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For the past ten years, digitization has been the backbone of preservation and access for the Walter J. Brown Media Archives (BMA) and Peabody Awards Collection of the University of Georgia. We have largely used digitization vendors to preserve film while simultaneously developing a robust media lab for in-house digitization services. In-house capabilities increased dramatically in early 2014 when the BMA acquired an MWA Choice film scanner that, for the first time, enabled the archives to make its own preservation-grade scans rather than resort exclusively to digitization vendors. Not only were we afforded the ability to scan problematic films (shrunken/buckled film, film with sprocket damage, etc.) because of the Choice's laser-guided, sprocketless film path, but we also digitized assets at a much faster rate than ever before.

The in-house film scanning workflow presented a steep learning curve but also resulted in a substantial gain in institutional knowledge in both detailed aspects of film scanning and broader preservation issues. Having experienced both sides of the customer-vendor coin, we have identified a number of important issues that ought to be considered when communicating with third-party vendors. For institutions that do not have first-hand experience with film digitization issues, the conversation with vendors can be limited by an imbalance of knowledge, or a lack of shared vocabulary, potentially creating less-than-ideal results for patrons and/or compromising the long-term preservation of film assets.

In this article, we will pull back the curtain on the film scanning process and elaborate on some of the decisions that go into making a film scan for preservation. While not an exhaustive catalog of the issues that require attention before sending films to a lab, our essay considers the nuanced issues we feel are often overlooked. Our perspective will provide readers with a new lens through which they can make informed decisions about the services they are paying for to preserve and make accessible their film assets.

To provide context, it will be helpful to briefly describe the history of moving image preservation and a significant change in moving image preservation technology in the last ten years or so, which may have created a disparity between lab and archive expectations. Since the advent of videotape, it has been common practice to transfer film material to videotape, especially for broadcasting purposes. At the heart of this process is a machine called a telecine, which converts moving images on film to a video signal for live broadcast or recording to videotape. Archives have used film labs or perhaps an in-house telecine setup to migrate film holdings to videotape, primarily to provide better access to their film holdings, but also for preservation purposes. However, because of its limited resolution and frame rate capabilities, videotape has never been an ideal format for film preservation. Film-to-film preservation has long been considered the ideal preservation method for film, but the supply of film stock and labs that provide film-to-film transfers are diminishing. Simultaneously, in the last ten years, the market for film scanning technology has matured to the point that it is now the primary method used by film labs for film digitization. At the same time, the technology has become affordable enough to be used by archives for film preservation purposes. Archives with significant film holdings might even have film scanners for digitizing in-house.

Whereas a telecine converts film to a video signal, film scanners make frame-by-frame scans of films and store the resulting images in a file-based format. Compared with video-based telecine technology, a film scanner has the ability to produce a more accurate representation of the original film due to the increased resolution and frame rate options afforded by file-based formats. We believe film scanning is the best method available currently, and for the foreseeable future, for film preservation. However, the increased flexibility afforded by film scanning means there are potentially more options to specify for deliverables, as well as the possibility of shortchanging those deliverables. To complicate matters, there are no definitive standards for archival film scanning that we are aware of, and any that emerge must account for the rapidly changing technological landscape in order to stay relevant.

Connected to this transition toward file-based preservation is the ongoing problem of DVDs as standard user copy and NTSC videotape as preservation format. Patrons and archives *should* want file-based preservation and access copies, yet the DVD persists and videotape is still sometimes used as a preservation delivery format. Unless the issues associated with these formats are well understood, archivists may continue to defer to them rather than move to a format that more accurately represents the original object.

The following sections cover different aspects of a film scanning workflow. They outline both our personal experiences and the decision-making processes that led to our digitization and preservation policies. More generally, though, we want to provide a discussion of the issues in order to allow the reader to decide the best possible course of action in a variety of contexts, to accommodate myriad budgets and technological capabilities when it comes to preserving film digitally.

Scanning Using A "One Light" Method Versus Applying Restorative Color Correction

Before we begin breaking down the options for strategizing about color correction, it is worth mentioning that our in-house digitization policy with regard to this matter is shaped by our capability vis-à-vis our MWA Choice Flashscan to do scene-to-scene color and lighting adjustments on the fly or synchronized to a timeline in MWA's AgiScan software. This equipment makes primary color correction a much more efficient process as it does not involve a separate workflow *after* the film has been scanned. Not all scanners—nor for that matter, older telecine technology—have the same capability of storing adjustments to the light source to be applied during a real-time scan of a film. Similarly, any given film lab's process will vary according to their particular scanner's capabilities.

