CINE-GT3049 The Culture of Archives, Museums and Libraries

Final Project

Instructor: Howard Besser

Shiyang Jiang

May 11, 2020

The Compression Dilemma:
Archival Moving Image in Streaming Media

Introduction

The last twenty years have seen a dramatic transformation of moving image presentation. First developed in the 1990s, video streaming has gained mass popularity from support from content providers and video sharing platforms. By using adaptive delivery methods, streaming provides instant playback of video in quality adaptive to the individual bandwidth. As the content is never loaded as a whole, streaming also increases the protection of intellectual property.

Cultural institutions have also started to use streaming platforms to take an active role in providing access to their collection. Museums and archives have used their Vimeo or Youtube channel to curate online exhibitions, provide public programming, screen feature films, and even upload thousand hours of videos as if it is a digital collection. However, what is often less considered is whether the streaming platform is suitable for presenting archival moving images. While streaming platforms may have the capability to deliver a good quality video to a wide audience, they also enforce transcoding on every uploaded video. This paper will analyze the current video compression technologies used by major streaming platforms and its implication for memory institutions.

Digital Video Compression

Video compression is a form of data compression. Data compression is "the process of reducing data in a digital signal by eliminating redundant information". It reduces the amount of bandwidth required to transmit the digital signal and the storage needed to store it.[1] The process can be both lossless and lossy. In lossless compression, the compressed file can recreate a replica of the origin. It is useful for computer-generated images that contain same information, for example, CG animation, cartoons, graphics. Videos captured by a camera are generally unsuitable for lossless compression because there is less redundant information in the source for the algorithm to compress. The limited reduction is not enough for making a considerable difference to be useful. For example, a video compressed in lossless FFV1 codec is roughly 40 percent the size of the origin, which is still too cumbersome for general usage.[2]

As a result, lossy compression is more widely used for video compression. To minimize the visible loss of data, the encoding algorithm identifies the spatial and/or temporal redundancy of the video and compresses them. The decoder will convert the compressed file to the human viewable video, which approximates the look of the origin.

Compression in Streaming Media

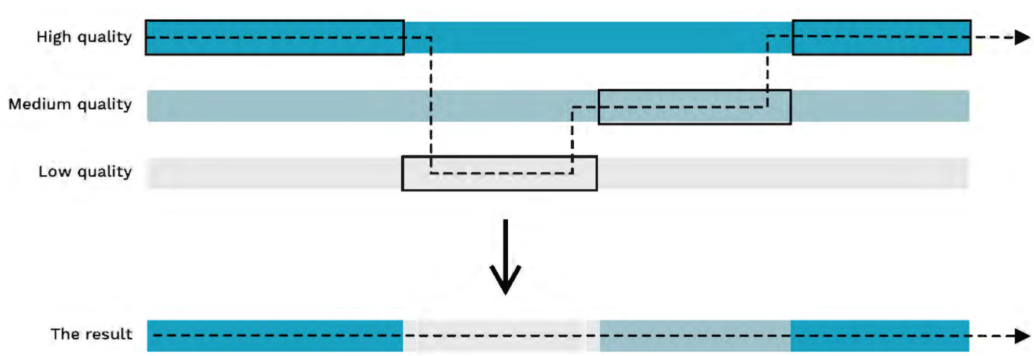
Streaming media refers to the process of delivering media over the Internet as a continuous stream of data in a compressed form.[3] Popular services include Youtube, Vimeo,

---

[1] Diana Weynand and Vance Piccin, "Compression," *How Video Works: From Broadcast to the Cloud*, New York, NY: Focal Press, 2016, 171.
[2] Reto Kromer, "Matroska and FFV1: One File Format for Film and Video Archiving?", Journal of Film Preservation, n. 96 (April 2017): 43.
[3] Diana Weynand and Vance Piccin, "Streaming Media," in *How Video Works: From Broadcast to the Cloud*, New York, NY: Focal Press, 2016: 297-314.

