD players as well as DVD-Video players can each be found for a few hundred dollars. However, each of these dedicated playback systems has extra requirements regarding the formatting of the MPEG discs. In order to play on a CDi player, Video CD player or DVD-Video player, the disc must be formatted in CDi, Video CD or DVD-Video formats respectively. Each of these formats has specific authoring requirements, which may significantly increase the development costs for these discs.

THE MULTIMEDIA DEVELOPMENT PROCESS

Rather than spend pages upon pages discussing the details of MPEG, we thought it would be more helpful to explain how MPEG fits into the development process. Chances are, if you're reading this document, you intend to actually create a multimedia application using MPEG.

This section explains how you would go about doing just that.

The Steps

Multimedia development is a relatively complex process, which tends to follow a specific progression from beginning to end. Video compression is an important part of the multimedia development process, but it is only a part. Whether you intend to create a CD-ROM, a web page, a computer kiosk, a sales presentation, or even a DVD, you will need to follow these basic steps.

1. Planning and Budgeting
2. Media Acquisition
3. Media Manipulation
4. Media Compression
5. Authoring
6. Testing
7. Mastering
8. Distribution

Planning and Budgeting

Measure twice, cut once is a common adage for seamstresses and carpenters alike. This adage is particularly appropriate for multimedia developers. A sound plan and a sound budget are absolutely essential to the success of your multimedia project. This plan should encompass dates, names and budgets for all nine steps listed above. You should be very careful to take all of the multimedia development steps into account. Do you have the right resources? Will you need to purchase new equipment? Will the resources required be available when you need them? How will you deal with "slippage" in your project? You may find it helpful to use a project-planning package like MS Project to help you keep track of the details.

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(For more information on planning and budgeting, please see "How to Plan and Budget for your Project " at the end of this white paper.)

Acquisition

During the acquisition phase, you will gather all audio, video, photographs and graphics required for your multimedia project. Photographs can be taken with a traditional camera and then scanned, or shot with a digital camera without ever going to film. Graphics are typically created with a graphics program like Adobe Illustrator.

There are lots and lots of ways to acquire audio and video these days. In general, use the very best tools you can afford. While a lot can be done to compensate for bad audio and video source materials, the adage "garbage in, garbage out" holds true for multimedia. To that end, shoot your video in the highest possible resolution. Recommended formats include D1, Digital Betacam, Betacam, or DV.

Some care should be taken in choosing subjects, lighting and background for your video. Generally speaking, the lower the bit rate you'll ultimately use for your application, the simpler you should make your shots. If you plan to use MPEG1 at bit rates of less than 1.5 MBPS, you should choose subjects with a lot of close-ups and relatively uncomplicated or unfocused backgrounds. Also avoid high-frequency data like scrolling text. With MPEG2 you have much greater flexibility. The resolution and the bit rate are much higher, so you have fewer artifacts. Nevertheless, the simpler and clearer you make your shots, the better your DVD will ultimately look. (For more information on this subject please see, "What you should know before you shoot your video" at the end of this white paper.)

Media Manipulation

During this phase, all of the media assets gathered in the acquisition phase are manipulated to prepare them for the multimedia process. All graphics need to be converted to an appropriate format for the multimedia project. This might mean bitmaps or JPEG for the Internet or a TIFF file for a CD-ROM. These files can usually be converted within a graphics program like Adobe PhotoShop.

All audio and video assets also need to be edited. Most people nowadays edit on a computer with some sort of nonlinear editing system. Here again quality is key. The better your editing system, the better your multimedia project will ultimately turn out. A professional system like a Media 100 system or an Avid Media Composer would be a good choice for your video editing. Both of these high-end systems allow editing at high resolutions, and allow a wide variety of special effects. In addition, HEURIS' MPEG Power Professional can take finished edited video directly out of these systems without redigitizing or going back to tape. In addition, on the Avid Media Composer, you won't need to render to QuickTime before MPEG encoding-you just export your OMF files and go. This direct path from editing to encoding is very important. Any time you have to go back to tape or redigitize you lose not only time, but also quality. With a Media 100 or Avid Media Composer, you simply drag your OMF or Media 100 QuickTime files and drop them directly into MPEG Power Professional.

Media Compression

Sometimes photographs and graphics will need to be compressed before inserting them into a multimedia application. Audio and video files nearly always need compression before inserting them into a multimedia application. That's because video files are big--make that really, really big. Uncompressed video files average about 27 Megabits per second. That's where HEURIS' MPEG Power Professional comes in. You can use the software to compress and convert your audio and video to MPEG1 or MPEG2. MPEG Power Professional fits seamlessly into the multimedia development process, because it was designed for the way you work. With MPEG Power Professional, you can pull video files directly from your nonlinear editing system, (like a Media 100 or Avid Media Composer) and use them directly in the encoding software. There's no need to render to QuickTime or dump to videotape and redigitize. You simply drag the files out of the editor and drop them into MPEG Power Professional. Then you pick the template that most closely matches your target application. You can either use the template as is, or you can modify the template to meet your particular needs. You can choose to use MPEG Power Professional's powerful built auto analysis feature and let the software make all of the encoding decisions for you. Or if you like to tweak, you can control every parameter of the encoding process on a frame by frame basis. With MPEG Power Professional, you'll be an MPEG expert in no time. Once you've created your MPEG files you can drop them directly into your application. This is generally part of the authoring process.

Why You Should Use Software for MPEG Encoding

You could use a software product like MPEG Power Professional to do your encoding, or you could use a hardware encoder. There are several advantages to using software instead of hardware for your MPEG encoding needs.

1. MPEG Power Professional is more flexible than hardware. Because you are not constrained by the need to produce a stream in real-time, you have greater control over the encoding parameters. With the software, it takes as long as is required to produce a beautiful MPEG video.
2. MPEG Power Professional has a better upgrade path than hardware. Developing hardware is typically slow and expensive. While a software update can be tested and distributed in a matter of weeks, hardware upgrades typically take 6 months or more. In addition, hardware upgrades are generally much more expensive to produce than software upgrades. Often you need to throw your board or system away and start over in order to upgrade your hardware. This means that software is generally upgraded more frequently and far less expensively than hardware.
3. MPEG Power Professional is more economical than hardware. If you compare a typical software encoder to a typical hardware encoder with equal features and capabilities, the hardware product costs more.

Most hardware encoders currently work faster than software encoders. If speed is your only requirement, then hardware is probably for you. But if price, flexibility, and image quality are just as important to you, software encoding is probably the way to go.

Authoring

The authoring step is where your application is really built. This usually requires a special piece of software. If you're creating a web site, you'll either use a web page builder like Microsoft Front Page or Adobe Page Mill, or you'll program your site directly in HTML. If you're creating a CD-ROM or kiosk you'll use an authoring package like Macromedia Director or Authorware.

If you're creating a sales presentation, you'll probably use presentation software like Microsoft Power Point or Lotus Freelance. And if you're creating a DVD, you'll probably use a DVD authoring package like Spruce DVD Maestro. You will import and organize all of your media like pictures, graphics and MPEG files within the authoring software. You'll then use these software packages to organize the information in your application, and create hot spots, buttons, menus or links to access this information. Once you're pretty sure you've got the application how you want it, it's time to test.

