Content Readiness
Ensuring Content Quality across Content Lifecycle

Shailesh Kumar
Product Architect
Interra Systems

Abstract

With file based workflows, the content lifecycle has become much more complex and demanding. Content supply has also evolved introducing new models, such as user generated content. The technology evolution in these areas has led to a significant proliferation of digital media formats for supply and distribution. This has led to complex IT infrastructure and workflows for content life cycle management. Interestingly, as more content transformation is added to the workflow, more content quality issues arise.

Content quality issues directly impact the operational efficiencies in terms of human productivity, improvement in content throughput, quality, management, and monetization throughout the content lifecycle. In addition, the tight time-to-delivery limits content scrutiny and hence leads to more content quality issues. There is a critical need for automated QC as a multi-point process to ensure not only content quality but content readiness at all stages. Content readiness goes beyond the generally known quality issues to regulatory issues, workflow issues, and others. The resulting content readiness would have direct impact on operational efficiencies across the entire content lifecycle.

Introduction

Content lifecycle involves multiple stages of workflows, multiple content transformations, and content transmissions. The content transformations include formats, characteristics, meta data, layout, and more. At each transformation, content interacts with diverse systems and technologies. To increase audience reach, the content needs to be delivered to multiple target platforms (broadcast, cable, IPTV, VOD, mobile, web) across multiple demographics (with varying regulatory standards) and for a wide variety of devices.

Throughout this fast moving content life cycle, content transformations, transmissions, and interactions impact content quality. Content quality is a multi-point process rather than a single-point event just before content delivery. A continuous QC process ensures content readiness which impacts operational efficiencies across a file-based workflow.

Content Readiness

Content readiness is a measure of the relevance and conformity of content at each stage in the content lifecycle. Content readiness spans a few attributes:

- Standards/formats conformance
- Quality issues specific to a stage, such as ingest or post production
- Regulatory conformance
- Content specifications
- Infrastructure fit (content access, alerts, reports)

Traditionally QC focused on formats conformance, and native content quality checks, but content readiness goes beyond the traditional QC. Content readiness deals with continuously expanding content checks to meet with regulatory issues (loudness, flashiness) and user experience issues (video signal levels). Content readiness also ensures that content suppliers meet specification issues of the content consumers (playout) and workflow issues. Workflow issues include, content access from where it is, when it is ready, verified for expanded quality, and stored appropriately

Content Quality Requirements across Content Lifecycle

As emphasised earlier, content quality is impacted across a workflow. Figure 1 illustrates a content flow and a sample of typical quality issues that are possible at a particular stage.

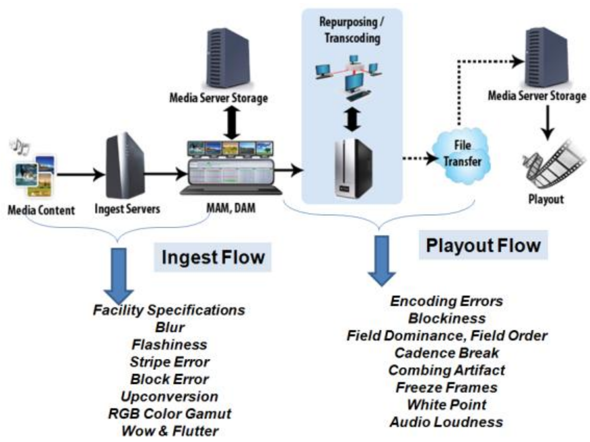

Figure -1

Ingest - The ingest process is responsible for ingesting audiovisual signals into the content rich organization. The signal may be an incoming feed from satellite or cable, or a signal from a studio device, such as a tape, a DAT, or a CD recorder/player. The signal is digitized during ingest and may be stored in multiple formats via suitable encoders and written to an online storage system. There may be pre-existing problems in the incoming audiovisual signals. Moreover, the encoding process at ingest may introduce some more errors. In addition, content may need to meet facility specific requirements.

Editing - Editing with Non-Linear Editing (NLE) systems typically involves exporting the data from Content Management Systems (CMS) to NLE system for editing and importing it back after editing is complete. These two operations may introduce several kinds of errors. If re-encoding of data is involved, it may cause loss of quality. Changes in wrapper formats may also introduce some standards conformance issues. Apart from import and export, the editing activities (cutting, trimming, multiplexing, de-multiplexing, color correction, special effects filters) may introduce unwanted perceptual errors in the content.