There are three distinct ways to think about color correction during a scan: one light, best light, and scene-to-scene. When technicians make a one light scan of a film, they are scanning with a single light setting that has been determined by the film technician to capture the widest range of exposure conditions for the film in question. One light transfers take exponentially less time to complete than other processes, and might be preferable when scanning film whose content is not considered improved by making adjustments to the light source. This method is the most straightforward way to capture how the film “actually looks” (how it would look when projected), or for films thought to be in good enough condition so as not to benefit much from scene-by-scene adjustment or color correction. Commercial films could fall under this category, as a print in good condition will have already undergone a significant amount of lighting adjustment and color grading in order to make the print. Best light refers to the technique of optimizing the white and black levels for each scene in a film—“scene” here referring both to differences of a single reel and the differences arising from compiling multiple reels together. A scene-to-scene transfer will, on top of white and black level adjustment, include color correction. For our in-house transfers, we provide primary color correction, specifically the adjustment to the color of the light passing through the film as it is captured, versus more nuanced secondary color correction in the digital realm. Our justification for doing color correction at all is predicated not on creating aesthetic effects but to make film that has turned, for example, blue or magenta, appear natural again. Because we can easily adjust color and light levels simultaneously, we argue that it makes sense to provide the former as a matter of course.

The crucial distinction that justifies our in-house practice lies in the difference between an “archival correction” —making changes so film looks as it did prior to its degradation—and an “aesthetic correction” —changing the film’s look to achieve a visual effect. We have inherited an understanding that a one light transfer is the most “archival” option, in that the film is being preserved as it is, versus how a colorist or a donor thinks it ought to look. But it is often the case that a one light transfer is not the best way to preserve the content.

This dilemma brings up the question of how our policies as an archives with a quality digital scanner compare with those of a professional digitization lab. For although we could take a strong line and say we never make adjustments a lab might (scene-to-scene, digital color correction, for instance), as a matter of principle, time management, and especially donor expectation management, there should be a threshold to this argument: it is not a given that the film’s non-altered state preserves the *content* of the film, be the film too dark or faded or bright magenta. The alteration of a film’s look in order to preserve its fundamental content, as distinguished from alteration in order to otherwise change the look (rescue vs. improvement vs. alteration) is a rationale for archives to use digitization methods normally associated with film labs or commercial film productions.

The decision to ask for color correction hinges on the type or genre of film and on the significance of a film’s image quality to its preservation and reuse—the latter criterion will be elaborated in a later section. Commercial films tend to require less adjustment, insofar as color correction and lighting levels go, and at least in the cases where productions are professionally lit and the film has not suffered any significant degradation, this difference is due both to the production conditions as well as to the fact that the commercial film will be a print made from a negative. The difference between the commercial film in relatively good shape and the home movie often composed of different 8mm reels spliced together should inform your expectations for the digitized version of a film. Consider this home movie example: the first shot is of a living room during the holidays with all the lights turned out so as to accentuate the brightness of the decorative tree lights. Cut to an outdoor scene shot from a sidewalk that catches the noonday sun glinting off a metal roof—the radical change in lighting levels will in all likelihood require a lighting adjustment if there is any attempt to capture a similar amount of detail in the respective shots. Consequently, a one light transfer will either lose detail of both shots or capture one well to the detriment of the other. Even when a natural change in lighting between scenes does not warrant adjustment of brightness, there is a possibility that a film faded to red will be spliced together with a film in which all the shots are blue.

To sum up, opting out of best light or scene-to-scene transfers for amateur films may result in less than ideal preservation of the content of a film, even if in a theoretical sense it better represents the way the film actually looks. If a commercial film seems to be in relatively good shape, it might not require much color correction, since it has undergone some process of color correction in the making of a print. This distinction doesn't account for color correction brought on by deterioration of the film, of course. It should merely be kept in mind when deciding whether or not to opt for color correction, as it will increase the cost of transfer.

Note the difference between a transfer with "neutral" settings (the clip on the left) and a transfer in which color adjustments were made (the clip on the right). This film was digitized in-house, so color adjustment here merely means changing the color of the light that passes through the film when the capture is made. (00:25)

Scanning Beyond the Frame Edge

All film cameras have a film gate that limits the exposure area of the film. Typically, projector gates were made slightly smaller than camera gates in order to ensure that only fully exposed portions of the film are projected for the viewer. This fact leads to a dilemma when scanning film: In order to recreate the viewing experience intended by the original creator, the viewing copy of your film should have a similarly cropped image. However, to have a true representation of the film for preservation purposes, an “uncropped” version that includes the entire exposed image is desirable as well. It is usually the case when capturing the full height and width of an exposed film image that the resulting image will have rounded corners where it was originally limited by the camera gate or aperture (again, why it is often cropped). There are also some instances where the image is exposed over the entire width of the film—sometimes referred to as an open-gate—including over the sprocket holes. In these situations, a substantial section of the image would be lost by cropping to a standard image size or excluding the sprocket holes from the scan.