Testing

Here's some tried and true advice from the multimedia trenches: don't ever underestimate the need for and difficulty of testing. One of the most common pitfalls of novice multimedia developers is insufficient testing. It doesn't matter that your application is really cool if the end user can't get it to work or it blows up her system. You'll need to test often and test thoroughly. Test on as many systems in as many configurations with as many people as possible. Test, test and then test some more. If you don't test sufficiently before you replicate, you may end up with ten or twenty thousand highly decorative (and expensive) coasters instead of CD-ROMs. With a web site, it may be simpler and less expensive to fix a mistake, than on a CD. But can you ever really repair the relationship with your client after he experiences egg on his face in front of the entire international web community? Think about how much testing you think is really required. Then double or triple that amount. You'll be glad you did.

Mastering and Replication

If you're creating a kiosk, sales presentation or web site, you may be able to skip this step. But if you're copying lots of CDs or DVDs, you'll need to send your application to the replication house. At the replication house, they'll check your data for errors, and then create a glass master. This glass master is then used as a template or stamper for the rest of the discs. Make sure that your replication house is reputable. Ask around. Are they known for quality and on-time service?

A crummy replication house can bring even a highly successful and well-organized multimedia development project grinding to a halt. Once the glass master is finished and approved, copies of your CD-ROM or DVD will be created. The replication house often also handles packaging the CD-ROM or DVDs as well.

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(For more technical information about Compact Discs, please see "Bit rates and Compatibility" in the Details, Details White Paper.)

Distribution

Congratulations, your multimedia application is ready to make its public debut. At this point you can send out your CD-ROMS or DVDs, post your web site to the net, or show off your kiosk or sales presentations. You've finally made it. It's time to bask in the glory of your highly effective and successful multimedia project!

How to Plan and Budget Your Multimedia Project

Perhaps the best way to describe the multimedia planning and budgeting process is to take you through a real-world example. We'll describe the planning and budgeting methods we used to create one of HEURIS' early tutorial CD-ROMs. (This early CD-ROM is no longer distributed by HEURIS. The currently shipping CD-ROM was developed from a different plan.)

The first step in our CD-ROM development process was defining specific goals. We started by brainstorming. The technical director and project manager sat down with the boss and made a list of all the things we wanted to accomplish with this CD. We did not edit, prioritize or discard anything at this stage; we just started writing. Here are some of our goals for the tutorial disc:

1. Show people who have purchased the product how it works.
2. Demonstrate the product (without actually installing the software) to people who haven't purchased yet.
3. Train dealers how to use the product.
4. Offer people with many different learning styles different ways to interact with the product.
5. Decrease the number of calls to technical support.
6. Increase the number of sales.
7. Develop a disc that can be used by our sales staff for sales demonstrations.
8. Develop something that can be used for "benchmark" or test media by our customers.
9. Demonstrate our willingness to help customers.

After we listed what we wanted to accomplish with the project, we prioritized. Sometimes accomplishing one goal conflicted with another. Sometimes there wasn't enough time or budget to accomplish all of our goals. So we listed these goals in order from the highest to the lowest.

1. Show people who have purchased the product how it works.
2. Offer people with many different learning styles different ways to interact with the product.
3. Demonstrate the product (without actually installing the software) to people who haven't purchased yet.
4. Train dealers how to use the product.
5. Increase the number of sales.
6. Decrease the number of calls to technical support.
7. Develop something that can be used for "benchmark" or test media by our customers.
8. Develop a disc that can be used by our sales staff for sales demonstrations.
9. Develop a disc that can be played at trade shows (looped unattended playback, great looking video).
10. Demonstrate our willingness to help customers. (This isn't so much a goal as an expected result of reaching the other goals.)

After we prioritized our goals, we considered the needs of our audience. Some of our goals were targeted at different people. That's why we prioritized them. Our most important audience corresponded with the most important goals of the CD. In describing the audience we were as specific as possible. We talked about who, what, when, where, why, and how the disc will be used.

Description of "Users" for HEURIS Tutorial CD

People who have already purchased our product; these people already have a pretty clear idea of why they need MPEG. Most of these people work at a post-production house, multimedia development company, or in a corporate multimedia or video department. Most of the people working with MPEG Power Professional are visually oriented. Research shows that some like using menu commands, some like using the mouse, and some like using keyboard shortcuts. There is no clear preference of one style of controlling the program over the other.

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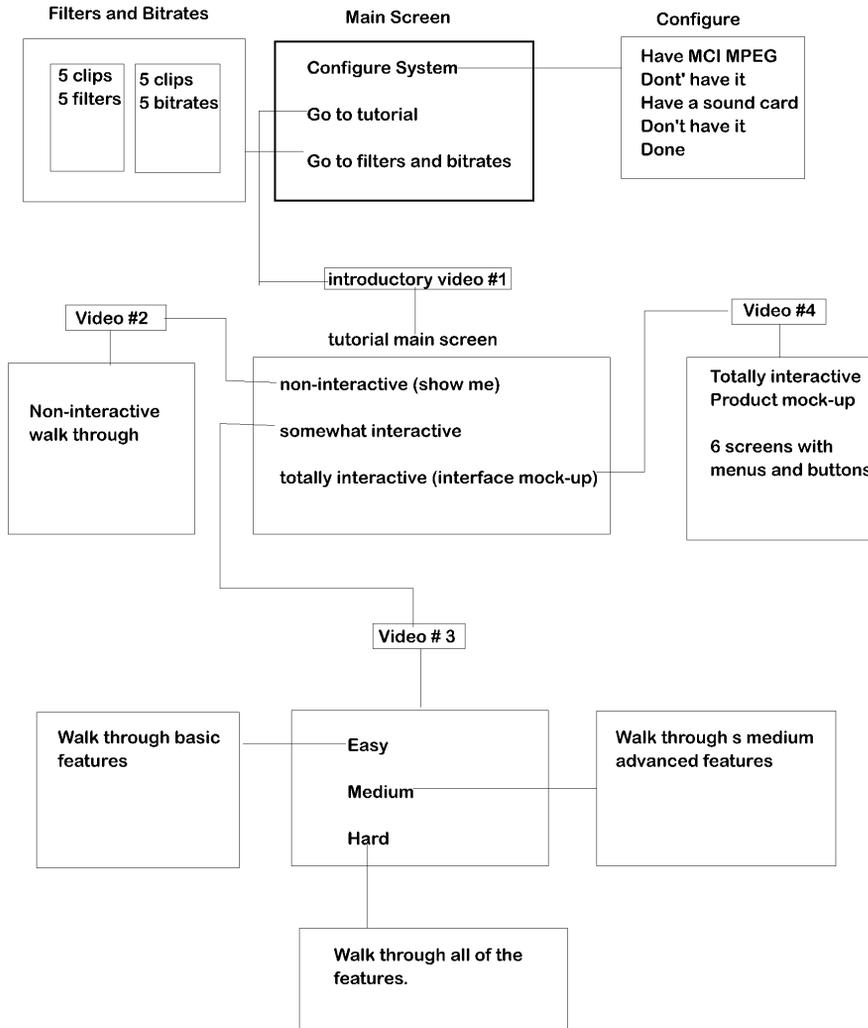
There is a variance regarding the level of interactivity desired by users of the product. It appears that some would like to watch a movie that just shows how to use the product, and some would like to click through themselves. Finally, it is important to this visually oriented group that we show the effect of various bit rates and filters on the encoding process in a visual space. The same level of detail was developed for other groups using the tutorial disc, such as people interested in buying the product, dealers interested in buying the product, and dealers who already have the product.