Archival - Tapes are used as near-online storage for archiving content that is not in active use. Tapes are heavily used for high bandwidth, high resolution studio content since storing them in hard disk based online storage is usually very costly. If content resides on tapes for long time, it may degrade slowly. Periodic checking of content ensures its integrity for long time.

Playout - Before final playout, content is transcoded for the target delivery platform. At this stage, content quality needs to meet customer expectation. Transcoding typically converts audiovisual signals from HD to SD or lower resolutions as per the needs of target platform. Compression with B frames is used to reduce final content size. Such operations are expected to reduce the perceptual quality of content. Hence, it is imperative to measure the perceptual quality at this stage to make sure that it doesn't fall beyond the levels expected by customers.

The fact of the matter is that errors may be introduced at any stage throughout the content life cycle and detecting an error early in the workflow can save a lot of time later. If QC is not performed at an early stage, it may be quite difficult at later stages to identify the source of the issues in content. Figure 2 illustrates how efficiency is affected when an issue in content propagates and is discovered too late in the flow. In this illustration, ingested content has some I frames with block error. Block error may have been introduced during digitization. This issue is not detected at ingest. When content is finally transcoded to MPEG-2 video, the block error in I frames is propagated to the B and P frames. The content, of course, is not ready for playout. The error trace leads to the ingest stage affecting efficiency and delivery.

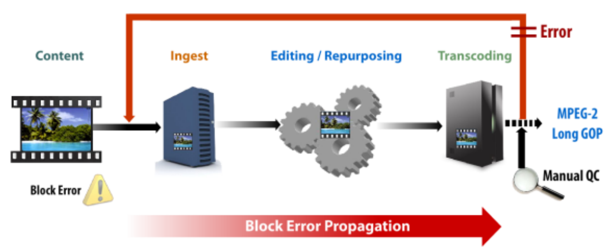

Figure -2

Quality Issues in Digital Content

Quality issues can be broadly classified into: regulatory issues, user experience issues, high-level facility/workflow requirements, standards conformance issues, and encoding errors.

Regulatory Issues

Regulatory standards are newly emerging requirements in content specification and mandatory in some countries, such as Japan and UK. Regulatory issues cannot be easily detected or measured through manual QC.

For example, rapid scene changes and sudden transitions in luma and red color, or regular patterns are potentially harmful to people who are prone to Photo Sensitive Epilepsy (PSE). Manual QC cannot detect flashy video until a person is affected by PSE. Again, the level of disturbance caused by flashy video may vary from person to person. There are ITU recommendations, which describe specific objective measurements for detecting harmful flashes. ITU-R BT. 1702 specifies how harmful flashes can be detected and how a video can labeled as flashy. Similarly, high pitches in ad inserts can irritate viewers. So ITU-R BS.1770 specifies audio loudness limits and a measure to check audio loudness.

User Experience Issues

There are several user experience issues, which may or may not be detected with manual, visual QC. Blockiness may be present due to low bit rate coding. Blockiness may also be present due to the encoding equipment's rate distortion algorithms. Processing of video content through different filters may add blurriness. Combing artifact may be present in high motion interlaced sequences. Transcoders may transform encoding errors into perceptual errors. For example, missing or misplaced slices (encoding errors) after transcoding may be converted to perfectly valid bit streams containing stripe errors. Freeze frames may occur due to video capturing issues, or when encoders may drop some frames to meet bit rate objectives. Field dominance may be present at places where video sequences with different field orders are stitched together.

Some user experience issues cannot be detected with manual or visual QC. These include issues such as color gamut issues or video signal level issues. However, these issues affect the user experience.

It is possible to check these artifacts programmatically. Let us look at video first. The general strategy works as follows. The video essence is fully decoded into base-band (uncompressed) and pixel values are examined for presence of visual artifacts. Blockiness can be measured by looking at pixel value differences at block boundaries. All the frames in a sequence can be characterized by their blockiness index and segments can be easily identified where the blockiness level is beyond a user-defined threshold. Color gamut is measured by counting the number of pixels whose values go beyond the permissible limits in the specified gamut. Users can specify maximum acceptable percentage of out of gamut pixels. Pixelation is detected if the amount of detail in specific parts of a frame is missing. Similarly for audio, audio samples can be averaged out to measure level and loudness. Left and right channel samples can be compared to measure level and phase mismatch. Spectral analysis of audio samples can help in identifying the presence of specific kinds of noises like transient noise. Similar techniques exist for objective measurement and detection of a wide variety of audio and video perceptual defects.