The solution in these situations is scanning beyond the frame edge to include the entire image, or even edge-to-edge scanning. In the edge-to-edge method, the film is scanned from one edge of the film to the other and creates the most complete representation of the film. In either case, one retains this overscan for preservation purposes and uses it in the future to crop any aspect ratio or dimension as needed. A cropped video file will ideally accompany this overscan for use as a mezzanine/production or access copy.

Even when the exposure area of film is normal, there is other information to be preserved from an overscan. For instance, it is possible to convert a scanned optical soundtrack into audio using software designed specifically for this purpose. Although at first read this option seems to be ideal for preservation, it is important to keep in mind that the moving image is necessarily scanned at a lower resolution when the scanning area includes the soundtrack. While it might be possible that a scanned optical soundtrack processed by software can produce equal fidelity audio compared to audio reproduced via an optical soundhead (the traditional method for reproducing optical soundtracks), we believe that it is unnecessary. Digitizing audio from an optical soundhead is a perfectly good method for preserving an optical soundtrack, and in many cases, the scanner resolution will be better spent on the image.

The other consideration when employing edge-to-edge film scanning is that it captures film-edge metadata that otherwise would require a database or other method for storing and making use of that data. For instance, date codes, keycode, film stock, and even perforation configuration can all be useful for inferring other information about a film. Having this information present in the scan means it does not necessarily have to be recorded as metadata.

This clip shows two different scanning options of an 8mm film shot with an open camera gate. The left-hand side shows a film shot with an open gate. Notice how more image is captured in addition to the film's date code and sprockets. The normal exposure area is shown on the right side. (00:47)

File Formats for Preservation

Research into the strengths and weaknesses of various file formats can be a laborious and confusing exercise in deciphering technical literature. In the end, the question is not "which is best?" but rather "which is most appropriate for my situation?" This question is usually answered by considering what is the highest quality format you can sustain with your resources. For our discussion purposes here, we will review three general classes of audiovisual file formats that you might consider: those which employ loss-y compression, meaning the original image data *cannot* be recovered post-compression; those that use lossless compression, meaning the original data *can* be recovered after compression is applied, or do not use compression, commonly called uncompressed; and those that use a series of discrete static image files to represent the frames of a film.

In most situations, an institution should not employ file formats with loss-y compression unless its digital storage infrastructure cannot support anything else. Compressed file formats offer less flexibility for downstream reuse, as compression normally results in visual artifacts that degrade the image quality. However, compressed file formats make file sizes more manageable and reduce digital storage costs. Apple's ProRes HQ codec, for instance, offers image quality that some say is comparable to Uncompressed 422 encoding, yet requires only 20 percent of the storage space.[1] It has the added benefit of being in common use in the broadcast and other video-centric industries.

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[1] "Apple ProRes 422 High Quality," Library of Congress, last modified December 16, 2014, accessed September 24, 2016, http://www.digitalpreservation.gov/formats/fdd/fdd000403.shtml.

Lossless and uncompressed formats have long been considered ideal for video preservation since they do not “throw away” data in the encoding process through the use of spatial compression. There are a number of codecs that are grouped into the “10-bit uncompressed 422” category, but these are generally not the best choice for film preservation because the “422” implies a method of color encoding—called chroma subsampling, which is a form of color information compression—that is not as complete or data-rich as “444” color encodings. As noted earlier, file sizes get very large with uncompressed video. Lossless formats, such as those employing the FFV1 encoder and lossless JPEG 2000 encoding, provide the best compromise between image quality and file size, but may pose preservation risks in the long term if they do not receive greater adoption outside of cultural heritage institutions.

Deficiencies in storage infrastructure notwithstanding, static image formats like Digital Motion Picture Exchange (DPX) and Tagged Image File Format (TIFF) have many benefits over uncompressed video formats, as well as a few drawbacks. Firstly, DPX is widely supported by the motion picture industry for digital film intermediates, and is a standard defined by the Society of Motion Picture and Television Engineers (SMPTE). Similarly, TIFF is an International Organization for Standardization (ISO) standard not originally designed for digital film workflows, but in use within the digital film industry. Secondly, these formats commonly store color information in greater detail, without chroma subsampling and with the possibility of greater bit depths, and are generally easier for computers to process and work with than 10-bit uncompressed 422 video files. For these reasons, DPX and TIFF formats are preferred for doing digital color correction and other post-processing.

As with uncompressed video file formats, arguments against static image formats center around the amount of storage space and infrastructure required to support their associated workflows. For comparison purposes, consider that a 2K Quicktime video file encoded with Apple’s ProRes encoder for a transfer of a one-hour feature sound film will be approximately 60GB, whereas a folder of static images for the same film using the 10-bit DPX format will be almost 700GB.

