

DVD Premastering: A Facility's Perspective

By C. Bradley Hunt

Digital Versatile Disk Video (DVD-Video) is a revolutionary new consumer video system. The expected demand for DVD programming represents a huge opportunity for the studios and content producers to profit from the sale of movies rereleased in this new format. Due to the richness and complexity of features and the image and sound quality of the format, content producers will need to work closely with DVD authoring facilities in the mastering of their movies to this new high-quality medium. From the facility's perspective, there are many steps involved in the DVD-Video authoring process. This paper will focus on the critical steps of element preparation, telecine transfer, video preprocessing, and compression that greatly influence the quality of the DVD-Video product.

DVD-Video represents a totally new consumer video format. Its high-quality video and audio playback capabilities will deliver an exciting new home theater experience. The format's specification was developed with an eye toward the future and its use in various applications. It has a number of important features and customer benefits that should accelerate its successful market introduction and acceptance. DVD-Video is the first consumer video format to play back component digital video at D-1 video resolution. A single-sided, single-layer DVD-Video can store up to a 133-min movie using MPEG-2 variable bit rate (VBR) video compression.

DVD-Video players have the capability to play back both widescreen 16:9 and standard 4:3 aspect ratio programming. The player's remote control allows the conversion of full-frame, anamorphic 16:9 programming to be played out as a 4:3 letterbox program. The MPEG-2 compression allows film-originated programs to be encoded at 24 frames/sec with the 3:2 pulldown reinserted by the decoder to produce the 60-Hz playback.

DVD-Video also has a number of

interesting audio features. It can carry multiple streams of Dolby Digital (AC-3) 5.1-channel surround sound to enable up to eight separate language tracks to be carried with the video. The DVD-Video Book B specification defines several other player features. The format allows full interactive branching capabilities; the inclusion of a parental lock feature that prevents playback of an R-rated movie by a child; the authoring of a DVD-Video title that carries multiple rating versions of a movie on one disk; creation of programs with multiple camera angles and multiple running times; and the development of interactive movies where the viewer steers the plot.

With all of these capabilities, the premastering of a DVD-Video by a facility involves many steps. The process, outlined graphically in Fig. 1, starts with a review of the customer requirements and continues with work on the film, audio, and graphics preparation and then compression. It finishes with DVD-Video authoring, formatting, and then output to computer tape.

The premastering of material for release on a DVD is not as simple as laying down audio and video to a videotape master. There are many new issues for a facility getting involved in premastering DVD-Videos. Because of the limited data capacity and bit rate of DVD, the authoring process involves compromises constrained by the length of the

program, the picture quality, the quality and number of audio tracks, the number of subtitles, and the level of interactivity and branching. The 4.7-Gbyte "bit budget" data capacity of a single-sided, single-layer DVD-Video allows the playback of a 133-min movie at an average data rate of 4.69 Mb/sec. If the movie is shorter, a higher average bit rate can be used to improve the image quality. On the other hand, if the movie has several audio language tracks, multiple rating versions, and multiple language subtitles, then the average bit rate allocated to the video images must be reduced. It is an authoring facility's responsibility to discuss these trade-offs with their clients to ensure that the best DVD-Video product is delivered.

The introduction of the DVD-Video format will raise the consumer's quality demands and thus impact the industry's quality requirements for feature film transfers. With the format's rich feature set and the use of compression, there will be differences from one facility's DVD-Video master compared with another. Because DVD is based on MPEG-2 VBR encoding, the allocation of the bit budget is critical to maximizing the subjective image quality of the DVD master. A large determinant of this quality is based on the quality of the facility's original film to component digital telecine transfer and the methods of video image preprocessing that is done just before compression. Processing to eliminate film grain, telecine noise, dust and dirt artifacts, and image unsteadiness is absolutely essential in order to avoid using the bit-rate allocation to unnecessarily encode these artifacts.