Meta Data (Workflow) Requirements

There are specific requirements for ingest or delivery at a particular facility. This can vary from one facility to different facility and also depend upon the kind of facility (e.g. post houses vs. broadcasters). A post house may be required to submit content to its customers with specific requirements. E.g. the audio content may be required to be in a specific format (PCM, FLAC), at a specific resolution (16-bits per sample), at a specific sample rate (44.1 KHz). Video content may be required to have characteristics, such as MPEG-2 main profile, 4:2:0 chroma sampling, ITU-T BT-601 color space, minimum bit rate 15Mbps, Long GOP, 640 fixed horizontal dimension, 1:1 pixel aspect ratio, 29.97 FPS. Such requirements are defined by broadcasters or content distribution networks and post houses are required to comply with it. Manual checking of these parameters is tedious, while an automated QC solution can parse the digital media data, look at the corresponding parameters in the file and verify them against the specifications quickly and easily. Similarly, when broadcasters release their content over cable networks, they must make sure that their content meets the requirements of the set top boxes on which the content is required to be played.

A related problem is ensuring correctness of meta data associated with content. There are two kinds of meta data. Structural meta data is for machine consumption. It includes information such as encoding used to compress video, audio, aspect ratio, resolution, presence of AFD, teletext. Descriptive meta data is for humans to read, e.g. Title, cameraman, producer. Meta data may be stored separately in XML files or databases or it may be embedded inside the content (as in MXF files). An automated QC solution can easily verify correctness of structural meta data. It can identify any discrepancies in meta data and report it. A QC solution integrated with CMS may also update structural meta data with corrected values. Descriptive meta data is usually examined and corrected manually.

Let us look at an example where a video with jitter motion is played out due to meta data error. A DV interlaced file (SD DV is bottom field first) is ingested to a workflow. The trascoded playout required is MPEG-2 in top field first display order. The captured DV video is bottom field first. The transcoder receives incorrect meta data in the picture header, which specifies Top Field First. The final display order is affected leading to video jitter as depicted in Figure 3. A QC solution could have analyzed the sequence of frames and determined whether the original content was top field first or bottom field first or progressive (by looking at the pixel values). The QC solution could then check the correctness of field order meta data associated with the content against the actual field order information inferred from content. An application/system could then be triggered to correct the field order meta data or reject the whole content.

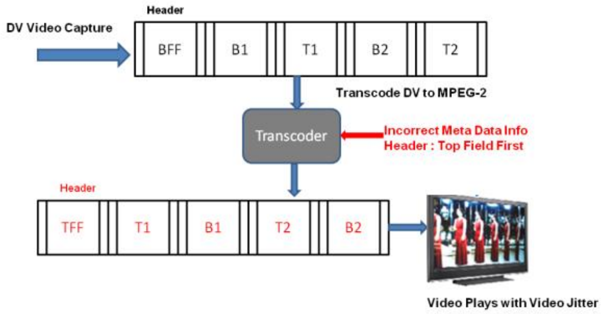

Figure - 3

Let us look at another example where incorrect AFD (Active Format Description) meta data can result in faulty upconverted video. AFD meta data is required at upconversion or down conversion. Typical SD to HD conversion or display of SD content on HD monitors may happen in one of following ways:

1. Full resolution content is mapped to HD by adding pillar boxes

2. 16x9 anamorphic content is mapped to HD by expanding the content back to 16x9 space

3. 16x9 letter box content is mapped to HD by removing the top and bottom bars and dislaying the content only

2 and 3 are possible only if the conversion / display process is AFD aware and AFD flags are present indicating the fact that SD content is either 16x9 anamorphic or 16x9 letter box. This is done when AFD information describing how the SD content is laid out is present and the conversion/display process is AFD aware.