Netflix, and HTML5 Players as JW player or Flowplayer. There are two types of streaming methods, progressive download, and adaptive streaming. Progressive download, also known as pseudo streaming, is similar to the traditional download. The viewer can only begin playback the file after it is fully downloaded. This method works best for smaller files, otherwise, it would take a long time to load. In comparison, adaptive streaming offers more scalability, copyright protection, advertisement insert, and faster playback. Currently, adaptive streaming has taken over most of the streaming services as the default mechanism for streaming.

In adaptive streaming, the file is never downloaded, instead "provided as a stream of video segments that are not saved on the client device". A typical adaptive streaming workflow consists of the following stages: acquisition, transcoding, manipulation, delivery, playback, and analytics. Transcoding refers to the process of converting one form of encoded content to another. A good streaming process is highly dependent on the success of the different stages, but transcoding is especially essential because it directly influences the content delivery to the user. In the transcoding process, the video will be transformed into multiple qualities for adaptive bitrate delivery. The result is the adaptive bitrate ladder. The player will select the most appropriate version based on the viewer's available memory, bandwidth, browser support, etc.[4]



[4] Jason Thibeault, "Streaming Video Fundamentals," *SMPTE Motion Imaging Journal* (April 2020): 10-14.

Figure 1. Adaptive Bitrate Delivery[5]

Codecs War

Codec is an essential element in the discussion about compression. It defines what is a "legal" bitstream and the method of decoding this bitstream to produce a video sequence. The development of codec over the last twenty years makes it possible to deliver higher quality video at a lower bitrate. However, streaming platforms demand even more efficient codecs.

The goal of the streaming platform is to choose a codec that balances between file size, image quality, patent-fee, and software support. As the perfect codec is yet to be created, most platforms use various codecs and profiles to suit the need of different contents and hardware. The four most popular codecs are H.264/AVC, H.265/HEVC, VP9a and AV1.

First standardized in 2003, H.264/AVC remains the most widely implemented codecs. Although H.264 isn't patent-free, the licensing terms are considered reasonable by the market.[6] Different levels of profiles also offer great flexibility in encoding quality, which ranges from baseline to high 4:4:4 lossless. The open-source encoder x264 also contributes to the wide ability of H.264 in amateur video production. Most of the current streaming platforms rely on H.264 as one of their encoding profiles, ensuring their contents are always playable. Youtube and Vimeo also encourage their users to upload files encoded in H.264 so that the transcoding result will be visually closer to the uploaded version.[7]

---

[5] "Adaptive Streaming Reference," JW Player, March 22, 2018. https://support.jwplayer.com/articles/adaptive-streaming-reference

[6] Julien Le Tanou and Médéric Blestel, 14-24.

[7] "Recommended Upload Encoding Setting," Youtube Help, https://support.google.com/youtube/answer/1722171?hl=enYoutube; "Video Compression Guideline," Vimeo, https://vimeo.com/help/compression

H.265/HEVC is the successor of H.264. Standardized in 2013, it claims to increase the encoding efficiency by 50 percent. However, unlike H.264 which patent license is only administered by MPEG-LA, H.265 is represented by three patent pools and a few individual patent holders. This situation limited the implementation of HEVC and caused a strong backlash from multiple content providers. The controversy further led to the emergence of AV1. However, in terms of compression efficiency, many researchers have found that HEVC is still more efficient than the other three. As a result, despite the looming future, it was still implemented in two billion devices in 2019.[8]