Storing individual frames as static image files does have one distinct advantage in terms of digital preservation: if any disk or file corruption occurs, it will only affect specific frames, as opposed to an entire video file. This means that data corruption can be ameliorated by replacing only those affected frames as opposed to replacing an entire video file. But without a supported digital storage infrastructure or the digital preservation expertise needed to manage tens of thousands of DPX files, the prospect of preserving even a handful of films using a frame-based format is quite daunting. Tracking a single video file for digital preservation purposes is a relatively straightforward proposition by comparison. Finally, being able to reuse a frame-based format necessarily demands powerful computers, professional video editing software, and personnel who have expertise in working with those tools. However, if you can support it, static-image preservation formats provide the most accurate representation of film in a digital format, support the highest resolution and bit depths in use today, and afford the greatest flexibility for reuse in the future.

File Resolutions: Which Is Appropriate?

When it comes time to specify deliverables for a project, it is important to understand what effect resolution has on the final product. To begin with, the resolutions a lab offers are usually predetermined by the lab. Again, this goes back to the fact that different scanners have different capabilities. Most film scanners are given a label such as HD, 2K, or 4K to indicate the native (and therefore the highest) resolution of the scanning system. There are many additional factors that affect image quality beyond resolution, but knowing what resolution a lab's scanner is capable of producing is a baseline for determining if they offer the appropriate services for your material. Upon request, a vendor should provide information about the scanners they use for your own preliminary research.

With that in mind, the question becomes: what resolution do you choose for your specific project? As with most services in life, there is a tradeoff between quality and expense, so you do not want to spend your money on services that are potentially above and beyond your needs. On the other hand, if you are investing funds in preserving a film, it is likely because you believe it has enduring value, so you do not want to degrade that value by asking for too little. The following general guidelines can help you decide what resolution is appropriate for your film, but in the end you should evaluate the quality of your deliverables to ensure they meet your needs.

One line of thought argues that the scanning resolution should be sufficient to capture the visual quality and detail of the original work in order to produce the most accurate representation of the original.[2] There is no direct correlation between film frame size and equivalent digital resolution, and it is important to reiterate here that resolution alone does not determine image quality. Yet the fact remains that we need to make a decision on what resolution is suitable for various films. The following thought experiment is an attempt to tease out some reasonable recommendations.

Those who have studied this question in detail have suggested that between 3,000 and 4,300 pixels-per-inch of horizontal resolution is sufficient to encode the maximum possible detail that film is capable of capturing.[3] The actual resolution of detail on any given film will most likely be less than maximal depending on the quality of lens used, image focus, shooting conditions, generational loss of duplicated film, skill of the camera operator, and film stock, among other variables. To make an average—but still conservative for real-life situations—estimate of the horizontal resolution required by a scanner to capture all detail across various film gauges, we will use 3,650 pixels-per-inch as our basis.

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[2] Anne R. Kenney and Stephen Chapman, "Digital Resolution Requirements for Replacing Text-Based Material: Methods for Benchmarking Image Quality. Tutorial," (Washington, D.C.; Commission on Preservation and Access, 1995), 1.

