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Best Practice - Scholars' Mine Producing Quality Video Files

James Roger Weaver
Missouri University of Science and Technology, weaverjr@mst.edu

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Introduction

Digital video files are, in reality, separate audio and video bit streams and have two parts, the “wrapper” that contains this audio and video data and the “codec,” the compression-decompression algorithm that encodes this data. Digital video files can therefore be complex, and there are many factors to consider when producing quality files of this type. Just as the quality of digital images depends on resolution, color depth, and storage format, the quality of digital video depends on the sampling rate, frame rate, and bit depth settings, as well as the choice of compressed (lossy or lossless) or uncompressed storage formats.

Most computers’ standard configurations support DVD quality video and the more common compressed video formats. Higher quality (higher sampling rate and/or greater bit depth) video capture may require additional internal or external hardware for both creation and playback. Since what is considered a standard hardware configuration constantly changes, the recommendations below do not cover hardware.

It’s important to note that in the context of quality and long-term preservation digital video is a new field in which many options but very few standards exist. As they emerge, we will revise these guidelines. In the meantime, we welcome your questions and comments.

General Recommendations

First, it’s important to understand that you will not improve your video by changing it to a “higher quality” format; you can’t create a better image by such a transformation. You can see this with video originally captured in a digital form like DV, where the best copy is made from a simple transfer, or capture, of the bits from the source tape to a hard drive.

You should choose a digital format that maintains the quality you think you will need but doesn’t create excessively large files. Here are some rough figures to highlight the tradeoffs:

Format	Data Rate: Megabits/seconds	GB/hours of video
Uncompressed	270	122
DV	25	11
MPEG-2 (DVD)	5	2.2

In general, you create a smaller file by discarding information. Without using any compression, going from 30 to 15 frames/second will create a 50% smaller file; shrinking the size (area) of your image by 50% will greatly reduce its size, but result in a

Sampling Rate and Bit (Color) Depth

The following provide the basic settings you should choose from when creating or converting to digital video. If you're interested in more technical details about sampling rate, see the Appendix for more information and reference sources.

- Best Quality (high bit-rate, ≥50Mbps)
  - Sampling rate = 4:2:2
  - Bit depth = 24-bit depth (also known as Truecolor)
  - Compression factor: negligible
- Acceptable (DV Quality, 25Mbps)
  - Sampling rate = 4:1:1
  - Bit depth = 24-bit
  - Compression factor: 5:1
- Acceptable (DVD Quality, 4-9Mbps)
  - Sampling rate = 4:1:1
  - Bit depth = 24-bit
  - Compression factor: up to 25:1
- Not acceptable (MPEG 1)
  - Sampling rate = 4:2:0
  - Bit depth = 16-bit (Highcolor)
- Compression factor: huge, and frame size of 352 x 240 (quarter screen)

It's important to note that audio specifications use parameters with the same names, but with slightly different meanings. For more about this, see Best practices for producing quality digital audio files.

Frame Size (Resolution) and Aspect Ratio

Use the same frame size as the original whenever possible/practical. In general, larger picture sizes are always preferred over smaller ones, although there will be no improvement in quality from using a frame size larger than the original. When converting from one digital format to another, maintaining the frame size of the original file is recommended, if possible.

When creating a digital video file from an analog source, be sure to keep the resolution of that format in mind, because converting to a digital version with a much higher resolution will not produce an equal increase in quality. For instance, a typical VHS tape has a standard resolution of 720 x 483. If you convert this to a digital format and use an "HD" frame size of 1920 x 1080, the resulting digital video won't be high definition-quality. It will simply be a large file with quality comparable to the original analog format.

Therefore, when creating a digital video file, it's important to keep in mind the intended file format, type of content in the file, and its intended future use. For digital video files, the following are suitable recommendations for resolution.

- For High Definition
  - 1920 x 1080
  - 1280 x 720 (minimum)
- For Standard Definition
  - 720 x 480 pixels
  - 640 x 480 pixels (minimum)

The following resolutions commonly in use today might better inform your decisions when choosing a frame size for your own digital video files and are provided for reference:

1920 x 1080: "1080p." Used for high definition broadcasts and as the resolution for the 'high' profile setting in MPEG-2. Differs from 1080i, which refers to two 1920 x 540 fields that are interlaced (combined) to form a 1920 x 1080 image.