Unsatisfied with the license situation of HEVC, major content providers and internet companies formed the Alliance for Open Media in 2015 to develop an open, loyalty-free codec. The governing members are Netflix, YouTube, Amazon, Apple, ARM, Cisco, Facebook, Google, IBM, Intel, Microsoft, Mozilla, Nvidia, Samsung Electronics, and Tencent.[9] The resulting AV1 codec was standardized in 2018. Despite the claimed high efficiency, two third-party research published in SMPTE Motion Imaging Journal found AV1 showing no significant improvement than HEVC while it is 130 times more complex to encode.[10] Nevertheless, free licensing still attracts many content providers. With the backing from Alliance of Open Media, AV1 is also expected to be optimized in the future. Youtube and Vimeo both have created their public testing AV1 channel, while Netflix claimed it has started streaming content in AV1 for selected titles in February 2020.[11]

---

[8] Jean-Yves Aubié, Franck Chi, Patrick Duménil, and Thierry Fautier, “Understanding the Video Codec Jungle: A Comparison of TCO and Compression Efficiency,” *SMPTE Motion Imaging Journal* (November/December 2019): 25-32.

[9] "About," Alliance for Open Media, accessed May 12, 2020, https://aomedia.org/about/

[10] Jean-Yves Aubié, Franck Chi, Patrick Duménil, and Thierry Fautier, 30.

[11] "Netflix Now Streaming AV1 on Android," Netflix Technology Blog, accessed May 12, 2020, https://netflixtechblog.com/netflix-now-streaming-av1-on-android-d5264a515202

Another codec worthy of mentioning is VP9, the predecessor of AV1. It was developed by Google as part of itsopen-source WebM project. As a royalty-free codec, VP9 is widely implemented by YouTube. By default, YouTube will load VP9 content in a supported device, such as Chrome or Firefox browser, and roll back to AVC for an unsupported one.[12] However, as the attention of AV1 grows and VP9 hasn't been updated since 2016, Youtube is likely to choose AV1 or other emerging codecs over VP9 in a few years.

Apart from the four major codecs, VVC (Versatile Video Coding), the successor of HEVC, will be standardized in mid-2020. The test version has already been claimed as the most efficient compression codec ever, advancing HEVC by fifty percent. [13] However, it's difficult to tell if the licensing problem with HEVC will repeat. The competition for more efficient codecs still goes on.

Codec	H.264/AVC	H.265/HEVC	VP9	AV1
Developer	VCEG and MPEG*	VCEG and MPEG*	Google	Alliance for Open Media
First version	2003	2013	2013	2018
Latest version	2019	2019	2016	2019
Base standard	MPEG-2	H.264/HEVC	VP8	VP9
Open format?	Patent-protected	Patent-protected	Royalty-free	Royalty-free

[12] "VP9: Faster, better, buffer-free YouTube videos," Youtube Engineering and Development Blog, accessed May 12, 2020, https://youtube-eng.googleblog.com/2015/04/vp9-faster-better-buffer-free-youtube.html

[13] Jean-Yves Aubié, Franck Chi, Patrick Duménil, and Thierry Fautier, 30.

Container support	Quicktime, MP4, AV1, Matroska and more	Quicktime, MP4, AV1, Matroska and more	Matroska, WebM, IVF	Matroska; WebM; ISOBMFF; RTP (WebRTC)
Implementation**	Every service provider	Netflix used for 4K content[14]	Youtube w/ H.264/AVC	Netflix started selected title in February 2020, Vimeo & Youtube in testing
Browser support[15]***	All browsers	Safari, Android browser	Chrome, Opera, Firefox and Android devices	Chrome and Firefox

Figure 3. Comparison between different codecs

* Video Coding Experts Group or Visual Coding Experts Group (VCEG) is a working group of the ITU Telecommunication Standardization Sector (ITU-T). Moving Picture Experts Group

[14] "Technical Details of Netflix," Wikipedia, https://en.wikipedia.org/wiki/Technical_details_of_Netflix

[15] Jan Ozer, "HEVC, AV1, VVC: How to Make Sense of 2019's World of Codecs," Streaming Media, https://www.streamingmedia.com/Articles/ReadArticle.aspx?ArticleID=133589&pageNum=2; "HTML5 Video," Wikipedia, https://en.wikipedia.org/wiki/HTML5_video

(MPEG) is a working group of authorities that was formed by ISO and IEC to set standards for audio and video compression and transmission.