Film, Audio, and Graphic Element Preparation

The initial client requirements review is critical to the beginning of a DVD-Video premastering project. This is especially true when an older title from the library is being premas-

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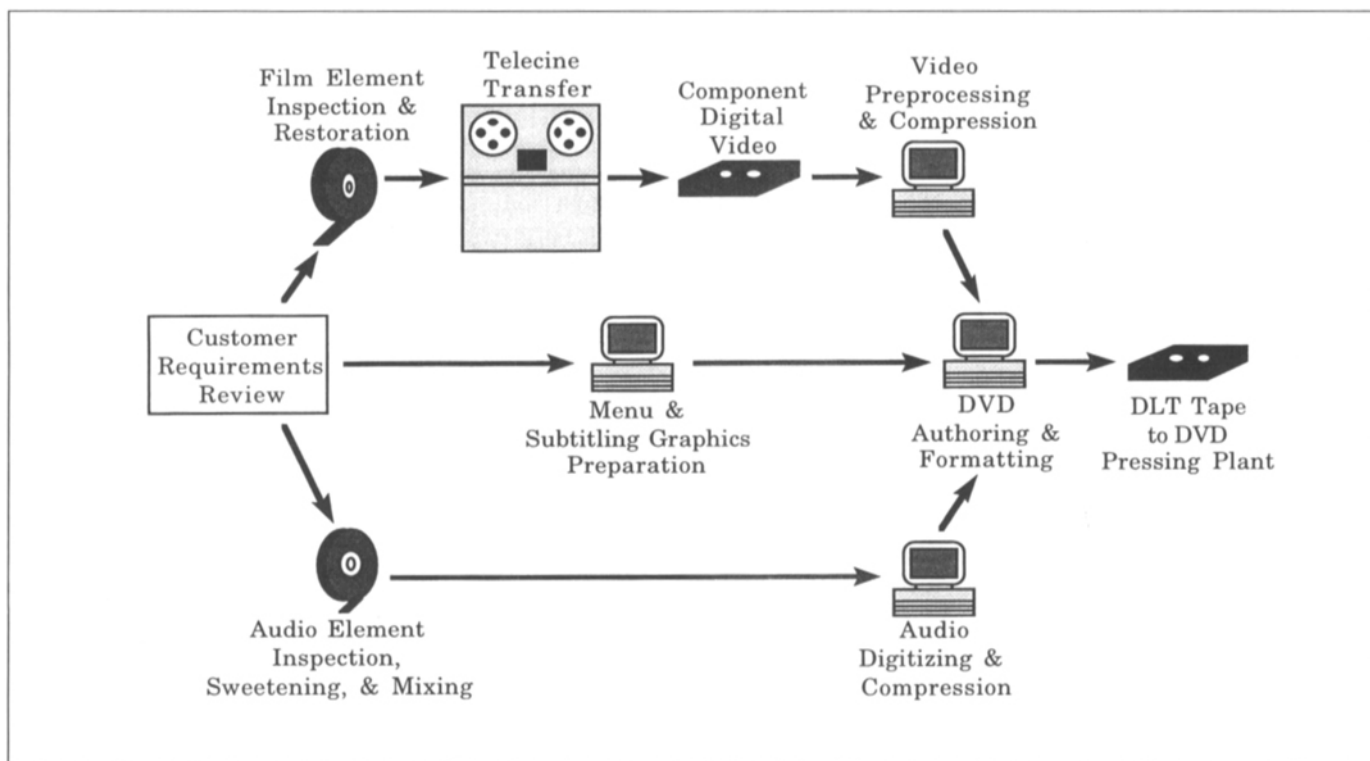


Figure 1. DVD-Video premastering process.

tered. In this review, important decisions must be made concerning the tradeoffs between image quality, program length, number of language and subtitle tracks, degree of interactivity and branching, and cost. In addition, the format's superior sound and video playback capabilities and consumer's high quality expectations may require content owners to consider producing new film elements, new remixed and sweetened audio masters, and/or the production of new telecine transfers prior to compression and authoring.

After the requirements review and decision on the content and feature set of the title, the client and facility must review the film and audio elements available for making the DVD-Video title. Some of the questions about the elements that need to be answered are:

- What age, film type, and in what condition is the film element?
- Is a mono, a stereo, a four-channel left, center, right, and surround (LCRS), or a full 5.1-channel surround audio track available?
- Does a fully filled music and effects track exist for making foreign language tracks?
- Do any foreign language subtitling files exist?