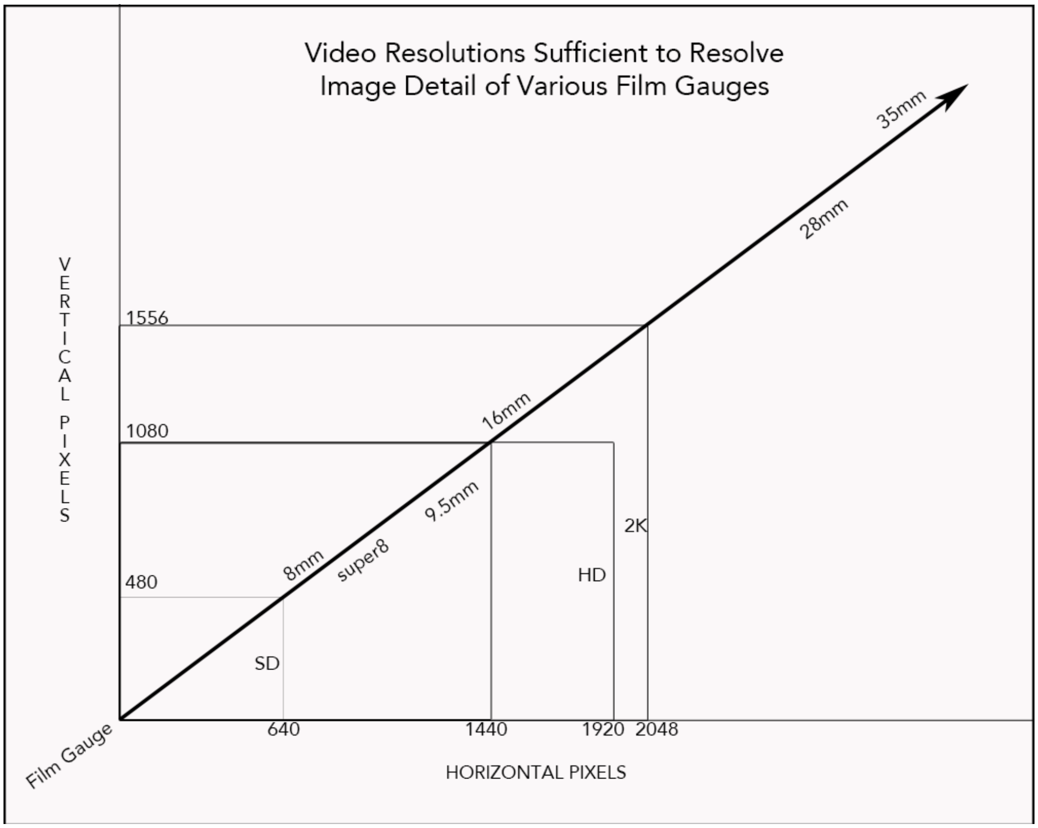
[3] Brad Templeton, "Pixels Vs Film," Luminous Landscape, accessed May 6, 2016, https://luminous-landscape.com/pixels-vs-film; Tom de Smet and Harm Jan Triemstra, "Film Scanning Considerations," Presto Centre, 12, accessed May 14, 2016, http://publications.beeldengeluid.nl/pub/79/White-Paper-Film-scanning-considerations.pdf; Timothy J. Vitale, "Projecting Digital Slide Images," (Hilversum, Netherlands: Netherlands Institute of Sound and Vision, October 13, 2003), accessed May 10, 2016, http://cool.conservation-us.org/byauth/vitale/digital-projection.

Format	Horizontal Resolution Required (edge-to-edge)	Horizontal Resolution Required (typical frame area only)
35mm	5,030 pixels	(22mm/Academy) 3,161 pixels
28mm	4,016 pixels	(19mm) 2,730 pixels
16mm	2,300 pixels	(10.26mm) 1,474 pixels
9.5mm	1,366 pixels (vertical)	(8.5mm) 1,221 pixels
8mm	1,146 pixels	(4.8mm/Regular 8) 690 pixels (5.63mm/Super 8) 809 pixels

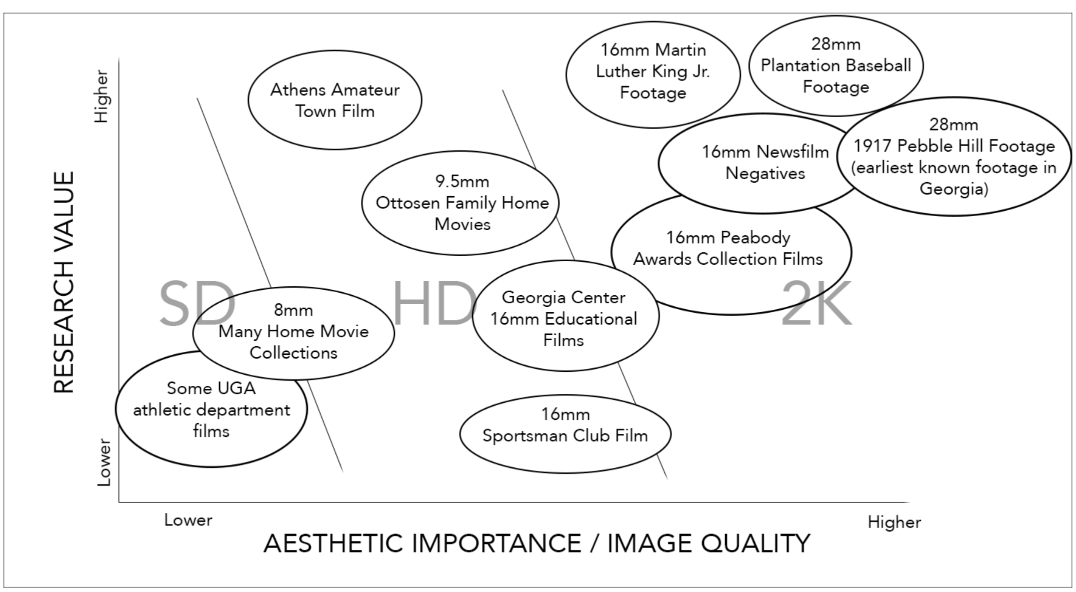
The idea behind this thought exercise is that there is a resolution associated with a film format beyond which the scanned image quality cannot improve because the original motion picture film could only resolve so much detail to begin with. In reality, the film in hand in most situations will not have as much detail to resolve. When taking into account the effect of generational degradation of film prints, the often less-than-optimal shooting conditions of non-professional film production, and human perception of visual quality, the practical numbers are lower than those given above. For instance, one European Broadcasting Union publication determined that 1,310 pixels of horizontal resolution is sufficient to capture 16mm film.[4]