** As few streaming media companies make their encoding profiles public, the observations are drawn from various sources, which are subject to inaccuracy and changes.

*** Refers to the latest version of the browsers. Not including browsers need special extensions to configure the codecs.

Challenges for archival moving images

How does streaming compression impact the memory institutions? First of all, archival moving images often suffer from poor image quality from streaming encoding because the images have different characteristics from born-digital videos. For example, film grains are notoriously hard to compress. Because unlike noise, grain can be more than one sample in size and show a high degree of randomness. "The randomness then makes prediction difficult and motion estimates less precise." Archival moving images also often have deterioration, which causes color swifts e from frame to frame. As a result, either the details are suppressed in the compressed file, or a high enough bitrate has to be used. It costs more processing power and the result often contains many compression artifacts. [16]

Another concern for memory institutions is the use of compression workflows that compromise the fidelity of the image. One of the typical approaches to address the film grain problem is to detect the film grain, denoising the video, compressing the denoised video, and estimating the film parameters. The film grains are later to be added to the reconstructed video in the decoding process. Although the new approach hasn't been standardized in any codecs, they

[16] Andrey Norkin and Neil Birkbeck, "Film Grain Synthesis for AV1 Video Codec," 2018 Data Compression Conference, 2018: 3-12.

are available as add-ons for H.264 and AV1.[17] If the workflow could save considerate amount of bitrate, it is highly likely that the streaming platforms would pose control over film grain and interfere with the image.

The lack of content-awareness is also problematic for archival moving images transcoding. The new developments of video compression are all focused on high performance for videos with different exterior characteristics, for example, high resolution, high frame rate, high dynamic range. The complexity of the image itself has yet to be recognized by the streaming field. The transcoding engine would compress a 2K film scan with the same encoder setting with CG animations. The lack of effective quality control also makes the compressed details published unnoticed.

From a practical angle, the creative team/publisher and archivist/curator split also present challenges. Archivist, or curator, who understands the original content the best, is often not in charge of the quality assurance process for video streaming. In the New York Public Library, digital videos are accessible through the digital collection platform via JW Player. The media preservation department usually delivers H.264/AVC access copies to the digital department, which publishes the content online. There is no further interaction between the archivists and the platform.[18] A similar situation applies to the Museum of Modern Arts. The museum uploaded ten recently preserved home movies to Youtube for the Private Lives Public Space Virtual View exhibition. However, most of the videos have so many macroblocking artifacts that they start to distract the viewing. Macroblocking is a video artifact in which objects or areas of a video image appear to be made up of small squares, rather than proper detail and smooth edges. The causes of

---

[17] Andrey Norkin and Neil Birkbeck, 3-12.

[18] Interview with Genevieve Havemeyer-King, Media Preservation Coordinator at NYPL

macroblocking might be Youtube's compression or the source file. [19] The uploading process is managed by the museum's creative team, whose unfamiliarity of the content might attribute to the result. Either way, these videos present a jarring experience that is unfaithful to the original creators and undermined the hard works of the archivists.