Prior to telecine transfer and video compression, the film elements must be inspected. This includes the feature program, the studio's opening logo, and any trailers that will be included on the disk release. At the film laboratory, the elements are examined and the client advised whether a new interpositive needs to be printed from the conformed camera originals. On an older film, the scene-to-scene timing is checked by making an answer print. Then a fully timed, wet-gate, slow-speed printed, estar interpositive is made. Many times the interpositives produced for the theatrical release have subtle color nonuniformities produced at frames where color timing changes occur. These are not visible in theatrical screening but are picked up in the telecine transfer. This is more of a problem with CinemaScope films since they use the entire height of the film frame. Slow-speed printing ensures that large, scene-to-scene timing changes do not create these intraframe color artifacts. Slow-speed, wet-printed interpositives are also sharper and eliminate much of the visibility of dirt and scratches on the original conformed negatives. Because of the significant granularity

improvement in today's intermediate stocks it is recommended that a new estar interpositive be made when the existing interpositive is more than 15 years old. This is not only an investment in making today's DVD master but also for making tomorrow's HDTV master.

Because of the digital quality and the diverse audio possible on a DVD-Video, the audio mastering for an older movie is a particularly complex area. This requires a thorough review of the audio options with the client including an evaluation of the audio elements available. Given the elements, decisions need to be made on the different types of audio mixes that will be created and mastered for the DVD-Video release. The standard, for example, allows up to eight different audio streams to be multiplexed with the video. All 525-line/60-Hz DVD-Videodisks must contain a Dolby digital audio bitstream and/or a linear pulse code modulated (LPCM) bitstream. All 625-line/50-Hz DVD-Videodisks must contain an MPEG-2 audio bitstream and/or an LPCM bitstream. Due to data rate constraints, most DVD-Video disks will be released with the more compact Dolby or MPEG-2 audio. The players

are only required to produce a full reconstruction of a stereo left and right audio program.

The digital audio bitstream can be encoded as one of seven different audio modes: 1) mono; 2) left and right stereo; 3) left-center-right; 4) left and right stereo with mono surround; 5) left and right stereo with left and right surround; 6) left-center-right with mono surround; and 7) left-center-right with left and right surround. The low frequency effect channel is a bandwidth-limited subwoofer track (the ".1" in "5.1") that can be optionally added to any of the above. With the variety of audio options available, the client needs to determine the most appropriate audio program content for the title and the geographical markets being pursued.

When remastering older movie titles to DVD-Video, the audio elements may come in a number of different forms: as a three-track magnetic fullcoat with mono dialogue, music, and effects; as a six-track mag with stereo dialogue, stereo music, and stereo effects; or as a six-track mag LCRS mix with stereo music, stereo effects, mono surround, and mono dialogue.

To create foreign-language-dubbed versions, separate music and dialogue tracks, kept to a minimum, must be supplied. Effects sounds in both the front and surround channels can be recorded in a Foley studio and filled for the foreign language audio masters. In addition, older audio masters sometimes need to be re-equalized, de-noised, and peak-limited to make them suitable for a digital audio home cinema release.

In addition to reviewing the various audio program release options available to the client, the facility must review the options concerning parental control features, subtitle graphics, chapter stops, program navigation capabilities, and the associated menu graphics. A DVD-Video title can be released as both an R-rated director's cut and a G-rated family version if the client supplies additional replacement scenes with matching audio or can specify offending scenes to be navigated around in the G-rated version. Plans for including foreign language subtitles need to be specified up front in the customer requirements

review. Standard subtitling files can be converted to TIFF files for overlaying as subpicture graphics during the authoring step. Chapter stops need to be specified as well as any particular requirements for the control menu graphics. Although complex DVD-Video titles can be produced, it is believed that in the beginning of the market, most titles produced will be simple, linear titles without complex branching or no more than a few language and subtitling tracks.

Once the DVD-Video program specifications have been agreed upon and the audio and film elements inspected and prepared, then the audio tracks can be digitized and the film elements transferred in the telecine operation.

Telecine Transfer

Because DVD-Video has such high video image quality, it is critical that the very best film transfers are used for DVD-Video premastering. Older videotape masters of films that were good enough for the broadcast or the VHS home video market may not be adequate for use as a master for DVD-Video. To determine a video master's quality after compression, the client may request the facility to do a short MPEG-2 compression evaluation. A few minutes of the movie are encoded and reviewed with the client prior to making a decision to retransfer. Clients should be aware that with DVD-Video's ability to handle squeezed, full-frame 16:9 video playback, many more letterbox-transferred movies will need to be retransferred to the full-frame 16:9 format. When a new film transfer is required, there are a number of details surrounding the transfer operation that are crucial to obtaining the very best MPEG-2 compression results.

