

Video Quality Issues in File-Based Broadcasting

Abstract

The media industry is rapidly migrating from tape-based media acquisition and broadcast to file-based workflows. This migration has resulted in many different dimensions of impact on the media content. The transformation of media content occurs at several stages in the flow. The transformation could start from conversion of analog to digital media and be affected by various systems involved in processing and delivery of media. The digitization of content has led to several changes in compression standards, editing, and transmission technologies. There are various options to create, edit, and repurpose the content. Additionally, the industry has to deal with evolving media compression technologies, container and delivery formats. There are several transmission methods based on delivery needs, such as IPTV, DTH, cable, and VOD. All these dimensions of impact on media content have increased complexities in a file-based broadcast workflow. Hence, there is increasing uncertainty in the quality of content that reaches the consumer. The consumer expectation of HD video and the increasing competition in media industry further add to the quality requirements of media content. Therefore, file-based broadcasting has to deal with constantly evolving technical complexities on one hand and expectations of quality by the consumers on the other. In this scenario, the legacy methods of quality control are inadequate. Manual checks become inconsistent, subjective, and difficult to scale in a globally accessible media workflow. This paper discusses the types and causes of issues that affect the quality of media in various stages during broadcast workflow. The paper looks at the adoption of automated tools for accurate detection of issues in media content to improve the content quality & consumer experience.

Introduction

The adoption of file-based media has spearheaded many advantages for broadcasters. There is ease of media storage and retrieval. There is the enhanced flexibility, speed, and sophistication of non-linear editing. File-based content has even changed the way media is delivered.

In the tape-based flows, many of the processes were handled manually and were cumbersome. With the newfound flexibility of file-based flows, the media files are being compressed and formatted using a wide range of compression technologies, file format types, and delivery formats. With the flexibility of digital data, complex operations are possible to create various types of output files using sophisticated editing techniques, repurposing, and transcoding.

The increase in complex operations on media files increases the possibility of injecting errors into the content. These errors can manifest in metadata of file formats. There may be errors with respect to the non-conformance to variety of compression standards. There may be errors related to degradation of video and audio quality. There may also be errors introduced during digitization of tape-based media.

In addition, the advancement of HDTV has led to the end consumer being media quality aware and more concerned in terms of the value for their money. Broadcasters have now added additional systems to check the end user media quality. These checks are performed either manually or automatically.

Thus, complexities in a file-based broadcast flow have been impacted by:

- Transformation of media content that occurs at several stages in the flow.
- Standards and technologies in media industry that have influenced compression standards, editing, and transmission technologies.
- Transmission methods based on delivery needs, such as IPTV, DTH, cable, and VOD.
- Consumer expectation for media quality propagated by technologies, such as HDTV.

This paper discusses existing scenario of file-based media broadcasting, the causes and effects of media quality degradation at various stages of a file-based workflow, and the advantages of automated quality verification of content.

File Based Workflow: Existing Scenario

In the pre-digital content flows, the traditional broadcasting environment dealt with media that was in tapes and handled manually by individuals. The media was captured at the studios, stored, sent for post-production, and then ingested. The ingested media was labeled with some known metadata for later retrieval through mechanical or automated systems.

With digital content, file-based workflows have started evolving rapidly. A generic file-based scenario is depicted in Figure 1.