Next we outlined the project. Our outline was not extremely formal, but it helped with subsequent steps. We wrote down all the features we could possibly want in our CD. After considering our established priorities and our audience, our outline looked like this:

- Introductory video clip.
- Video clip explaining choices of main screen.
- Main screen allowing user to go to highly interactive, somewhat interactive and passive sections.
- A video clip that pops up whenever you go to one of these sections.
- Passive section is a "movie" describing how to use the product.
- Somewhat interactive section is a guided tour, allowing user to step through the product.
- Highly interactive section allows user to click wherever they wish in a mock-up of the product.
- Main screen also gives access to filters and bit rates section, which shows effect of various bit rates and filters on video quality.

MPEG - THE BIG SQUEEZE

Next we "flowboarded" the project. This blueprint of our project was a combination of a flow chart and a storyboard. We took our outline, and made it visual, like this:



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At this stage we didn't worry about placing items on menu screens or what each screen would look like; those steps came later. We simply created a visual representation of how we wanted the disc to work.

Finally, we generated a timeline and a budget. The timeline was a very important part of our CD development project. We referred to it (and revised it) often during the development process. Using Microsoft Project(tm), we broke down the project into tasks and subtasks, and determined which tasks could happen concurrently, and which were dependent on one another.

A word of caution in developing a time line. Most projects take longer than expected. Furthermore, the last ten percent of the project tends to take 90 percent of the time. We planned for problems and planned for mistakes. If we hadn't run into any problems (Hey, we can dream...), we'd have finished ahead of schedule and under budget. I've never heard of a boss or a client complaining about that. Here's a rough idea of the schedule we used:

Planning: 2 weeks

Development: (authoring, scripting, shooting, editing): 1.5 months

Testing and revision: 1 month

One item often underestimated in the timeline process is testing. We developed our tutorial disc to play back on a wide variety of platforms. The disc had to be tested on every machine we could get our hands on. Testing, revision, and retesting took up almost 50% of the total project time! Let me say that again, almost fifty percent of the time spent on this project occurred after the testing phase began. Underestimating this part of the process is the most common, deadly mistake we've seen among multimedia developers.

Whenever we take on a project requiring a new technical feat, we either indicate that in the time line, or pad like crazy. I don't recommend putting anything into a project that hasn't been successfully accomplished before. When we start a project, we want to know what software and hardware we will be using and we want to know that it works as specified. We test tools in advance to

make sure they work. Sometimes pre-testing is not possible, so we seek out someone we trust who has used the tools before. If we can't find anyone, we check out a user group on the Internet for that product.

Once we finished our outline and created a detailed Microsoft Project Gantt chart, we started budgeting. We associated costs with each task. We padded the budget for unforeseen difficulties. If we had developed this CD-ROM for an outside client, we would have developed a formal bid as well. (Incidentally, it might be tempting to develop bids for outside clients without this level of detail. It's not recommended. It's probably safer to bet on horses-the odds are better.) We made sure our boss knew that ANY deviations from the established design plan of our project would affect both the time line and the budget. Once our timeline and budget were finished and approved, we were ready to dive into actual development.

What You Should Know Before You Shoot Your Video

DO opt for a component video format if available.

AVOID converting your video to or from a composite format at any time during production or post-production...

BECAUSE you will suffer an irreversible quality loss and potentially introduce artifacts that will stick with you all the way to the finished product.

DO use high quality, first generation video.

AVOID using second or third generation video...

BECAUSE the higher the quality you start with, the higher the quality of the end result. High quality video is often less "noisy". Since MPEG cannot distinguish between moving video and "noise", it will attempt to encode the noise, taking bits and quality away from your moving video.

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DO use nice big fonts.

AVOID MPEG encoding text over moving video...

BECAUSE text is high-frequency video data. The moving video in the background will cause your foreground text to fade in and out. In addition, the text uses lots of bits that could be allocated to making your video look better.

DO use animation with medium amounts of detail and lines that are several pixels thick.

AVOID using computer-rendered animation with extremely fine lines (less than 3 pixels) or extremely fine detail...

BECAUSE extremely thin lines and fine details tend to "disappear" due to the lower resolutions displayed by MPEG and television monitors.

DO use fast moving video with tightly focused close-ups.

AVOID using fast moving video where background and foreground are both highly detailed and in-focus...

BECAUSE when background and foreground are both in focus, they vie with each other for bit allocation--both will require a lot of bits. This can lead to "blockiness" or "pixelization".

DO use talking heads in video; preferably a tightly focused close-up on the face.

AVOID using talking heads that are too small...

BECAUSE when characters on the screen talk, the viewer's focus is drawn to the mouth. If the mouth is too small, it may not be clear and will not look "natural". This can be distracting.

DO use computer or hand-drawn animation.

AVOID using computer or hand-drawn animation with very sharp diagonal or vertical lines...

BECAUSE this can lead to "aliasing" which makes smooth lines look like stairsteps.

DO use scene changes and relatively quick cuts.

AVOID using extremely fast scene changes that comprise less than 2 frames or blinking or flashing screens...

BECAUSE very rapidly blinking screens and rapid scene changes are difficult for MPEG encoders to handle. Encoders need to work over multiple frames in order to achieve optimal compression.

DO use video with contrast.

AVOID using high contrasts in luminance, i.e. flames, explosions, fireworks, etc.

BECAUSE high contrasts may lead to blockiness.

DO use video with lots of colors.

AVOID using monochrome scenes...

BECAUSE while the resolution levels MPEG can handle are lower than computers, the number of colors MPEG is capable of is very high.

These guidelines are not meant to suggest that there are "hard and fast" rules for MPEG encoding. These are observations made from our experience in doing real MPEG projects. MPEG Power Professional allows you to make the stuff in the "avoid" category look pretty good. However, if you are looking for optimum video quality, especially at low bit rates, it is best to follow these guidelines as much as possible.

How to Judge MPEG Quality

Image quality is subjective at best. What looks good to one person may not look good to another. This is especially frustrating when you are trying to decide which MPEG encoding products or services to go with. However, you can educate yourself as to what to look for in MPEG encoded material.

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First of all, compare apples to apples. MPEG has a difficult time handling lots of fast motion with detailed backgrounds, areas of highly contrasting light intensity, (explosions, fireworks, lightning, etc.), and (believe it or not) simple 2-D animation sequences. Try to compare demos that display some of these difficult scenes. Just about anybody can make flowers blowing gently on the breeze or a duck gliding over the water look good.

Next, get close. All MPEG encoding looks the same from 20 feet away. Optimal viewing distance for MPEG on a standard size computer monitor is 5 feet away, at about eye level. Also, you'll need to check for compliance with playback standards. Sometimes encoder companies use techniques that make the video look better, but make the stream incompatible with some aspects of the Video CD or MPEG standard or the DVD specification. This non-compliance means that the video may not play on all target decoders. It doesn't matter if your video looks good or not if you can't play it back!

Finally, turn down the sound. The sound can have a strong effect on your perception of the video quality. If you're really trying to level the playing field, turn off the sound.