1280 x 720: "720p." Used in high definition broadcasts. 720 x 483: Standard component/composite. Historically used for broadcast transmissions and for VHS tapes, both NTSC and PAL standards (American and European, respectively).

720 x 480: Digital Standard Definition. Commonly known as 480p or 480i if interlaced. Also used as the resolution for the 'main' profile setting in MPEG-2.

352 x 240: Used as the 'low' level profile setting resolution in MPEG-2.

Also related to a video's resolution/frame size is its aspect ratio. The "aspect ratio" of a video refers to the ratio of the width to the height. For "widescreen" video files, an aspect ratio of 16:9 is the standard, while an aspect ratio of either 16:9 or 4:3 is the norm for Standard Definition resolutions.

Frame Rate

Selecting a frame rate for capture depends on the final use of the video. For example, if the purpose is to do scientific analysis on a phenomenon that occurs very rapidly, such as a video of an automotive crash test, the sky's the limit.

In most cases, you will want to keep the frame rate of your original video. Using a higher frame rate will not get you more information. Using a lower frame rate—which reduces your storage requirements, but at the cost of video information—may be acceptable, depending on your content and your needs.

For regular viewing of a television program or movie, note that human visual perception tops out at roughly 75 frames per second (fps). People vary in their sensitivity, but sampling done at a higher rate than this will not be perceptible by most viewers, and typically much lower values are fine. For example, motion pictures are recorded at 24 fps, and video is recorded at 25 fps (PAL) or 30 fps (NTSC). Your video files, therefore, should generally be at a range of 25-30 fps.

File Formats and Compression

Ideally you will want to create and deposit your video files to Deep Blue in file formats that are non-proprietary, with a high potential for future readability. Virtually all digital video employs some kind of lossy compression, either at the frame level (JPEG 2000) or frame-to-frame for the video as a whole.

Per the sampling rate discussion above, acceptable compression factors vary from negligible to 25:1. What you should use is largely determined by the video source itself and the intended viewer and use. If the source images change a great deal from frame-to-frame, as would be the case when showing objects moving at high speeds, then using a great deal of compression may give poor results whereas if there is relatively little motion, as in a typical interview where two people sit and talk with each other, viewers will probably not notice if it's heavily compressed. Similarly, if the intended use includes frame-by-frame analysis, the less compression the better.

- Recommended
  - Motion JPEG 2000 (.mj2, .mjp2)
  - MXF (Material Exchange Format, .mxf) – see note below
  - MPEG-2, using AAC encoding for audio (.mpg, .mpeg)
  - MPEG-4, version 2, using AAC encoding for audio (.mp4)
- Acceptable
  - DV (Digital Video Encoding, .dv, .dif) – either as raw .dv/.dif or encoded in .avi/.mov "wrapper"
  - AVI (Audio Video Interleaved, .avi) – default Windows Media wrapper
  - MOV (.mov) – default QuickTime wrapper
- Not Recommended
  - Real Media (.ra, .rm, .ram)
  - Windows Media Video (.wmv)

If you have materials in other formats you can still deposit them in Deep Blue, however it is best to submit materials in formats that are not proprietary. So, even though it is still a lossy compression format, MP4 files are preferred over Real Media or Windows Media files because MP4 is an open standard, supported by multiple vendors.

Motion JPEG 2000 is used by many archival institutions, often in conjunction with a MXF (Material Exchange Format) wrapper, because it is an open standard and losslessly compressed. The MXF wrapper is open source and widely used because it attaches 5 of 9 various metadata to the video file; however, depending on how it is encoded, MXF files may not "play" in the traditional sense because they are intended for professional use, not for playback on PC applications. Both MPEG-2 and MPEG-4 currently also stand as one of the best options for long-term storage of digital video files because both are used for commercial broadcast and for government institutions like the Library of Congress, increasing the likelihood that they will continue to be preservable, viable formats long into the future.

If using one of the above recommended file formats/wrappers is not possible, DV, AVI, or MOV are acceptable alternatives. The DV format, while compressed, is widely supported by various software options, and AVI and MOV, while proprietary formats, are both acceptable choices for digital video files because they are so widely adopted.

Codecs

The term "codec" is a short-hand term for (en)coding/decoding or compression/decompression and refers to the method by which an audio or video stream is encoded and decoded. Being able to play a video file with an encoded bit stream is dependent on having the correct codec software to decode it.