Given that the above values were produced from a calculation, it is necessary to map them to standard broadcast resolutions. Not only are these the most likely options that a lab will offer, but your end users will want to use these standards as well. 4K resolution can capture the highest quality 35mm film negatives. However, after generational loss is taken into account for 35mm copies, 2k is likely a more appropriate choice. In addition, 2K resolution correlates closely to the 28mm format, and is sufficient for 16mm films. HD resolutions are more than adequate for smaller gauges such as 8mm, Super 8mm and 9.5mm (1920 X 1080 for 16:9 aspect ratio/pillar box style, or 1440 X 1080 over the image area for a 4:3 aspect ratio). SD resolution (640 X 480) is often satisfactory for regular 8mm, but clients will generally want an HD format delivered.

[4] European Broadcasting Union, "Preservation and Reuse of Film Material for Television," Tech. no. 3289, (Geneva: European Broadcasting Union, 2001), 58, accessed May 10, 2016, https://tech.ebu.ch/docs/tech/tech3289.pdf.



In addition to film gauge, we suggest that you take into account the research value and image quality of a resource so that, even within these resolution recommendations, you can justify scanning at lower resolutions, thereby saving resources. For instance, if the research value is not directly related to the visual quality of the image, then a lower resolution could be chosen. A 16mm art film would likely warrant a 2K scan, whereas a 16mm film of a lecture would probably be appropriate at HD or potentially even SD resolutions, unless the subject is an important historical figure. The following chart is a tentative attempt to illustrate these distinctions as they relate to some of our holdings:



From left to right, the same 16mm film shown at 2K, HD, and SD resolutions, enlarged for comparison purposes. As this image demonstrates, if the original film image was not of a high quality, then there is not much detail lost by choosing lower resolutions. In this instance, the perceived detail mostly varies by the amount of film grain that is resolved.

What Happens When Non-Standard Frame Rates Are Authored to DVD or Preserved on Videotape?

It is an unfortunate reality that, for many people, optical media like DVD or Blu-Ray is still the access method of choice. While there is an undeniable convenience and familiarity that comes with using a DVD, the fact is that the format is full of compromises that affect the overall quality of the moving image it is attempting to store. The most obvious compromise, especially for consumer-writable DVD formats, is the limited data capacity of 4.7 gigabytes. The limited storage space requires that source material be compressed and data rates restricted, which necessarily degrades the overall quality of the image. Blu-Ray has more than ten times the capacity of a DVD—so the image quality is better—but still requires a compressed file format for authoring. Another aspect of the DVD standard is the restriction of allowable frame rates to 23.976 frames per second (fps) and 29.97 fps, while Blu-Ray allows 23.976 fps, 24 fps, 25 fps, 50 fps, and 59.97 fps.

Video formats like BetacamSP and DigiBeta do not have the compression issues of DVD and Blu-Ray, and they are professional broadcast formats so they have a history of being used for preservation. However, like DVD, they are restricted to the 29.97 NTSC frame rate. When film is preserved to these formats, it is through the use of a telecine, which converts the film into a video signal. The telecine slows down the playback of the film to 23.976 fps and uses a process known as 3:2 pulldown to convert the 24 fps film rate to the NTSC 29.97 frame rate. This process is widely used and produces natural-looking motion to most eyes. And to recover the original frame rate, it is possible to use a reverse-telecine process in digital video editing software.