When you're looking at the quality of an encoded stream, you should look for artifacts. Artifacts are anything that shows up that was not part of the original picture like: film scratches, Telecine noise, composite signal crosstalk, connector problems, electrical interference, digital encoding errors, and much more. Some of these errors come in the MPEG encoding process, but they can really happen at any point from shooting to burning onto a CD or DVD. Often, errors are blamed on the encoding process that have nothing to do with encoding. Here are some common artifacts and their probable causes:

Blockiness: when your picture breaks up into little squares. Especially noticeable in fast moving highly detailed sequences, and sequences with high contrasts in light intensity like explosions and fireworks. This is usually an MPEG artifact. Using filters or increasing the bit rate can usually alleviate this. This is sometimes called pixelization.

Aliasing: when lines that are supposed to be straight (especially diagonal ones) look like little "stairsteps". Not necessarily indicative of bad encoding, but aliasing may be reduced by good encoding or extra image processing.

Fuzz and snow: images that look as though your monitor is dirty or you lost a contact lens. Little gray or white flecks that intrude randomly throughout the picture. A dirty signal or bad digitizing usually causes this. Some MPEG encoders deliberately inject noise into the signal during preprocessing to hide MPEG artifacts.

Worms: crawling dots and squirming lines. Probably the result of low quality video or bad digitizing.

Halos: small area of distortion surrounding the outline of moving objects. This is an MPEG artifact. It is also called Gibbs effect. It can be alleviated with filtering or a higher bit rate.

Mosquitoes: These are little dots that occur randomly around the edges of moving objects in the video. This is an MPEG artifact that can be alleviated with filtering or a higher bit rate.

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Details, Details

Useful Explanations and Appendices

By: Jeanette DePatie

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APPENDIX A: MPEG: A TRUE INTERNATIONAL STANDARD

Unlike DVI, TrueMotion-S, and Indeo, MPEG is an official international standard. MPEG was developed as a joint project under the long committee description of ISO/IEC JTC1 SC29/WG11. This committee is made up of representatives from many countries throughout the world. The representative organizations are very diverse, ranging from one-man consulting companies to universities to extremely large international corporations like Philips. These companies contributed research and resources to cooperatively design a common standard method for the compression of sound and video.

To a newcomer attending an MPEG meeting, the international standard making process looks slow and cumbersome. But the committee faces many challenges both technical and political. To come to a global consensus on any technical issue takes time, and lots of it.

The general development cycle of an MPEG Standard is as follows:

1. Ideas are suggested and researched by individuals or organizations.
2. These ideas are presented to the MPEG Committee, which may form an Ad-Hoc Committee to judge the merit of the idea and to propose a recommendation to the entire MPEG Committee.
3. Proposed wordings of the idea are established and then presented to the MPEG Committee in the form of a ballot.
4. The idea is added to the MPEG Standard based upon standard voting practices.

All additions, deletions, and modifications to the particular MPEG standard proceed similarly.

APPENDIX B: HOW DOES MPEG WORK?

To keep this discussion relatively short, focus will be on the video aspects of MPEG compression. In particular, this discussion will talk about MPEG1 video compression, or video compression targeted at playback from computer hardware such as CD-ROMs. However, it is first necessary to understand what video is, and more importantly, what digitized video is.

Three Important Characteristics of Video

Video is simply an electronic sequence of still images displayed or projected (quickly) in succession to one another. As a result, the human mind is fooled into believing that people or objects in the presented sequence move. In terms of computers, there are three important characteristics of video:

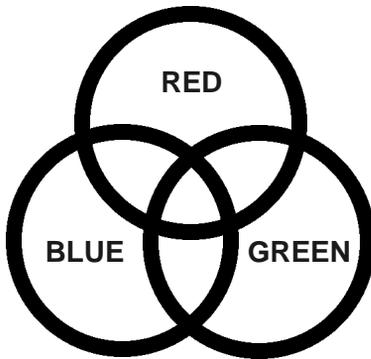
- How fast each picture is displayed (frame rate).
- How many elements create each picture in both the horizontal and vertical dimensions (frame size)? This is normally given in terms of pels.
- How many different color the picture/pel is made from.

Frame rate is the number of frames that are displayed to a viewer each second. For example, in motion picture film in the United States it is common to display 24 frames each second. In color television for the US home (called NTSC) 29.97 frames a second are displayed. Even though computers are not normally thought of in terms of frame rates, most computers "refresh" the screen by repainting every element of the screen as often as 72 times a second.

Frame size or number of picture elements is the next component of video. This is measured horizontally and vertically in pels. "Pels" are picture elements -- the small dots that make up the displayed picture. Some common dimensions, or resolutions numbers, in the computer world include 640 horizontal pels x 480 vertical pels, 1024 horizontal x 768 vertical, and 800 horizontal x 600 vertical pels.

USEFUL EXPLANATIONS AND APPENDICES

The number of colors that make up each picture or frame is a third component of video. As is the case with a painter's palette, a color can be described in terms of several "primary" colors. For instance, when playing with paints as a child, mixing equal parts of red, yellow and blue created black. By mixing these primary colors in different combinations, it is possible to produce any other color. Color mixing works a bit differently with light than with paints, but we can still make any color from three primaries. In the video world, however, we substitute green for yellow in our "primary" color palette.



A Video Color Palette

In mixing colors of light, we vary the amount of red, green and blue light that makes up the color of a pel. To make video practical, it is necessary to limit the number of differing shades of red, green, or blue that can be generated. This puts an upper limit on the total number of colors that video can recreate. Here is an example of a common digital color scheme. Each primary color (red, green, or blue) may have 256 different levels or shades. Since a color may be composed of the three primaries, this means we can generate 16.8 million different colors, or 256 levels of red times 256 levels of green times 256 levels of blue (16.8 million roughly equals $256 \times 256 \times 256$).

The color for a pel is normally written as follows:

```
pel_color = (red_level, blue_level, green_level)
```

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What is 24 Bit Video?

The previous example just described 24-bit video, without calling it that. The term 24 bit comes from the fact that 256 shades of the primaries may be represented as an 8-bit value. Since it takes three primaries to represent a single value it takes 8+8+8 or 24 bits to represent color for a single pel:

8bits red 8bits green 8bits blue
RRRRRRRRGGGGGGGGBBBBBBBB = 24 bits

As a final note about color and video, it is possible to choose different primaries or entirely different colorspace/colorsystems. The way we described colors above is not the only way to identify colors. Different "colorspaces" or methods of describing colors have different uses. For example the common colorspace for printing is CMYK, or cyan, magenta, yellow, and black. CMYK is useful to describe color for print purposes because these color components correspond to the colors of the inks used.

Another colorspace is YCrCb, or luminance (shade intensity) and chrominance-red and chrominance-blue (chrominance components define the hue and value of the color). This last colorspace is commonly used in video, primarily because it more closely resembles the colorspace of human eyes, where rods detect luminance components and cones detect the chrominance components of color.

Because you have many more rods than cones in your retina, you are much less sensitive to chrominance than luminance. For this reason, video uses often rely upon imperceptible subsampling or reduction of the chrominance component.

Now that we have discussed frame rates, frame sizes and touched the surface of color and colorspace, let's talk about MPEG's definitions of these values. For the purposes of this discussion, let's assume our video source is a typical professional digital video format called ITU-T 601 (formerly known as CCIR 601).