Just as file formats (wrappers) themselves can be "lossy" or "lossless," so can codecs. In many cases, applying a lossy video compression codec reduces file size by discarding information (fully independent "I-frames") needed for precise video editing. Afterward, it may no longer be possible to make cuts at the exact frame desired, so it is inadvisable to apply lossy compression on videos that may not be final products. A lossless codec on the other hand, retains all data from a file while still reducing its size. Lossless codecs reduce file sizes by using, for example, variable bit streams rather than discarding certain portions of the data itself. Even when compressed, lossless codecs do not compromise the quality of the video file. Many codecs can be set up to function either as lossy or lossless.

- Recommended
  - JPEG 2000
  - HuffYUV
- Acceptable
  - AAC (Advanced Audio Encoding) – for encoding of audio bit streams
  - FLAC (Free Lossless Audio Codec)

Research into the suitability of various codecs for digital video preservation is ongoing and has not yet reached any solid conclusions about which codecs should be considered standards or best practices. The use of lossless codecs or simply no compression at all is preferred at this time whenever possible, however, when creating compressed files (in either MPEG-2 or MPEG-4 format, for example) , AAC (Advanced Audio Coding) encoding is preferable to any other alternative for encoding audio streams within video files. This codec is part of the MPEG-2 and MPEG- 4 standards, is widely supported, and offers greater efficiency and wider frequency bands than MP3 audio.

The proprietary HuffYUV codec is one of few examples of a truly lossless codec, and its use is recommended by the National Archives. The JPEG 2000 codec is an open standard and considered the best lossless codec option for archival-quality digital video files. While FLAC is free and open source and provides lossless compression of video files, it is poorly supported by playback and editing software and hardware, which means that it might not be an ideal codec for long-term preservation.

Any files that have been “transcoded,” that is, files that have been encoded with more than a single codec, are unacceptable for potential preservation. Regardless of which codec you use for your digital video files, you should not apply a second one once they have been encoded the first time.

To Create Quality Digital Video using Direct-to-Digital Recording

Whatever format your source recordings are in, the first step is to get them into a digital form so you can process and transfer them to Scholars’ Mine.

If your recordings are already in a disc-based digital form like video DVDs, MP4s or other formats, your job is easier. There are many tools available for purchase or as freeware that allow batch processing of media files from one format to another, so if you need to transcode your video files all you’ll have to do is start the process; you can leave the heavy lifting to your computer.

If your recordings are in a digital media-based format like DV video tapes or other formats, then you will have to play your recordings back in real time to capture. Fortunately, most digital media formats allow for a digital transfer to your computer, eliminating the process of converting from digital to analog and back to digital. It’s just like copying a Word document from one computer to another: the copy is literally a clone of the data contained in the original.

To Create Quality Digital Video via Conversion from an Analog Recording

Analog sources require the most effort to get into an appropriate digital form. The hardest part of this process is getting the best possible playback of the source recording. In most cases it is a matter of aligning the playback device for the best playback, but in some cases it can start with trying to find the right device. If you have the recorder that you used to make the original recordings, keep it!

While it is tempting to think you need the absolute best possible digital transfer in terms of sampling rate and bit depth, once you examine what sources you have and what your actual needs are you may find that a standard, common format suits your needs. You should balance the quality of your source recordings, potential future uses, and ease of access. For example, typical VHS tapes will not suffer from transfer to a digital form at DVD quality of 4:1:1/24 bits. This can be your master copy, and it offers the added advantage of allowing the direct creation of DVDs, eliminating the need for transcoding from a higher sample rate or bit depth. This type of transfer is an easy way to digitize your material. Subsequent processing to MP4 or MOV/QuickTime is also easy.

Finally, digitizing video from an analog source requires hardware other than the playback device, and this technology changes so fast that we won't discuss it here. We'll be happy to talk to you in person when you are investigating options.

Summary

If you take away nothing else from reading this, remember:

Use a supported, non-proprietary format for your files whenever you can. Available tools for batch processing video files into a non-proprietary format can make this task much easier.

Balance your efforts in digitizing against the actual use of the recordings. Is high fidelity reproduction the priority or is basic access to and viewability of the content what is really important? Set realistic standards for your content without sacrificing possible future improvements in technology. *This often means capturing your analog recordings at one level higher than the perceived future need.* Recordings originally made at a higher quality or having content that would benefit from better resolution (high-speed video for purposes of data analysis) are good candidates for digitizing at higher specifications than standard DVDs.