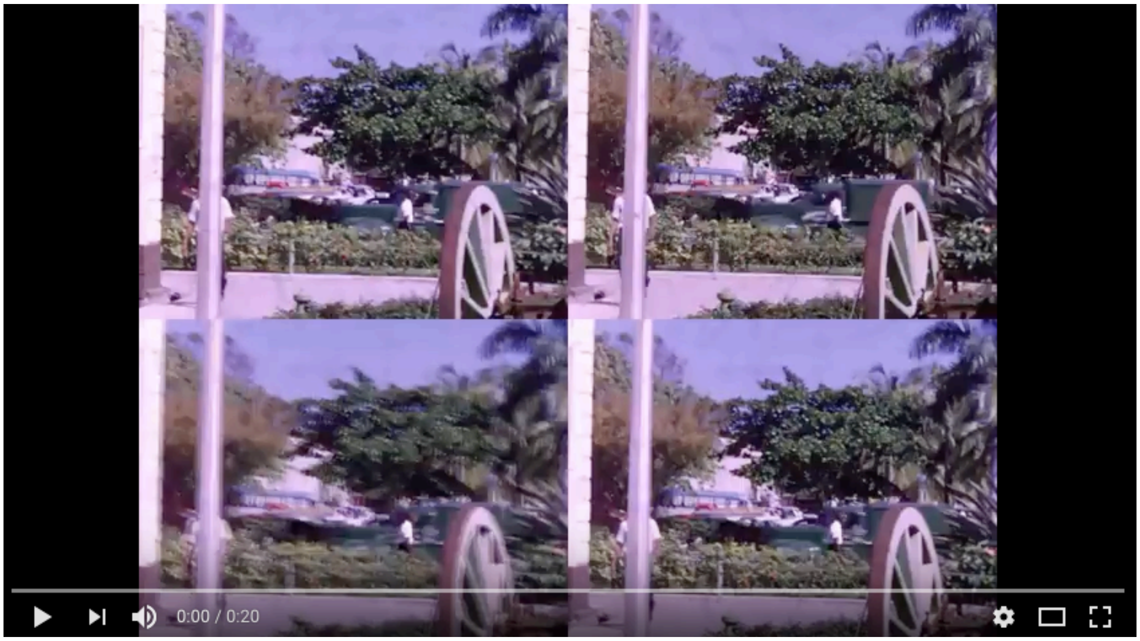
So what is the problem? Wasn't most historic film shot at 24 fps? The answer is yes, unless it is an early consumer format or amateur film. In many cases, these films were shot at slower frame rates, including 16 fps (the 8mm standard), 18 fps (the Super-8 standard), or 20 fps. There is no standard telecine process for these frame rates. Instead, some other sort of frame rate conversion is necessary in order to achieve the NTSC standard, which is inherent to DVD and videotape formats commonly used for preservation or access.

There are three ways to achieve frame rate up-conversions. The first method is frame rate conformance, which consists of playing the film back at the target frame rate and causes the footage to look fast. The second method involves repeating certain frames to achieve the target frame rate, which maintains the correct speed of the footage. The last method is to mathematically interpolate new frames where no frames existed before, which also maintains the appearance of correct playback speed. The last two methods are preferable, since they preserve the playback speed of the footage, but they can be problematic as well. Frame repetition can result in a jerky and unnatural appearance to the motion as certain frames are repeated while others are not. Some frame interpolation methods can produce blurry lines if adjacent frames are blended. Other interpolation methods can produce smooth and fluid motion, but this can also appear unnatural if it is too smooth—often referred to as the soap opera effect—or if the interpolation results in unwanted visual artifacts.

While we have been outlining what can be problematic about DVDs and NTSC videotape, it is okay if DVDs are a necessary part of your access paradigm, or you have been using NTSC videotapes as preservation formats. As previously noted, the DVD format can be the most convenient or the only access paradigm for some users and it does a good enough job for most situations. Also, NTSC videotape was the only option available for a long time, and it may still be the only one your institution supports. However, since DVDs and NTSC videotape require frame rate conversion from film sources, such formats should only be used for access copies as it will be difficult or impossible to get back to the original footage unaltered from a frame rate converted videotape copy.

There are other options for preserving non-standard frame rates in the form of file-based formats. Some file formats and codecs do not have the same frame rate restrictions that NTSC formats like DigiBeta or DVD do. A ProRes encoded Quicktime file or H.264 encoded MP4 can be encoded with virtually any frame rate. Better yet, static image formats are frame-rate agnostic and typically are not restricted by resolution either. For films with non-standard frame rates, a file-based format for preservation and access ensures that this essential characteristic is preserved and the original artifact is more accurately represented. Additionally, by avoiding irreversible frame rate conversion, this approach also ensures the greatest flexibility for reuse in the future.

The following clips illustrate the results of various methods of frame rate conversion and frame interpolation. The first clip shows the various conversion methods next to one another. Since the conversion is a simple doubling of every frame (12 fps to 24 fps), the playback of the top left quadrant is visually identical to the original 12 fps footage, even though it is played back at 24 fps. Note how there is fast motion in this footage, which results in noticeable visual artifacting. The second clip highlights an example of the visual artifacting that results from pixel blending. The third clip shows the conversion methods applied to 16 fps source material. In this example, the conversion is not achieved by simply repeating each frame (as 24 is not a multiple of 16). Therefore, the top left quadrant illustrates the results of uneven frame repetition. Additionally, the motion in the footage is not as fast compared to the footage in clip one. Notice how the interpolated frames display less visual artifacting as a result



Top Left: 12 fps film with every-other frame repeated to create 24 fps. Top Right: 12 fps conformed to 24 fps. Bottom Left: 12 fps converted to 24 using Adobe's frame blending. Bottom Right: 12 fps to 24 fps using Adobe's pixel motion interpolation. (00:20)