USEFUL EXPLANATIONS AND APPENDICES

In this format, we see the video is represented in the following fashion:

- frame rate of 30 frames a second
- picture size of one frame 720x480 (NTSC)
- color and colorspace: YCrCb 4:2:2

Luminance is sampled at full resolution; each chrominance component is sampled at full-resolution one half as often. On average then, it takes 16 bits to represent each pel.

Using these values, it is easy to calculate the total disk space required to hold one second of uncompressed video in this format:

| | | | |
|-------|------------|------------------------|---|
| | 720 | horizontal pels | |
| x | 480 | vertical pels | . |
| <hr/> | | | |
| | 345,600 | pels per frame | |
| x | 30 | frames per second | |
| <hr/> | | | |
| | 10368000 | pels per second | |
| x | 2 | bytes per pel | . |
| <hr/> | | | |
| | 20,736,000 | total bytes per second | |

This means that the average 200-Megabyte hard drive could hold about 10 seconds of uncompressed video. Clearly this is not practical for most applications. This is where the incredible compression power of MPEG comes in. MPEG1 will reduce this 20 Megabytes/second to 187,500 bytes/second (about 1.5 Megabits/second). This is a compression ratio of over 100:1!

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Bits, Bytes and other Mysteries

There is a great deal of confusion surrounding these terms. One reason for this confusion is that computer programmers and engineers do not always use these terms in the same way. This booklet deals with these terms as computer programmers understand them, with bits being the smallest unit and Megabytes being the largest. Here is a rough conversion table of these units:

8 bits=1 byte

8 Megabits=1 Megabyte

1,048,576 bytes (or 2 to the 20th power)=1 Megabyte

1,048,576 bits (or 2 to the 20th power)=1 Megabit

So, if you had 23,640,251 bytes, and you wanted to know how many megabytes you had, you would divide this number by 1,048,576:

23,640,251 bytes

divided by 1,048,576 (bytes per megabyte)

22.55 megabytes

However, for the purpose of rough estimates, you could just move the decimal over 6 places to the left to tell how many Megabytes (about 23 Megabytes). Then to convert to Megabits, just multiply by 8.

To convert from Megabytes to bytes, simply multiply by 1,048,576 or for a rough estimate, move the decimal 6 places in the other direction.

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From 20 MBPS to 187,500 BPS

The first step of MPEG1 is to reduce the number of pels representing the image. It reduces the resolution of the image from 720x480 pels to 352x240 pels--providing more than a 4:1 compression:

| | | | |
|---|------------|------------------------|---|
| | 352 | horizontal pels | |
| x | <u>240</u> | vertical pels | . |
| | 84,480 | pels per frame | |
| x | <u>30</u> | frames per second | |
| | 2,534,400 | pels per second | |
| x | <u>2</u> | bytes per pel | . |
| | 5,068,800 | total bytes per second | |

Thus 20 Megabytes per second is reduced to 4.83 Megabytes per second. The 720x480 image size is considered to be professional video size. It is the image size broadcast studios use when making video. The basic premise (in analog video) is to work with something larger than you need, and hopefully by the time it gets to the home (after video editing and retransmission) it will still contain acceptable quality. Thus MPEG reduces the picture size to 352 x 240.

The next step of video compression is to realize that over a small region of a single frame, the image does not change much. For example, take a picture of a field with a pond in it. If you only look at a small portion of the picture, say 8x8 block of pels, you will probably see a block of grass, a block of blue sky, or a block that only contains the pond. In other words, most of the pels in any given block probably look pretty similar to one another. MPEG takes advantage of this property of images. It breaks the image into 8x8 blocks and then applies a mathematical function to each block called a DCT. (DCT stands for Discrete Cosine Transform.)

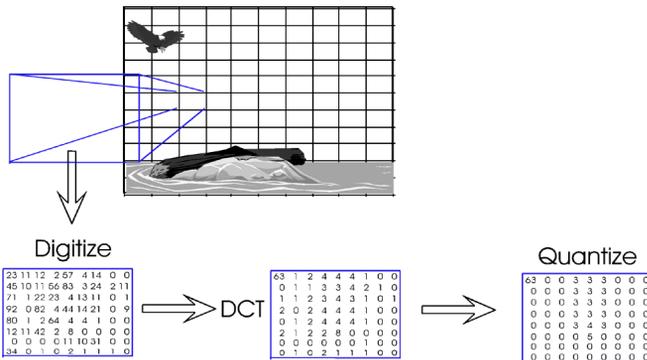
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The DCT in and of itself does not provide any compression. However, the DCT does provide a means for compression. There are two properties of the DCT that make it well suited for assisting in video compression:

- It packs the data most visible to the human eye into a tighter spot, e.g., more zeros appear in the DCT encoded block (zeros are easy to compress).

- It orders the data so that it is easier to throw parts away that are not particularly visible.

Generally the DCT results in data in the upper left hand corner as data to keep, while the bottom right contains data that can be thrown away (possibly noise in the image).



The key to using the DCT is quantization. The purpose of quantization is to keep only the pels in the 8x8 block that are most likely to be visible to the human eye. Quantization also attempts to make the data more compressible by making values near each other more similar to others (the more similar the values are the higher the compression). One example of quantization is rounding.

1.4 = 1, 2.6 = 3

In rounding, several digits become fewer digits. This is the only step of MPEG that is considered "lossy". Again, using the rounding example, once a number is rounded to 1, it is impossible to determine whether the original number was 1.2 or 1.4 or any other number between .051 and 1.5.

USEFUL EXPLANATIONS AND APPENDICES

At this point, the data in the 8x8 block has been DCT transformed and quantized, (which helped to organize the data). In the next step, the data is actually compressed (and redundant data is discarded). The compression takes place by removing the redundancies in the data, or more specifically reducing the entropy. For example, we can see that $x+x+x+x$ can be represented as $5x$. One example of reducing the entropy or redundancy within the data is as follows:

| | | | | | | | | | |
|----|---|---|---|---|---|---|---|---|---|
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |



{23,0,0,0,0,0,0 ... ,0,0,0}



{23,(63,'0')}

This notation implies that there is a number '23' followed by 63 0's. This is clearly a compression of the original data. That is, it is shorter to write {23,(63,'0')} than (23,0,0,0,...,0,0,0) with sixty-three zeroes written out.

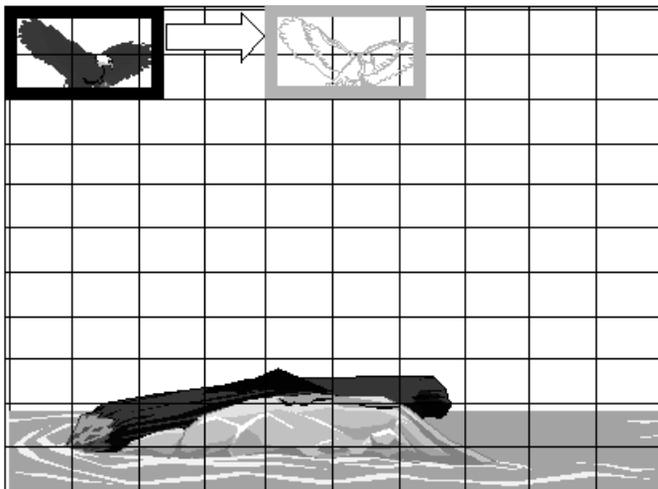
MPEG uses a mathematical process called Huffman encoding for entropy encoding. The DCT along with quantization can (depending on your source material) compress data from 10-20:1 without unacceptable video "artifacts" (errors or noise visible on the screen). The amount of compression is mostly a function of the amount of quantization that takes place.