Questions

If you have questions please contact us at scholarsmine@mst.edu and we will be happy to assist you.

Appendix

Sampling Rate

A digital video signal has three components: luminance or brightness (Y) and two chrominance or color values. The two chroma components are derived relative to the luminance value, and are equal to the luminance deducted from the color red (R-Y = Cr) and the luminance deducted from the color blue (B-Y= Cb), respectively.

> This seemingly complex process was invented because television was originally only black & white, needing only the luminance value. When color TV was invented, the FCC mandated that color television pictures be compatible with the existing black & white TV sets. So this system of 'piggy-backing' the color information was implemented, and this is why, even today, you can turn down the 'color' (saturation) on a TV and get a black & white image.

During digitization the encoder looks at each group of four video pixels at and takes samples for recording. With a 4:2:2 sampled video signal, all four of the luminance pixels are sampled, two of the Cr pixels are sampled and two Cb pixels are sampled. This sampling rate is used with Digital-S, DVCPRO-50, Digital Betacam, BetaSX, D-1 and D-5, for example. With a 4:1:1 signal, all four of the luminance pixels are sampled but only one pixel is sampled from each of Cr and Cb. This lower sampling rate records less color information and affects the accuracy and intensity of the color in the video signal. The 4:1:1 sampling rate is used for all the NTSC DV formats: DV, miniDV, DVCAM and DVCPro25. 4:2:0 sampling is used in PAL DV and DVCAM, DVD, and MPEG-2, but not DVCPro which still uses 4:1:1).

The advantage of 4:1:1 sampling is that you can record twice as much as 4:2:2 using a given amount of storage, though at the cost of some loss of quality. Some digitizing systems may not offer this as an option.

Regarding the 'Best Quality' recommendation above, you may ask "Why not use 4:4:4 sampling?" The reason not to do so is that it will require expensive hardware and will create huge files. Unless you know you need to have digital files that surpass current industry standards, you are unlikely to see any benefits that outweigh the pain of the process.

File Formats and Compression

Uncompressed video at a framerate of ≥50Mbps is the only truly archival ("Level 1") format for video. Unfortunately, it is unlikely that you can produce or store this, even temporarily.

As a result, Scholars' Mine Level 2/"Limited" format—one for which we will preserve the content of the deposit, but whose appearance and functionality may not be preservable over time— is the best we can do at this time. We recommend Motion JPEG 2000 and MPEG-2 using I-frame (where each picture is encoded independently, without reference to a preceding image) at 25Mbps because Motion JPEG 2000 and MPEG-2 are publicly documented, widely used, and employ lossless compression so they retain all the original information from the source video. MP4 and MOV are also considered examples of Scholars' Mine Level 2 format. These are not as desirable, however. For example, MOV files are technically a proprietary Apple QuickTime format. It is because of this QuickTime "wrapper" that they are only considered acceptable. It is unlikely that MOV files deposited in Scholars' Mine will become unreadable without plenty of advance warning. If QuickTime formats will become unsupported in the future, there should be ample time to have them transcoded into a more enduring one. MP4, though it is an open standard, ubiquitous, and provides reasonably good quality given its higher compression than MPEG-2, is less flexible and its use during initial capture will almost certainly preclude effective frame-by-frame analysis later.

All of the above video formats involve some level of "lossy" compression, meaning that once a video file is processed into these forms the original images at full quality cannot be regenerated from the compressed version. (Moreover, each time lossy compression is applied, more quality is lost.) Lossy compression schemes usually result in smaller compressed files since they eliminate details and information many playback mechanisms can't use. If frame-by-frame analysis is an expected use of your video, Motion JPEG 2000 or MPEG-2 using I-frame is the most appropriate choice.

Bibliography

Based on the University of Michigan Library's "Best practices for producing high quality PDF files", available at http://hdl.handle.net/2027.42/58005 , where it is available under a Creative Commons "Attribution" license: http://creativecommons.org/licenses/by/3.0/ .

Video Preservation Resources. http://palimpsest.stanford.edu/bytopic/video/

The NINCH Guide to Good Practice in the Digital Representation and Management of Cultural Heritage Materials. http://www.nyu.edu/its/humanities/ninchguide/index.html

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