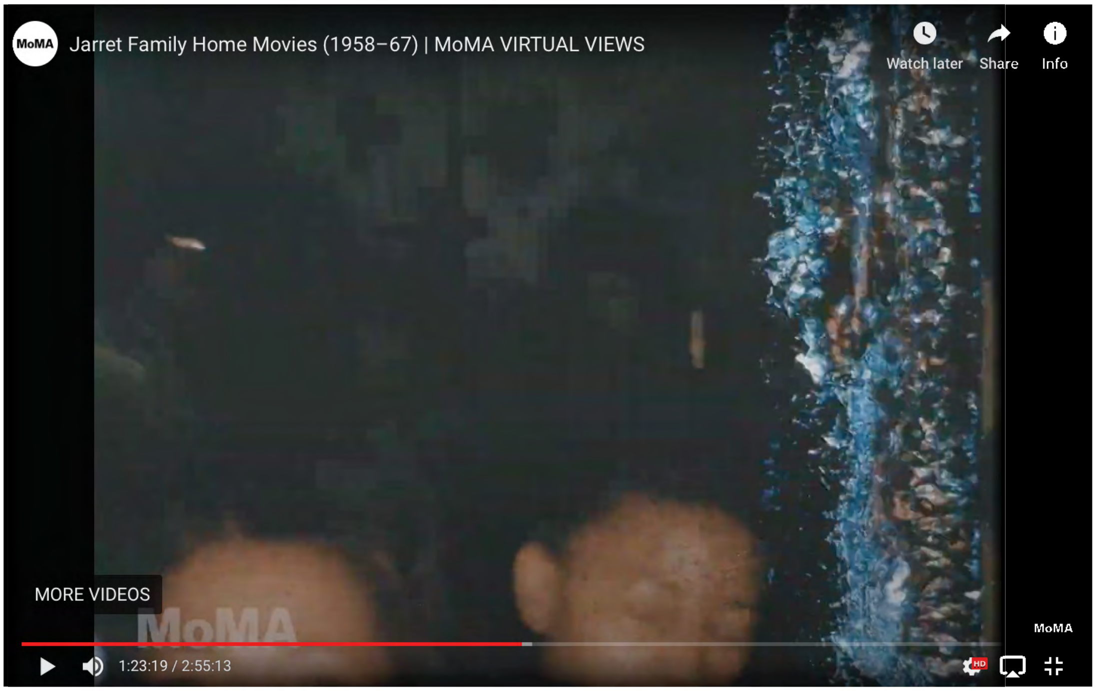


Figure 4. Screenshot from Janet Family Home Movies (1958-67) (Museum of Modern Arts)[20]

Test

To gain a better understanding of the problems in streaming compression, I used a ProRes video to test the results. The video I chose is a section of *If Antarctic Ice Cap Should Melt* (1929). The tinted positive element was scanned at 2K from a Lasergaphic scan station at 24fps. The source video was encoded using ProRes 422 HQ at 252 Mbps. The bitrate is close to

---

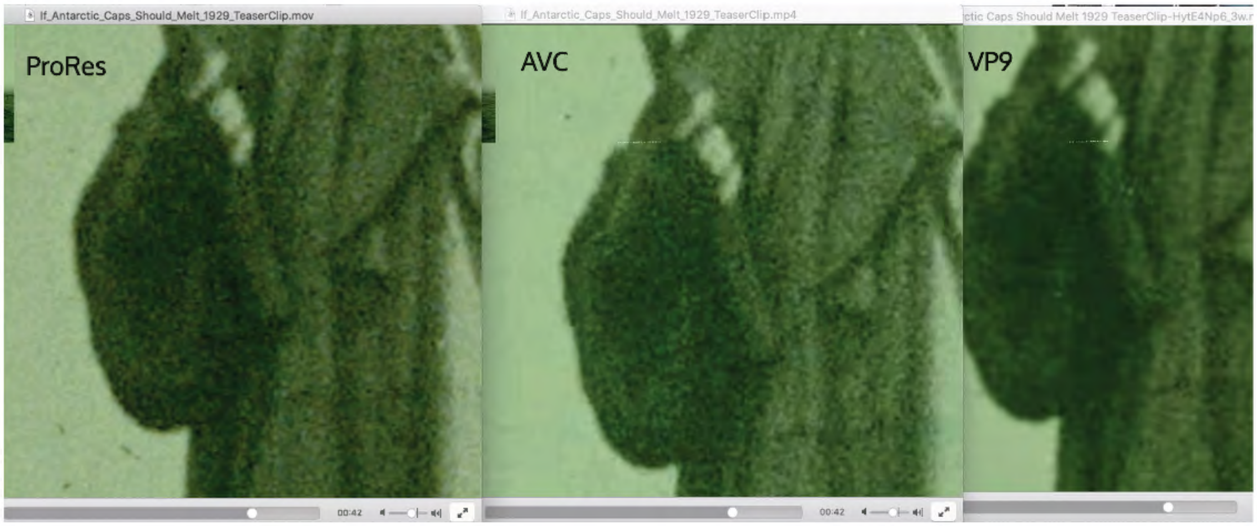
[19] "Macroblocking and Pixelation: Video Artifacts"https://www.lifewire.com/macroblocking-and-pixelation-1847333