The remaining 4.83 Megabytes/second is now reduced to 0.322 Megabytes/second (15:1 compression).

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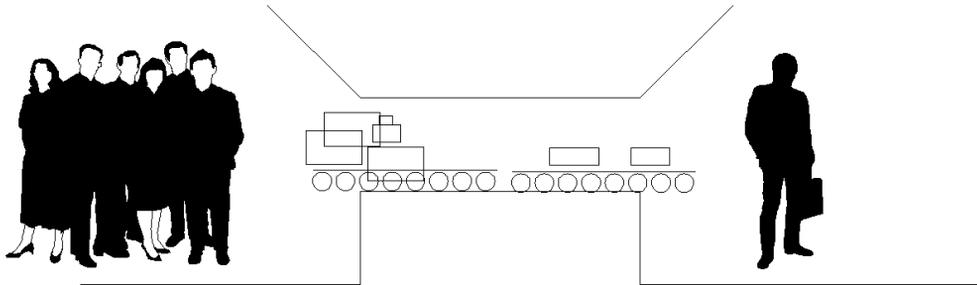
The next major feature of MPEG compression is the realization that the interframe differences are also small (intraframe is within a frame, interframe is between frames). If you have ever looked at two frames of video side by side, you would be hard pressed to see the differences. Or, better put, the majority of the frame stays the same, while only a small portion changes. MPEG uses this property as its final tool to assist in compression.

MPEG uses the notion of motion vectors to track movement in an image. Similar to how the image is broken up into blocks for DCT compression, MPEG again breaks the picture into blocks (but this time 16x16 pels, commonly referred to as macroblocks). Each macroblock can be encoded as its own completely separate motion vector. Therefore, if there are parts of an image that are staying still (the pond) from frame to frame, a motion vector that does not change from frame to frame can encode a portion of the pond. If there is a bird flying across the pond, a moving motion vector that tracks the bird can determine the changes in the bird's position and encode the bird from frame to frame. Using motion vectors can easily add 2-4:1 compression so the 352,188 bytes/second easily approaches our target rate of 187,500 bytes/second (about 1.5 Megabits per second).



MPEG and Constant Delivery Bit rates

An often overlooked, but important part of MPEG1, is that it provides a constant delivery bit rate. Although this is not important to compression, it is important to real world decoding applications. For example, in the case of MPEG1, the target delivery rate was 187,500 bytes/second or 1.5 Megabits/second. This implies that the bit rate does not fluctuate. On average, no matter the content of the video, the delivery rate will be 1.5 Megabits/second. This is important to anyone who needs to transmit the encoded material either to a satellite, from a CD-ROM, or through a telephone switch. Without constant bit rate delivery methods in these cases, it is impossible to determine (cost-effectively) the most efficient method for transmitting the data. A good analogy is a mailroom chute. When the delivery rate is constant, the packages move smoothly through the chute. Without a constant delivery rate, the chute can become overloaded or underused. The only means to handle a non-constant delivery rate is to build a mechanism into the chute that either speeds up or slows down the conveyor belt (a costly choice when that "conveyor belt" is really a satellite already orbiting the earth or a transoceanic cable buried under the sea). The best way to maximize efficiency of the chute is to determine the capacity of the chute and make sure all packages are the same size, and are designed to just fill the chute at all times.



The mail chute.

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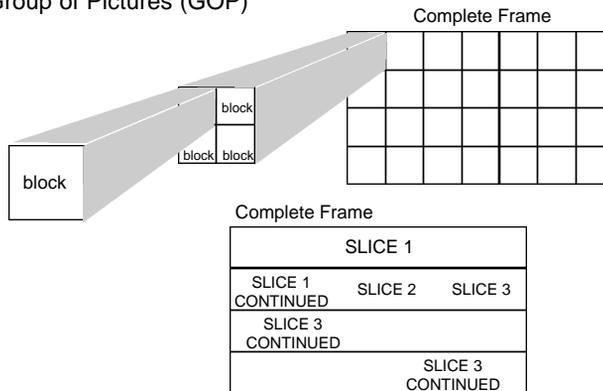
MPEG2 and Variable Bit Rate

MPEG2 for DVD often incorporates the capability for variable bit rate encoding and decoding. This means that the bit rate of the video can fluctuate, depending on the complexity of the content. More difficult scenes with a lot of detail and fast motion will have higher bit rates (say 7 MBPS) while simpler scenes will have a lower bit rate (say 2 MBPS). This doesn't mean that anything goes in DVD. Generally, a DVD requires the bit rate to average out to about 4.7 MBPS and the upper limit is about 9 MBPS. While this is not quite as efficient in terms of transmission bandwidth as constant bit rate delivery, the constraints still help to pack more information into a smaller space.

I, P, and B Frames

MPEG organizes video into several logical units. Each unit is logically composed of smaller units. The basic units of MPEG in order of increasing size are:

- Blocks
- Macroblocks
- Slices
- Pictures
- Group of Pictures (GOP)



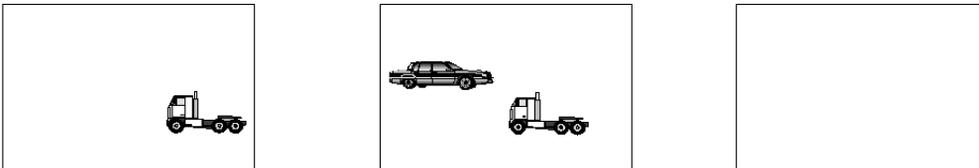
GOPs are made up of pictures that are in turn made from slices that contain macroblocks that contain blocks.

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The group of pictures (GOP) is a self contained, completely decodable unit. It may consist of an arbitrary number of frames of any of the primary types (I, P or B frames).

Blocks are composed of an array of 8x8 pels. The DCT is performed on the block level. Macroblocks are composed of blocks (in MPEG1 a macroblock consists of 4 luminance blocks and 2 chrominance blocks). Motion prediction and interpolation are performed at the macroblock level.

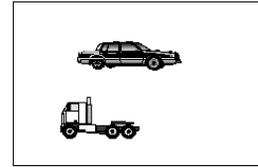
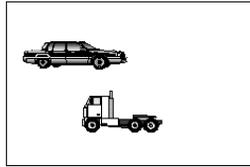
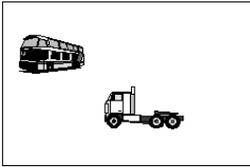
Motion prediction is useful when objects are just appearing in the current frame and will continue to exist in future frames. Prediction can also be used when the object exists in the past and exists in the current frame.



Truck is predicted.

It is important to note that MPEG can also make use of interpolation. This is useful when much action is taking place in the scene. Since the truck exists in all frames, it can be reconstructed with information from both the future frame and the past frame. The truck is therefore interpolated. The average of the two will result in the final reconstructed truck. On the other hand, the car is predicted, since it only exists in the future frame. Use of both prediction and interpolation results in a better quality "current frame". Simply put, the more information used to build the "current" frame the better the image will appear.