First, it is important to transfer the film to a component digital video master to optimize the MPEG compression process. Composite video masters make encoding more difficult and produce noticeable compression artifacts. Although composite masters can be MPEG-2 encoded, the best results are achieved when starting with a component digital video master. It should be clarified that DVD-Video premastering does not require

a separate film transfer optimized for DVD premastering. A good, high-quality film transfer to a component digital video format will serve both DVD and the TV broadcast, VHS home video, and laserdisk markets.

Another area of critical importance is the noise level in the film transfer. Noise is a big problem for compression systems. Noise in a film master consists of the film-related noise associated with the film grain, dirt and scratches, and the electronic noise introduced by the telecine, image processing, and recording systems. Since noise represents random information, it creates a problem for MPEG compression systems that look to eliminate the redundant information between frames. It is important to make sure that the telecine system is performing optimally to obtain the best signal-to-noise performance.

A slight amount of film grain noise reduction is also recommended, especially if an older film element is being used. In addition to film grain, film-related noise can also come from dirt and scratches. Adequate ultrasonic cleaning combined with particle transfer rollers will ensure that dirt defects are kept to a minimum. There is also digital image processing hardware available that can be used to digitally eliminate dirt and scratch artifacts during the transfer or in a tape-to-tape correction suite. It is critical not to use excessive amounts of noise reduction, especially recursive noise filtering, because this can create its own set of unnatural image artifacts that can make the video harder to encode. The idea is to use the bits to encode picture information and not to waste them on encoding noise or artificial image processing artifacts.

Image steadiness is also an important aspect of the film transfer process that can impact the efficiency of video compression. If a picture is moving due to mechanical unsteadiness introduced at the printing or telecine transfer stage, then the MPEG-2 encoder will not be able to detect redundant frame-to-frame image information. This will cause it to use its precious bits inefficiently. The use of a real-time steadiness improvers can enhance the vertical and the horizontal steadiness of film transfers. These steadiness improvements at the

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telecine stage can save significant amounts of encoding data that can subsequently be used for encoding picture information.

The amount of aperture correction used to enhance the high-frequency detail in a film transfer can also create problems during video compression. High levels of aperture correction can create ringing artifacts on the edges of objects. These ringing artifacts and the over-enhanced scene details can again unnecessarily use precious bits of data. The general rule of thumb is to use a realistic level of aperture correction so that the resulting film transfer is pleasing to the eye and does not create visible artifacts. If an over-enhanced film transfer is encountered, some of the unwanted effects can be eliminated at the video preprocessing step prior to compression. However, the best DVD-Video masters will be obtained by starting with the cleanest, most natural-looking, artifact-free film transfer for encoding.

Finally, the last area of the telecine operation that can have beneficial results is in oversampling the image and spatially interpolating the image back to standard, interlaced CCIR 601 video. Today, there are a number of different ways to do this. The film transfer can be made on an HDTV telecine and then downconverted in a standards converter to D-1 video. One can also use an 8:4:4 telecine to scan and then downconvert in the frame store/interpolator.

Again, it is important to reemphasize that DVD-Video premastering does not require a completely different type of film-to-video transfer. The quality of the format and the com-

pression used, however, does put real demands on the film transfer in order to get the very best DVD-Video image quality. Once the film transfer is made, the next step of video preprocessing is important as it prepares the video master to further optimize the compression process.

Video Preprocessing and Compression

DVD-Video utilizes the MPEG-2 VBR compression process. This allows the encoding bit rate to vary from a low of 1.5 Mbits/sec to as high as 9.8 Mbits/sec based on scene content and complexity. The nominal video bit rate will average about 3.5 Mbits/sec. A simple, static scene with a talking head will require fewer bits to encode than a scene with moving areas of fine detail. Because of the limited data capacity and bit rate of DVD-Video, a good video master needs some video preprocessing before compression to make the best use of the bits. The idea of preprocessing is to modify the image to allow encoding to be as efficient as possible. The limited data should be used for encoding only visually important picture information. Preprocessing can make a significant improvement in the encoding results especially when starting with less-than-optimum video masters. There are several types of video preprocessing that are used in order to optimize MPEG-2 compression.