[20] "Janet Family Home Movies (1958-67), Museum of Modern Arts, Youtube, accessed May 5, 2020, https://youtu.be/VK0-YgBIQi0

one commonly used for Digital Cinema Package, which makes the video file very high quality. The resolution of the video file is 2048*1556. The file size of the 53-second clip is 1.7 GB.

I uploaded the ProRes file to Vimeo and Youtube respectively. For Vimeo, I was able to download the re-compressed file at the highest resolution with the user interface. Youtube users are only able to retrieve their file at 720p, despite the player offering playback up to 1080p. So, I used the command line tool youtube-dl and managed to retrieve the video file at the highest resolution. Using MediaInfo, I found both files have been scaled down from the original resolution to 1896*1440 (4:3). The Vimeo file is encoded with AVC High level 5 profile at 11.9 Mbps bitrate. The file size is 77.8 MB. The Youtube file is encoded in VP9 at 5.6 Mbps bitrate, which results in a file size of 29.4 MB. In addition, although the frame rate remains 24 fps, the durations for the two compressed files are slightly different from the original. The original is 53s 583ms, while the Vimeo file lasts 53s 588ms and the Youtube file lasts 53s 638ms.

To compare the files together, I used VLC Player to play three files and stop the playback at the same second. Although I couldn't get the precise same frame, the result is enough to spot the difference. In the following screenshots, I use VLC Player to zoom in the file at the highest ratio. The file at the left is the original, Vimeo in the middle and Youtube at the right.



Figures 5 and 6. Comparison between the original and two compressed files.

The first thing to notice is the background detail. In Figure 5, the technique used by Youtube completely erased any grains in the background and substituted it all in the same color. In the Vimeo file, there are still some details in the background although the grains are now less pronounced. The Youtube version also has some mosquito noise artifacts around the edges of the architecture. It is a distortion that appears near crisp edges, which appears like random aliasing. In Figure 6, we can also spot that the sleeve of Statue of Liberty is difficult for VP9 to encode. As a result, large areas of the sleeve, made by grains of different colors and sizes, are encoded into a single color.

What I discovered from the test proves the dilemma between bitrate and image quality still troubles the streaming platforms. The Vimeo version of this video is visually closer to the original than the Youtube version. However, it also demands a higher bitrate to deliver to the users. The VP9 version saves the bitrate at the cost of image quality. I also found that the automated transcoding process by the streaming platforms is hard to be decoded through one test. Only through more experiment can we get a further understanding.

Conclusion

Video compression is still one of the most competitive and fast-changing fields for the video industry. How should moving image archivists react to the rapid development of the video compression world? First of all, moving image archivists need more awareness of the transcoding process in streaming media and take the initiative to monitor the changes. Understanding video compression will help archivists preserve and present in the ever-changing digital world. The file format registry at the Library of Congress has been a good resource for understanding the sustainability of the different formats. However, the project hasn't been updated since 2016. It could be a good resource to more archivist to add new formats as well, Best practice guidelines should also be developed on how to present archival materials on streaming platforms.