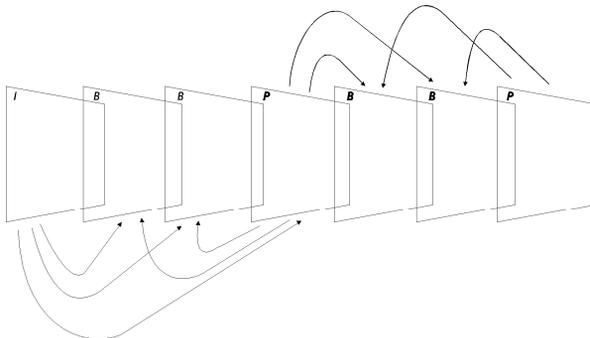
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Truck is interpolated and predicted, car is predicted.

A picture is composed of one or more slices. The "height" of a slice is one macroblock and the length can be the entire picture or any portion thereof. Slices can be used to aid in error recovery. In the case of "perfect" transmission mechanisms, such as CD-ROMs, there is normally one slice to one picture. (Compared to "imperfect" transmission mechanisms like terrestrial broadcast where error detection and correction must be performed on smaller units of data.)

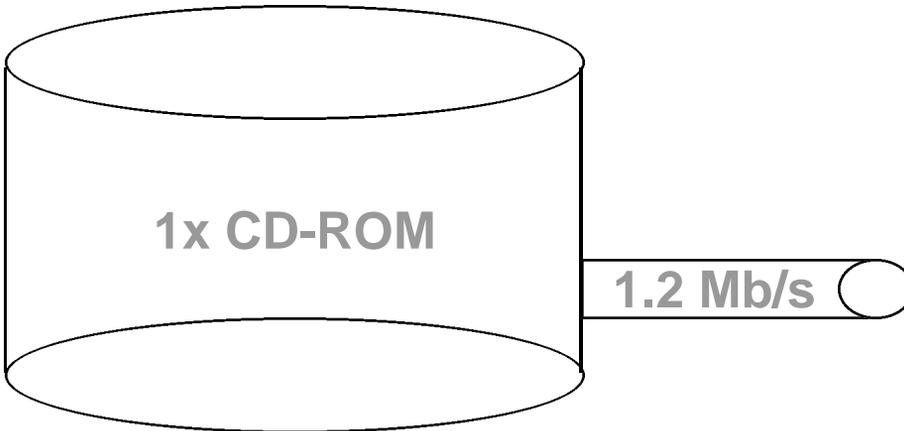
MPEG uses three different types of frames. The primary difference among these frames is how motion vectors are used in them. Intraframes (I frames) do not use any form of motion vectors. Predictive frames (P frames) make use of predictive type motion vectors. Bi-directional frames (B frames) make use of both predictive and interpolative motion vectors.



A typical GOP illustrating information flow from I and P frames to B frames and I frames to P frames.

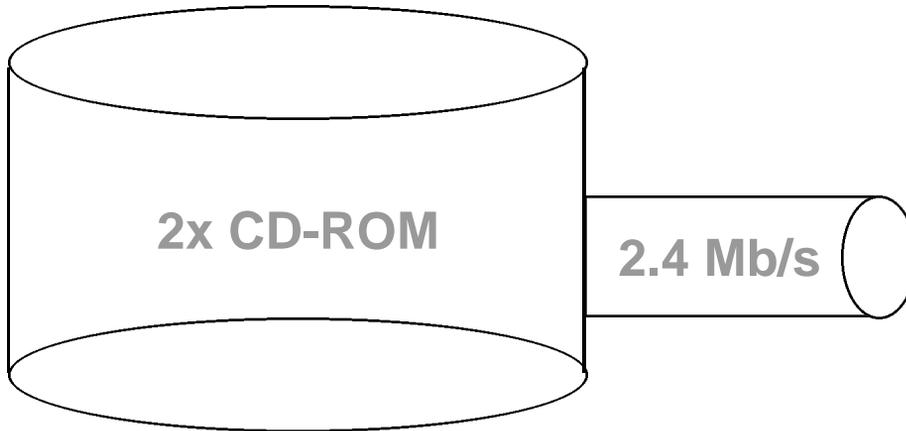
APPENDIX C: BIT RATES AND COMPATIBILITY

The "bit rate" describes how much material (how many bits) can be moved from a CD-ROM or hard drive in a given amount of time (usually per second). The standard bit rate for a single-speed CD-ROM is 1.2 Megabits per second. That means you can transfer 1.2 Megabits of data from the CD-ROM in one second. Sometimes it's helpful to think of "bit rate" as a pipeline coming from a water tank. Here's the common bit rate for a single-speed CD-ROM:



Now a higher bit rate (or larger pipe) allows you to get more information off the drive or CD (or more water out of the tank) at once. Since you can move the information faster, you don't need to compress it as much. This means that, usually, higher bit rates can produce higher quality video images. However, since each minute of video isn't compressed as much, it takes up more room on the CD or hard drive. A CD encoded at a higher bit rate can contain fewer minutes of finished video than one encoded at a lower bit rate. What's more, in order to move the data off a CD-ROM faster, you have to spin it faster.

That means, in order to play MPEG sequences encoded at bit rates above 1.2 Megabits per second/s, you need to have a double or triple speed CD-ROM drive or a bigger pipe:



Not all playback machines or CD-ROM drives are capable of playing all bit rates. What's more, the higher bit rates have both advantages and disadvantages. What bit rate you choose to encode at depends on many factors, including:

- Can my chosen playback unit play at higher bit rates?
- Do I have, or wish to be compatible with single, double, triple or higher speed CD-ROM drives?
- How important is image quality to my overall project?
- How much material do I need to fit on a single CD-ROM, or do I plan to play from the hard drive?
- How much money do I have to spend?
- Can my encoding tools provide encoding at different bit rates?

USEFUL EXPLANATIONS AND APPENDICES

DVD discs work just like compact discs in terms of bit rates, and transfer speeds. However, DVDs simply hold a lot more than a CD-ROM. Even though a DVD spins roughly equivalent to a 9x CD-ROM they can still hold several hours of video encoded at higher bit rates. But just like CD-ROMs, the higher the bit rate of the included video, the fewer minutes it holds.

DVDs are also capable of playing video at variable bit rates. With variable bit rate (VBR) encoding, more bits can be allocated to more complex video sequences and less to simple sequences. However, DVD variable bit rate encoding usually tops out at 9.8 MBPS and averages between 2-4 MBPS.

APPENDIX D: THE 4 MAIN CONFIGURATIONS OF DVD

There are 4 main types of DVDs:

- Single Sided, 1 layer
- Double Sided, 1 layer per side
- Single Sided, 2 layers
- Double layer, 2 layers per side

Naturally, double-sided DVDs hold more than single-sided, and dual-layer DVDs hold more than single layers. And of course, Dual sided-dual layer DVDs hold most of all. Here's how the discs break down:

Table 1

| Format Type | Format Name |
|-----------------------------------|--------------------|
| 12 cm, Single Sided/ Single Layer | DVD-5 |
| 12 cm, Single Sided/Double Layer | DVD-9 |
| 12 cm, Double Sided/ Single Layer | DVD-10 |
| 12 cm, Double Sided/Double Layer | DVD-18 |

Replication of DVD-5, DVD-9 and DVD-10 discs is relatively simple, and there are many facilities offering replication services. Replication of DVD-18 discs is still pretty tricky, and a lot of replication houses won't do them. It's anticipated that DVD-18 replication will be relatively widespread by the end of next year.