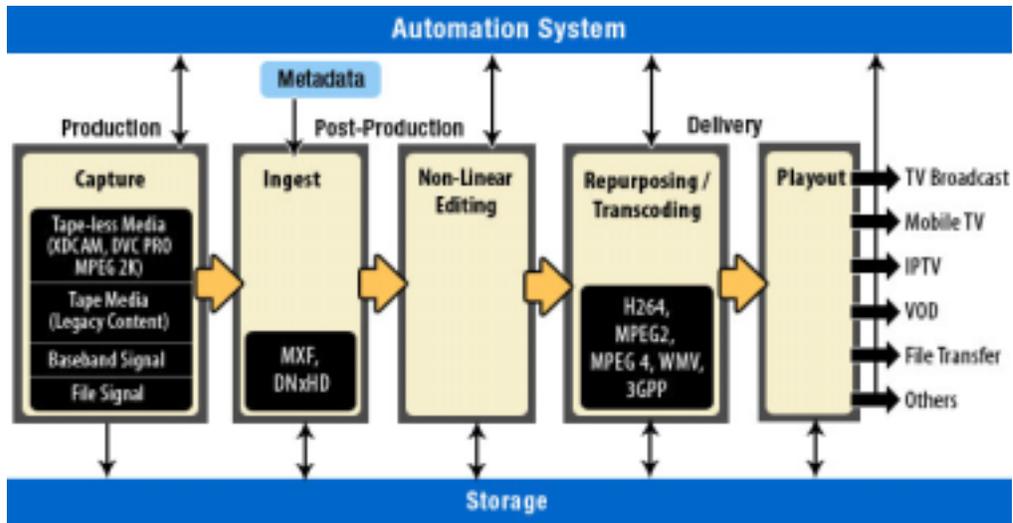


Figure 1: A File-based Workflow

The first stage is media capture, which can be a capture from camera within a typical studio or production house. This is the production stage of the media in which the video can be stored in formats such as DV, MJPEG, XDCAM, etc. The capture can also be achieved using network resources, such as FTP. The capture can also happen after conversion of media available from legacy tapes.

Ingest is a process of transferring or accepting content to or within a digital editing / storage system. This process includes operations such as digitizing the content from analog tape, inserting metadata for efficient retrieval from a very large database of files. The ingest process includes embedding the metadata within known formats such as MXF and MOV.

In the post-production stages, the media is processed and edited. Here the processing includes adjusting color values for increasing/decreasing the brightness and removing some frames from the captured video. This stage usually does not involve any loss of quality after real capture.

Before the distribution of media content, the media has to be processed again to satisfy the requirements of the distribution network or ultimately the end consumer. This processing can be in the form of transcoding in which the bit rate of the given audio/video is altered. The processing could also involve change of compression format of the given audio or video.

The automation system involved would then schedule the transcoded media to be distributed to end consumer systems or networks involved for delivery.

Each stage in the workflow has different types of files based on its contained media, the file format used, the bit rate, frame size, and frame rate. The files are created at various stages and stored in the storage systems with the applied metadata scheme. For efficient access and search, there are automation systems at various stages of the content flow.

Video Quality Issues

The above file-based workflow spanning capture, post-production, and transcoding, involves numerous cases of media transformations. The numbers of cases of transformations depend on the requirements of a given broadcaster or a vendor. These requirements in turn affect the complexities involved, which in turn increase the possibilities of errors in content.

A broadcaster has to validate media received from a vendor or production house. The objective is to check for any degraded content prior to it being ingested into the workflow.

At ingest, there could be video quality issues, such as blurring, brightness, or flashing. For example, in case of flashing, the video should not contain the temporal and spatial patterns that would induce seizures in photosensitive-epileptic viewers. If flashing is not checked at the time of ingest and delivered to the customers, it could lead to severe legal implications for the broadcasters.

In case of tape-to-file conversion systems, there could be issues related to some part of the video not being captured or part of captured block getting noisy due to dirt between tape heads and tape.

After ingest and editing or repurposing, there could be a variety of video errors because of erroneous handling of video streams by editing systems or editing experts. The editing may involve cutting and pasting of content into/from the video stream. This operation may disturb some of the already known and fixed parameters such as field order, required telecine, and field-dominance. If a new video were inserted in an existing content, there would be an issue of field dominance near the location of *join*. The editing may also involve inserting color bars or black frames for specified time duration within the stream. The durations of these types of sequences needs to be rechecked before the next stage. The requirement of putting special effects or adding graphics may disturb existing sequence signal levels.

The transcoding stage refers to transforming a given media from one format to the other. The transformation can be with respect to the container format such as MP4, DV, MXF, and MPEG2 TS, or it can be resizing the video frame size, changing the bit rate or sampling format. The conversion may also involve changing the compression format from MPEG2 to H264, DV to MPEG2 at some specified bit rate and other parameters. For example, there could be a requirement of changing the container format from MPEG2 Transport stream to 3GPP format for 3G mobile distribution networks. After the transcoding, issues such as blockiness, pixelation, combing, blurring, or ringing can reappear in content.

Consider a case of blockiness artifact as a well-known issue of video quality. This is the most common artifact in case of transform based video compression schemes. The artifact starts appearing while transcoding in lower output bit rate for a highly detailed video. In a general case of MPEG compression scheme, an input frame is divided into smaller independent entities called as blocks. Each of the blocks is transformed to frequency domain using transformation such as

DCT (Discrete Cosine Transform). The transform generates discrete frequency coefficients where the low frequency coefficients would have more weightage for representing information within a block. If a block contains high details, coefficients for high frequencies may also contain important information. Lowering the bit rate would result in lesser bits being allocated for each of the blocks. In this case, the blocks would be forced to ignore coefficients at higher frequencies and lesser bits would be included in output encoded video stream. At the decoder side, the inverse transform would generate a block. If the block contains very few edges or is visibly smooth, then ignorance of higher frequency components would not effect the reconstruction. On the other hand, if there exists a gradient or edges or higher details within the edge, this would definitely affect the block decoding. The edges at the boundaries would not be continuous because of inadequate reconstruction.