If AFD information is missing or incorrect, the following could happen:

1. 16x9 anamorphic content is made worse by adding piller boxes around it

2. 16x9 letter box content becomes a postage stamp content by adding further pillar boxes to it as depicted in Figure 4

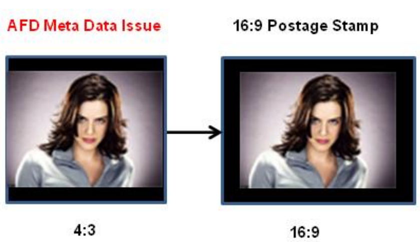

Figure - 4

To handle AFD issues, a QC solution can be used to determine the presence of black bars. If AFD information is not present, the QC report can be used to identify the right AFD and assign it with content. If AFD information is present, the QC solution can be used to verify its correctness and in case of error, AFD information can then be corrected.

Encoding Errors

Encoding errors are introduced by problems in the audio/video encoding or transcoding equipment. They may also be introduced by transmission channel if some media data gets lost or corrupted during transfer. Consider the picture below.

In the picture, we can see that data for a specific macroblock in the picture seems to have been copied in the top left and the macroblock in the middle seems to have been blackened. Detailed analysis of this video sequence reveals that a horizontal motion vector component was found to be out of picture boundary in the encoded video data, which resulted in this error.

Here is another picture.

In the above picture, macroblock vlc code could not be decoded for the first macroblock in the first slice of the picture. Thus, the whole slice is corrupt. Interestingly several decoders have error concealment techniques built-in, and they may hide such errors during playback. Whereas an automated QC solution will go through all the bits of media content and diligently find all kinds of encoding errors and report them. A QC solution doesn't require any error concealment strategy. Rather, we expect it to be designed with error revealing strategies.

Standard Conformance Issues

Digitally encoded media data contains lot of structures (video sequences, access units, pictures, slices, macroblocks, blocks, sequence headers, picture headers, macroblock headers, PES packets, transport packets) Different standards define how these structures are to be organized and interpreted in a media bit stream and what are the semantically valid values in these headers. Incorrect values may lead to problems in decoding and using the media data later. Here are some examples: The profile or level fields in an H.264 sequence parameter set may be invalid. Reference picture parameter sets or sequence parameter sets may be missing. The address of a coded macroblock may be beyond the allowed range in a picture. The cropping parameters may be incorrect. Adaptation fields inside transport packets may be incorrectly encoded. Continuity counter in transport packets may not be properly maintained. Apart from this, there may be several constraints on the size of data. E.g. an H.264 NAL unit may be too large for a given H.264 profile and level. The video data may not be conformant with coded picture buffer conformance model leading to situations where it may not play well on memory constrained devices. These errors cannot be detected by manual inspection and require sophisticated QC tools which have complete support for standards compliance.

Broad Requirements of an Automated QC Solution

As stated before, content verification or QC is a multi-point process to ensure content readiness throughout the content lifecycle. This means a QC solution must be able to handle all aspects of quality checking specific to every stage across the content lifecycle. This includes planning, formats, checks, workflow integration, and much more.

QC Planning Process

Different stages in content life cycle require different kinds of content checks. The QC solution should take this into account and provide flexible mechanisms for setting up different kinds of test specifications at different stages or for different types of content.

The solution should provide ways to select the essence and container formats for which the tests are being performed. The solution should also provide ways to select specific perceived video/audio quality checks as deemed required at different stages in the content life cycle. In addition, the solution should provide ways to specify facility specific requirements at different stages in workflow. It should also be possible to exchange these specifications between different deployments of such a QC solution so that multiple workgroups possibly spread across multiple sites or organizations can benefit from well-developed test specifications.

Workflow Integration

QC solutions should provide easy hook for integration into a workflow. The QC solution maybe loosely coupled with workflows or maybe tightly integrated with MAM systems or workflow engines. A tight integration requires API support for programmatically controlling Baton inputs, job and outputs handling The QC solution should provide effective notification support in form of email alerts and/or TCP/UDP based alerts.

Extensive Format Support

The number of digital media formats (essence containers, exchange formats, essence formats) has increased significantly. Some formats are wide spread while some formats are applicable to niche domains. The QC solution is expected to provide support for all these formats.

Extensive Checks Support

Different stages in the workflow introduce specific errors. A comprehensive QC solution is expected to provide support for workflow specific issues. In addition, the solution should provide support for regulatory issues.

Universal Content Access

There are a wide variety of content servers in use in different facilities. A particular facility grows its infrastructure over time and this naturally leads to different kinds of content servers existing within the same facility. The QC solution is expected to provide support for all these content servers to access content. These include different flavors of FTP servers, dedicated video servers like Omneon, SeaChange etc., UNC based access from servers like Avid Unity ISIS, to name a few.