Archives also need to take streaming seriously as a resource. People has grown to discovering and enjoying moving images in this way. It demands more attention. Every year, Cinema Ritrovato gives out DVD awards, encouraging and giving visibility to quality home entertainment DVD and Blu-Ray from around the world. "The awards are well respected within the industry and are one of the few to focus on the release of old films." As streaming has become a market as important as home entertainment, high quality streaming video should get similar attention.

Archives also need to be more transparent in using streaming platforms. For example, UCLA’s Preserved Silent Animation website lists not only the physical characteristics of the original films, but also the technical information about each generation of the digital video and the one that is accessible for streaming on the website. [21]

Last but not the least, one way to maintain the integrity of the video is to allow the user to directly download the content. For example, every video uploaded into the Internet Archives is available in their original format without transcoding. The user can also stream the video on the website player in a transcoded AVC/H.264 version. [22] In the originally free spirit of Internet, memory institutions don't have to sign a devil's pact with streaming platforms.

---

[21] "UCLA Preserved Silent Animation," UCLA Film & Television Archive, accessed May 5, 2020. http://animation.library.ucla.edu/#

[22] https://help.archive.org/hc/en-us/articles/360014487651-Files-Formats-and-Derivatives-A-Basic-Guide

Bibliography

"About," Alliance for Open Media, accessed May 12, 2020, https://aomedia.org/about/

"Adaptive Streaming Reference," JW Player, March 22, 2018. https://support.jwplayer.com/articles/adaptive-streaming-reference

Aubié, Jean-Yves, Chi, Franck, Duménil, Patrick, and Fautier, Thierry, "Understanding the Video Codec Jungle: A Comparison of TCO and Compression Efficiency," *SMPTE Motion Imaging Journal* (November/December 2019): 25-32.

Fautier, Thierry, "Next-Generation Video Compression Techniques," SMPTE 2017 Annual Technical Conference & Exhibition, 2017.

Kromer, Reto, "Matroska and FFV1: One File Format for Film and Video Archiving?", Journal of Film Preservation, n. 96 (April 2017): 43.

"HTML5 Video," Wikipedia, https://en.wikipedia.org/wiki/HTML5_video

"Recommended Upload Encoding Setting," Youtube Help, https://support.google.com/youtube/answer/1722171?hl=enYoutube

Tanou, Julien Le, and Blestel, Médéric, "Analysis of Emerging Video Codecs: Coding Tools, Compression Efficiency, and Complexity," *SMPTE Motion Imaging Journal* (November/December 2019): 14-24.

Thibeault, Jason, "Streaming Video Fundamentals," *SMPTE Motion Imaging Journal* (April 2020): 10-14.

Weynand, Diana, and Piccin, Vance, "Compression," in *How Video Works: From Broadcast to the Cloud*, New York, NY: Focal Press, 2016, 171.

Weynand, Diana, and Piccin, Vance, "Streaming Media," in *How Video Works: From Broadcast to the Cloud*, New York, NY: Focal Press, 2016: 297-314.

"Netflix Now Streaming AV1 on Android," Netflix Technology Blog, accessed May 12, 2020, https://netflixtechblog.com/netflix-now-streaming-av1-on-android-d5264a515202

"Video Compression Guideline," Vimeo, https://vimeo.com/help/compression

"VP9: Faster, better, buffer-free YouTube videos," Youtube Engineering and Development Blog, accessed May 12, 2020, https://youtube-eng.googleblog.com/2015/04/vp9-faster-better-buffer-free-youtube.html

"Technical Details of Netflix," Wikipedia, https://en.wikipedia.org/wiki/Technical_details_of_Netflix

Ozer, Jan, "HEVC, AV1, VVC: How to Make Sense of 2019's World of Codecs," Streaming Media, https://www.streamingmedia.com/Articles/ReadArticle.aspx?ArticleID=133589&pageNum=2

Norkin, Andrey and Birkbeck, Neil, "Film Grain Synthesis for AV1 Video Codec," 2018 Data Compression Conference, 2018: 3-12.