The possibility of blockiness artifact increases with the decrease in the required output bit rate. The dependent frames, such as *P* or *B* frames, would be affected more severely if the *I* frame has been encoded or decoded with this artifact. A single blocky frame would not affect overall quality of the video, but a sequence of video would play an important part in deciding the quality.

There are video quality issues that are related to signal issues, such as RGB gamut and signal levels. Video data is captured and preprocessed as per the specified levels for color components so that the signal voltages representing these signals do not exceed the specified levels. The captured and preprocessed data is then passed to encoding systems for compression. The captured RGB data has to follow specified RGB color space called Gamut. The data as captured in RGB format is converted to YUV space as input to encoding systems. Because of loss of information and some processing of data by the encoder, the YUV data could be different from the original data as captured. This would lead to improper relationship among each of the luminance and chrominance components. The improper red, green, and blue components may become out-of-gamut. Similarly, YUV data can also be out of range as per the specified limits. But, RGB gamut and signal level issues cannot be manually detected and would require an automated system to scan each of the decoded YUV values as well as the converted RGB space.

There are issues where the encoded stream does not comply with the recommendation or common standards for encoding and decoding a stream. Non-conformance to specifications can be a result of encoding systems or transmission bit errors. Non-conformance also needs to be verified as it can lead to erroneous video output or may lead to crashes in the decoding systems.

A recent development in validating video quality is to conform to various guidelines for detection of flashing and regular patterns in video by ITU, ISO, and ITC. These guidelines are circulated for broadcasters to avoid harmful flashing video and patterns that had affected many cartoon viewers with 'Photosensitive Epilepsy' in Japan. A couple of years ago in Japan, nearly 700 children were hospitalized after viewing a cartoon sequence of "Pokemon" series. These photosensitive epileptic children were affected by seizures as triggered by rapid scene changes, flashing images and some specific color patterns.

Medical experts examined these harmful video sequences and found that some specific types of spatial and temporal characteristics of video sequences were responsible for the harmful seizures. Based on the study of given videos, the Japanese and UK governments formulated guidelines for broadcasters to restrict video sequences containing any kind of harmful video flashes and patterns. Various organizations and forums such as ITU, ISO, and ITC formed recommendations specifying concrete thresholds and restrictions on the temporal and spatial

characteristics of video content. It is quite difficult for a normal viewer to find out if any video contains the harmful flashes. The detection is only possible if an epileptic person is viewing the video.

The Requirement of Automated QC

File based systems in the above workflow have made the automation systems work efficiently. But, with the file-based systems, there is increased challenge of processing and delivering content faster, with competitive quality, and fulfillment of expectations.

On the other hand, the end-user has been provided with a choice of devices and media for viewing. HDTV represents a major advancement for end user experience compared to the existing SDTV video. In this case, broadcasters need to be more concerned about the higher media quality expectations of end user.

The content provider may provide the best quality media to the broadcasters. However, all the conversions and transformations leading up to media delivery make it important for broadcasters to maintain the end user media quality.

The human eyes often cannot perceive the inherent errors in a video frame, for example - RGB color gamut, video signal levels, width of bars, or expected standard of color bar. The detection of these errors requires some computations that the human eye cannot validate just by viewing a frame.

Manual inspection is useful in cases where human eyes can perceive the defects in video frames, such as blockiness and blurriness. However, manual inspection can only judge one frame at a time. Manual inspection cannot judge the overall quality degradation in objective terms. The quality index provided by personnel varies based on skill, experience, and individual preference. Thus a formalized, computational method is required for an objective and measurable quality feedback.

Since there are numerous file formats and delivery formats, manual validation would tend to become increasingly error prone with the increase in information to be validated for each of the media essence. The fast pace of new formats or guidelines coming into the industry necessitates constant re-training of the personnel. This involves cost and time, but still leaves scope for uncertainties in the quality of media.