Pixel Blend Detail - Notice how the man in the background is rendered almost perfectly, while the fast-moving cyclist has a halo of artifacts. On some frames, parts of the bicycle he is towing seem to disappear. (00:11)

Top Left: 16 fps film with certain frames repeated to create 24 fps. Top Right: 16 fps conformed to 24 fps. Bottom Left: 16 fps converted to 24 using Adobe's frame blending. Bottom Right: 16 fps to 24 fps using Adobe's pixel motion interpolation. (00:32)

Quality Control and Delivering Files into a Digital Preservation Workflow

Quality control is an essential task to complete in the process of working with a digitization vendor. Before file-based preservation, quality control simply meant inspecting the deliverables received from the vendor to ensure that they played back properly and were free from visual defects. For quality control of digital files, the paradigm is similar, but there are additional software tools to help determine whether or not a deliverable conforms to your specifications and is free from defects.

One such tool is MediaInfo, a free and open source application for inspecting the technical attributes—often referred to as technical metadata—of audiovisual files. By inspecting various attributes of a file, such as the encoding method (codec), resolution, or frame rate, one can determine that these attributes match the specifications requested from the vendor. While an essential part of quality control, this method does not provide a means for determining that the data received from the vendor is uncorrupted. In other words, there should be a means for determining that the data you receive from the vendor is an exact copy of the data they intended to deliver.

The free application Bagger was developed by the Library of Congress and the California Digital Library for the purpose of data verification and is widely used within the digital preservation community.[5] Bagger can verify the integrity of digital assets comprised of a single file, but it is especially useful when verifying the integrity of

[5]"The BagIt Library," Digital Curation Centre, November 24, 2014, accessed September 21, 2016, http://www.dcc.ac.uk/resources/external/bagit-library.

digital assets comprised of thousands or tens of thousands of files, as is often the case with films preserved as DPX or TIFF static images.

Bagger creates a manifest of specified files, creates and records a digital fingerprint known as a checksum for those files, and places all of those files in a directory referred to as a bag. This bag is portable and self-describing, meaning it is not tied to any one computer system and all the information necessary to use the bag is contained in the bag itself. A vendor can "bag" a digital asset, deliver it over the internet or on a hard drive, and the contents can be verified upon receipt with the Bagger application. This system allows the archives to verify that no files were left out or corrupted in the various copy processes that must happen in any digital workflow. Furthermore, the bag can be reused at any point in the future to verify that its contents are complete and uncorrupted.

Some vendors may be unfamiliar with Bagger, so it could require additional time for initial implementation if you pursue this option. Archivists should also determine how bags will be used in their own workflows since those details will need to be communicated to the vendor ahead of time. For instance, it is essential to determine the level at which digital assets will be processed, stored, and reused, as this level informs how those assets will be bagged. One could bag many digitized films together, but this only makes sense if they will be processed and accessed together, since the entire contents of a bag must be present in order to verify its integrity. Once these details are sorted out and communicated to the vendor, the implementation of Bagger should add only a small amount of time to a project workflow because a digital asset can be bagged and copied at the same time. This copy process will almost always happen when a vendor creates the deliverables for the client—for example, copying files to an external hard drive—so it should not significantly drive up the labor costs of a project even with large data footprints.

While it is possible to "bag" a digital asset after it is received by the archive, it is essential for the bagging process to happen as early in the life cycle of a digital object as possible, since file corruption can happen at any time. Ideally, it will happen just after a vendor conducts quality control on a digitized film and the file has been determined to be complete and ready for delivery. When implemented this way, Bagger will additionally benefit the vendor as it provides a means to manage quality control for both a vendor's local storage and copy procedures and the delivery and ingest of files on the client side. Once received by the archive, the pre-bagged digital asset will be ready for verification, archival storage, or delivery into some other part of a digital preservation workflow. If your archive does not have a digital preservation workflow to speak of, the simple step of bagging digital assets and storing multiple copies will go a long way to ensuring that asset's health and reusability in the future.

Conclusion

If thinking about all of these options seems overwhelming, you are not alone. Often what a lab provides—in addition to scanning equipment and expertise—is the convenience of relinquishing decision-making to professionals to let them decide the best course of action. However, it is best to engage in these conversations with your lab or vendor to make sure that nothing is taken for granted. We have tried to articulate, in general terms, the important and under-discussed issues regarding film preservation to provide a framework through which you can think about your own assets and anticipate the issues you might encounter. In the end, your policies should inform the services you contract out to vendors, and should be evaluated based on how well those services meet the needs of your institution and your patrons. While the conclusions you reach might differ from ours, we believe these issues to be integral when considering a film digitization policy.

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