How Much Does a DVD Hold?

How much a DVD holds depends a great deal on which DVD configuration you're using. Obviously a double sided, dual layer DVD-18 disc holds more than a single sided, single layer DVD-5 disc. While one might guess that a DVD-5 holds 5 Gigabytes and a DVD-18 holds 18 Gigabytes, unfortunately, it's not quite that simple.

USEFUL EXPLANATIONS AND APPENDICES

How Big is a Gig?

A gig is a gig is a gig, right? WRONG! The computer industry defines a Gigabyte as 1.073 billion bytes or 10243. Most of the time when you talk to someone about storage capacity, i.e. a 9-Gigabyte hard drive, you are using this computer definition. However, just to make things complicated, the DVD specification defines a Gigabyte as 1.0 billion bytes or 10003. So if you use the DVD specification's definition of a Gigabyte, a DVD-5 holds 4.7 Gigabytes (which could be rounded up to 5 by marketing types) while the computer industry's definition only yields 4.3 Gigabytes (which can't really be rounded up to 5 by anyone who's passed third grade math). So here's how the sizes break out:

| DVD Configuration | Computer Defined Sizes | DVD Spec. Defined Sizes |
|--------------------------|-------------------------------|--------------------------------|
| DVD-5 | 4.38 GB | 4.7 GB |
| DVD-9 | 7.95 GB | 8.5 GB |
| DVD-10 | 8.75 GB | 9.4 GB |
| DVD-18 | 15.9 GB | 17 GB |

GLOSSARY OF TERMS

AC-3: (Also called Dolby Digital) this is the audio format developed by Dolby Laboratories for "surround sound". This format is often used in DVD-Video discs.

Arithmetic encoding: a mathematical entropy encoding process for the compression of data. May provide better compression than Huffman Encoding.

Aspect ratio: The proportion of horizontal to vertical in a viewing screen. For example 4:3 aspect ratio means the proportion of the viewing screen is 4 (horizontal) to 3 (vertical).

Authoring: the process of arranging audio, video, and graphic files with indexes, buttons and hotspots, to create an interactive application.

CDi: "Compact Disc - Interactive" is Philips' entry into the home video multi-player market. In common usage for industrial video CD applications.

Colorspace: system for measuring and describing color. For example, CMYK (cyan, magenta, yellow, and black) is a common colorspace for printing.

Copy protection: Proprietary scrambling techniques embedded in a DVD to prevent illegal, high-resolution copying of audio and video.

Country code: In zone locked DVDs, the discs will only play on DVD players with the correct country code. The country code is the number 1-6, which corresponds with the geographical areas defined by the DVD Consortium.

Decoder: the software or hardware used to decompress and play an MPEG file.

Digitize: the process of converting an analog video file into a digital one. This is usually accomplished with a digitizing board that takes video in and outputs a form of motion JPEG.

DIVX: a now defunct format developed by Circuit City and a Hollywood law firm. This format allowed the creation of discs that could only be played for 48 hours. In order to play the disc longer, the disc had to be reactivated by sending information over a modem and paying more money.

DV: digital video. Typically refers to a digital video capture format used in many new video cameras, in conjunction with Firewire (IEEE 1348).

DVD: Digital Versatile Disc. A high capacity optical storage format which holds audio, video, graphics, and other types of information. May actually refer to a DVD-ROM, DVD-R, DVD-RAM or DVD-Video disc.

DVD player: Usually refers to a DVD-Video player. This is a consumer playback device used with a television and surround sound stereo system.

DVD-R: a DVD recordable disc. Similar to a CD-R or gold disc. This is a write once, read many format.

DVD-RAM: A DVD read/writable disc. Similar to a CD-RW disc. This is a write many, read many format.

DVD-ROM: A high capacity disc which holds audio, video, graphics, and other kinds of information. This disc is usually played in a DVD-ROM drive in a computer or laptop.

DVD-Video: A format used for recording motion pictures onto high capacity optical discs. This subset of the DVD format contains many special features such as zone lock, parental lock, and multiple camera angles.

HEURIS - THE WHITE PAPERS

Entropy coding: a class of lossless compression methods characterized by their orientation toward finding the shortest expression of data.

HDTV: high definition television.

Huffman encoding: a mathematical entropy encoding process for compression of data.

ISO: An acronym for International Standards Organization.

Linear PCM: a very high bandwidth format of audio compression. Sometimes used to record audio on DVDs.

Lossless: Converting a black picture using a lossless process and then applying the inverse process would yield an exact duplicate of the original black image. Mathematically, lossless algorithms are one to one functions.

Lossy: Converting a picture using a lossy process and then applying the inverse process may result in a picture slightly different from the original. Mathematically, lossy algorithms are many to one functions.

Mastering: the process of turning an application into a glass master to be used in mass replication of the application.

MPEG: An acronym for "Moving Pictures Experts Group", MPEG is the collective noun often used to refer to ISO working group WG11 (ISO/IEC JTC1 SC29/WG11), which defines data compression techniques and standards for motion pictures with sound.

MPEG1: Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Megabits per second (International Standard IS- 11172, 1992). MPEG1 is used for interactive multimedia and video CDs. The normal parameters for MPEG1 are frames of 352x240 pels in the YCbCr color space delivered at a rate of 30 frames per second.

MPEG2: a standard of compression for audio and video commonly used in DVDs, HDTV, Direct Broadcast Satellite, and other high bandwidth applications.

MPEG4: a standard under development which is designed for very low bandwidth applications. This standard is not expected to be finalized until late 1998 or early 1999.

MPEG7: a standard under development which is designed for cataloguing and retrieval of audio and video resources. This standard is not expected to be finalized until at least 2000.

Multiplexing: the process of combining audio and video files together into one synchronized stream.

Nonlinear editing: a type of editing, usually done on a computer, which allows an editor to access or change any point of the video at any time.

Parental lock: a feature of DVD-Video that allows a parent to password protect objectionable scenes or content.

Pixel: A picture element, the smallest dot on the screen. Also called pel.

Quantization: A method of renumbering values to aid in compression. An example of quantization is rounding: 1.4=1, 2.6=3, etc.

SMPTE: An acronym for the Society of Motion Picture and Television Engineers, a professional organization concerned with the technical aspects of movies and television.

Standard Target Decoder: the hypothetical model of an MPEG decoder. Encoded streams must be decodable by the standard target decoder (STD) or they cannot be labeled MPEG.

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STD model: standard target decoder; see definition above.

Symmetry: In the context of data compression, symmetry is used to describe the relative complexity of the encoding and decoding algorithms. Because MPEG requires a great deal of complexity to encode and relatively little to decode, MPEG algorithms are described as "asymmetric".

UDF: Universal Disc Format. The file format used to categorize assets on a DVD. Will replace the ISO 9660 format commonly used on CD-ROMS.

Variable bit rate: an encoding technique used for DVD where the bit rate varies according to the difficulty and complexity of the video material. Usually DVDs require an average bit rate of 4.7 Mbps and an upper limit of 9 Mbps.

VOB: A special method of multiplexing used for DVDs. This multiplexing usually occurs in the authoring software.

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