Therefore, media validation needs to be automated using an intelligent and flexible environment that can process huge volumes of data in an accurate and consistent manner. This system would be parameterized with the required expectations and rules of validating the media and be aware of various media formats, conformance rules for compression formats, recommendations, guidelines of various standards, and other complex media attributes. The system would rely on processes and algorithms to detect the quality of a frame or multitude of frames in an objective manner and correlate it with the human experience for video quality.

Take the case of a 1-hour media file containing audio and video. A manual process would take at least 1-hour at each of the stages of the workflow to check against a defined set of specifications. Also, multiple specification sets may require checking of the entire media multiple times. In the worst case any change in requirement would require the whole process to be repeated again.

Additionally, the audio and video data has to be processed separately. The validation process would require utmost attention and complete knowledge about the requirements or specifications.

On the other hand, an automated system can operate on a 24x7 basis for such a validation process, giving accurate and consistent results irrespective of the amount of data to be processed. This system can operate in parallel to all the stages of the workflow, thus saving time. Detailed specifications and guidelines for all compression formats and delivery formats can be part of the knowledge base of the automated system. In case of the automation system working in real time, a validation report can be provided in just an hour, thus saving time and costs.

A sample workflow with the automated content verification system checking media quality at various stages is illustrated in Figure 2.

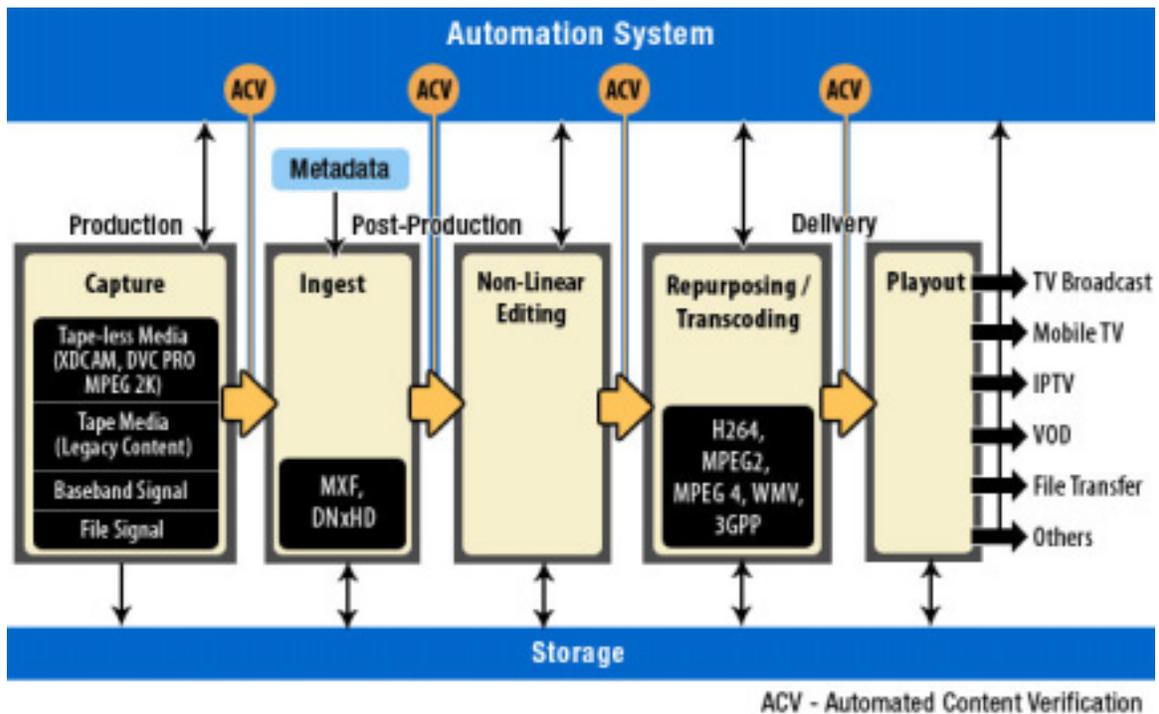


Figure 2: A file-based Workflow with Automated Content Verification at various Stages

Conclusion

The issues and complexities involved in file-based broadcast workflows necessitate the adoption of automated content verification for video and audio quality.

Visual or manual inspection of media content invariably fails in identifying problems and cannot easily scale for large media volumes and complex specifications. As manual checks are inconsistent, subjective, and dependent on individual skills, absolute dependence on manual quality checks cannot justify return on investment.

The adoption of automated content verification is the only way to fulfill the expectations of consumers and achieve a competitive edge in the media market.