Scalability and Availability

As content organizations grow, the amount of content to be verified keeps increasing. The QC system should be scalable with the hardware resources so that more verification capacity can be achieved easily. In addition, the QC solution should be available as a service, which is accessible to any agent (human or machine) 24x7. Redundancy should be built so as to ensure that in case of software or hardware failures, the QC operations are not interrupted.

Throughput and Performance

It is crucial for the verification of individual files to be completed as fast as possible. The performance depends upon several criteria. Higher resolution and higher bit rate content usually takes more time to verify. More perceptual quality checks take more time. Some formats (like H.264) are more complex (c.f. DV), so they take more time to verify. While it is usually possible to verify

SD content on a single core, HD requires much more effort. QC system should be designed to take advantage of recent multi-core machines by parallelizing verification work on available cores. Moreover, the system should be designed to verify multiple files in parallel by adding more hardware to the system. Guiding the users to define the right level of testing for a given content can also help speed up content verification or QC. Some QC solutions already offer such guidance in their environment.

Meta Data Extraction

The QC solution should provide for ways to extract structural meta data from content as part of its content analysis report. It should fully examine meta data information available at the wrapper and essence levels and report any discrepancies found between the two. If meta data is placed in other sources (like associated XML files), the QC solution should provide ways to include them in content verification process. It should be possible to use this information to update meta data in the CMS or embed the information in the content with correct values.

Independent and Objective QC

The QC solutions should be able to verify content independent of workflows or tools that transform the content. They should provide objective reports of the content quality that are again independent of any biases to a specific workflow or a tool.

Challenges in Automated QC

The challenge for automated QC solution lies in ensuring the continuity of the solution. There is a constant evolution of content formats and technologies used in the workflow. The QC solution needs to constantly upgrade itself meet the quality requirements of new formats. More so, the QC solutions constantly need to be in sync with the quality issues introduced by new technologies or methods of content production/editing. With the splurge of content generation techniques and several regulatory standards being evolved, the QC solutions needs to constantly be on an evolutionary path.

If automated QC is expected to be integrated as a continuous process in a workflow, the solution needs to integration ready for various kinds of workflows and technologies used in the workflow.

Error reporting is a major challenge. The QC solution is expected to accurately report all errors and warnings found inside a media file during verification. Not all computer algorithms can be deterministic in detecting quality issues on real world audio-visual content. There are two kinds of issues, which may arise with the results generated by the QC system: false positives and false negatives. A false positive happens when an error is reported which doesn't really exist. E.g. blurriness may have been introduced on purpose in some shots, which gets detected as an error by a QC solution. An operator on looking at error details may choose to ignore such an error. A false negative happens when an error, which exists in the content, doesn't get reported. This is not acceptable since the error passes through the automated workflow and nobody gets to know about it. Error detection algorithms in the QC system should be designed with a conservative approach. They should avoid false negatives while a limited number of false positives should be manageable once in a while.

Conclusion

Automated QC is a continuous process to ensure content readiness across file-based workflows. Content readiness impacts operation efficiencies. Not all content quality issues can be detected by manual, visual QC. Hence, there is a need for an automated QC. A comprehensive QC solution should support extensive formats, quality checks, objective and independent verification, enterprise scalability, high availability Continuity of automated QC also requires accurate results, integration with other technologies, and evolution in step with the industry trends. Automated QC is a mainstream requirement today and companies involved in content supply-chain are adopting the QC solutions as a means to improve their content quality as well as to improve their operational efficiencies.

References

1. Professional content management systems, Handling digital media assets; Andreas Mauthe, Peter Thomas; John Wiley & Sons, Ltd; 2004
2. ISO/IEC 13818-1 and ISO/IEC 13818-1:2000/Final Draft Amendment 3ISO/IEC 13818-1(MPEG-2 Systems)
3. ISO/IEC 14496-10, Advanced video coding for generic audiovisual services
4. ISO/IEC 13818-7:2006 Information technology -- Generic coding of moving pictures and associated audio information -- Part 7: Advanced Audio Coding (AAC)
5. WAVE PCM sound file format
6. BT.1702 : Guidance for the reduction of photosensitive epileptic seizures caused by television, ITU-T, 2005
7. Baton 3.0 user manual (www.interrasystems.com)