One of the more important steps of preprocessing is noise reduction of the video signal prior to compression. The same comments hold here as they do for noise reduction at the telecine stage. Because MPEG encoding is

based on looking for redundant image information, noise's random nature has a large impact on the efficiency of encoding. Noise reduction during video preprocessing is much more subtle than the noise reduction typically used during telecine transfer. The idea is to remove only the noise that has no visual impact but would unnecessarily use bits during encoding. A subtle amount of noise reduction should be used that produces no image artifacts. Because preprocessing noise reduction can sometimes help simplify encoding but also create artifacts if incorrectly applied, a skilled video compressionist with a trained eye must closely monitor the compression process to optimize the level of preprocessing noise reduction.

Another form of preprocessing to improve MPEG-2 compression involves elimination of the frame redundancy associated with the 3:2 pull-down of film-to-tape transfers. When film-originated programming shot at 24 frames/sec is transferred to 30 (29.97) frame/sec video, the telecine creates redundant fields of video. During telecine film transfer, 24 frames of film are used to create the 60 (59.94) individual video fields. This is done by a process known as 3:2 pull-down whereby the first frame of film is used to make two fields of video, the second frame of film is used to create the next three video fields, the third frame is used to produce the next two video fields, etc. The order of the video fields results in a unique pattern that repeats itself every five frames.

MPEG-2 decoders have the ability to accept a 24-frame/sec MPEG video stream and turn it back into a standard 29.97-Hz video signal. This ability to do frame rate conversion at the decoder allows 29.97-Hz film-originated video to be converted back to its original 24 frame/sec film image sequence. This removal of the 3:2 pull-down redundant fields is called "inverse telecine" processing. By eliminating the redundant fields of video, the compression system can allocate more bits to encoding the original film image frames. This is especially important with the encoding of long movies with multiple language tracks where the data capacity

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is limited. Inverse telecine preprocessing will always provide better looking MPEG-2 video streams.

Finally, another technique used in improving the process of MPEG-2 VBR encoding is the process of "forcing" I-frames during encoding. There are three types of frames in an MPEG-2 video stream: Intra or I-frames, which are encoded using only information present within the frame; Predicted or P-frames, which are computed based on forward prediction using the nearest previous I or P frames; and Bidirectional or B-frames, which use both a past and a subsequent frame as a reference to calculate the compressed frame. I-frames carry the most image data and are the basis for creating the standard sequence of frames of I-B-B-P-B-B-P-B-B-P-B-B-P-B-B-I, which is known as a group of pictures (GOP) of 15. Fifteen represents the number of frames between I-frames. If during encoding, a scene has excessive motion or many rapid scene cuts, the compression operator can modify the I-B-P sequence by adding additional I-frames at scene cuts. This forces more bits to be used to encode a larger number of high-quality I-frames, which should improve the reproduction of these difficult scenes.

Conclusion

DVD-Video represents a revolutionary new consumer video format. For studios and content producers considering releasing movie titles in this new format, a number of recommendations can be made. First, due to the richness and complexity of features and the image and sound quality of the format, content producers need to work closely with their DVD authoring facility in requirements clarification and in the mastering of their movies to this new high-quality medium. Second, the format's superior sound and video playback capabili-

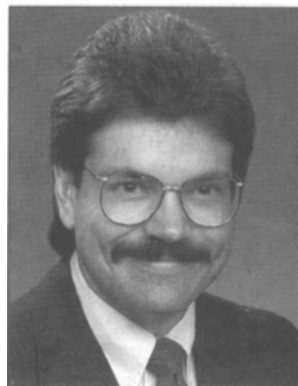
ties will raise consumer's quality expectations. This may require content owners to consider producing new film elements, new remixed and sweetened audio masters, and new component digital telecine transfers to deliver DVD-Video titles that meet these higher consumer expectations. Finally, many steps can be taken by the facility in the telecine transfer stage, in video preprocessing, and in compression that can dramatically

improve the quality of the end product.

Not all DVD-Video masters will be created equal. By working with a knowledgeable DVD premastering facility with the broadest range of in-house experience across multiple disciplines of audio, film, and compression, clients have the best chance of introducing their DVD movie title to the marketplace with the highest quality possible.

THE AUTHOR

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Hunt graduated from Rose-Hulman Institute of Technology with a Bachelor's degree in chemical engineering in 1976. He also received an M.B.A. degree, in 1990, from the William E. Simon Graduate School of Business Administration at the University of Rochester. He is an executive member of the Technology Council of the Motion Picture-Television Industry, a Fellow of SMPTE, and a two-time recipient of the SMPTE Journal Award.