HDR Production
Tone Mapping techniques and Round-Trip conversion performance

Set Expo 2023
August 2023

José Filipe Ferraz Valente
For decades, video production had one target: The STANDARD DYNAMIC RANGE (SDR) reference monitor.

The introduction of HIGH DYNAMIC RANGE (HDR) offers new perspectives, with greater freedom and flexibility in content creation.

For **live video production**, HDR comes with some new challenges:

- to master the capabilities of an **expanded creative palette**,
- to execute **careful tone mapping**, accommodating disparate sources and workflows,
- to **deliver the best image** possible with no alteration of the artistic intent.
Plan

Tone Mapping in Live Production

SDR-HDR-SDR round-trip using dynamic solutions

SDR-HDR-SDR round-trip conversion performance
Plan

Tone Mapping in Live Production

SDR-HDR-SDR round-trip using dynamic solutions

SDR-HDR-SDR round-trip conversion performance
The need for Luminance conversion:

**HDR production** => 4000 cd/m^2 or 1000 cd/m^2
Peak Luminance with very deep blacks (< 0.01 cd/m^2)

**SDR production** => 100 cd/m^2 Peak Luminance

**Consumer display (TV / mobile)** => large disparity in Peak Luminance and dark management

The solution: Tone Mapping
Tone Mapping in Live Production

The need for mixing content in Live HDR Production:
ITU-R Rep. BT.2408 defines Reference levels:

HDR Reference White, a.k.a HDR Diffuse White is prescribed as 203 cd/m² meaning:

- Primary scene with details in [0..203] cd/m² range
- Speculars: very bright pixels with few details above 203 cd/m²

=> Limitations in the creative process

ITU-R Rep. BT.2408 Annexes 1 and 2 (analysis of produced HDR content):

- 203 cd/m² HDR Diffuse White as a nominal value is relevant
- Large HDR Diffuse White variance [44-735] cd/m² depending on the content

=> HDR Diffuse White should be dynamic and adaptive with the content
The need for perceptually identical SDR-HDR-SDR Round-Trip:

A native SDR content undergoes two successive conversions:

1. Tone expansion to create the HDR program
2. Tone compression to create the SDR feed

Commercials and logos are very sensitive => look & feel and colors should be preserved

=> Round-Trip needs to guarantee artistic intent of the SDR content
Tone Mapping: the need for care

Not all the details captured in 4000 cd/m² HDR creation can be displayed on a 650 cd/m² HDR display, nor can they be maintained in a calibrated 100 cd/m² SDR stream.

Most video content is a succession of very different images => pertinent details will be found concentrated along varying portions of the luminance axis.

How do you ensure that details important to storytelling survive as tone mapping is applied, whatever their placement on the luminance axis of the native HDR image happens to be?
Tone Mapping in Live Production

Static Tone Mapping

**PROS**
- Conversions are fixed and well-known
- Reproducible
- Invertible: OK for Round-trip
- Easy to implement in 3D-LUTs

**CONS**
- No adaptation to the content => no focus on concentration of details
- Constraints on HDR creation: Fixed Diffuse White (e.g. 203 cd/m²) and only one Tone Mapping curve => limited freedom
- Round-trip: need to ensure that the correct counter-party are used
Dynamic Tone Mapping
Adaptation to each image => preserve details where needed

No need to fix reference levels => no restriction on HDR creative process

Colorists have graded SDR and HDR versions of content for years now => ability to use AI driven solutions
Tone Mapping in Live Production

Live HDR workflows constraints – Video operator needs

• Adjust settings for every camera and every scene / conditions changes => **Dynamic** Tone Mapping is a great help

• **Real-time** processing tools

• Ability to control the aesthetic choices => **Tunable** solutions

• Ensure that successive conversions preserve the artistic intent => **Imperceptible Round-trip**
Plan

Tone Mapping in Live Production

SDR-HDR-SDR round-trip using dynamic solutions

SDR-HDR-SDR round-trip conversion performance
SDR-HDR-SDR round-trip using dynamic solutions

One system based on dynamic conversions under study: Advanced HDR by Technicolor®

Consists of two principal tools:

• **Technicolor HDR ITM** (Intelligent Tone Management, named ITM in the following): upconverts SDR to HDR => the **tone expansion** tool

• **Technicolor SL-HDR** (named SL-HDR in the following): delivers a single layer output stream with dynamic metadata for presentation on any display:
  • SL-HDR1: SDR base layer with dynamic metadata (ETSI TS 103 433-1)
  • SL-HDR2: HDR10 base layer with dynamic metadata (ETSI TS 103 433-2)
  • SL-HDR3: HLG base layer with dynamic metadata (ETSI TS 103 433-3)

=> SL-HDR1 is the **tone compression** tool
SDR-HDR-SDR round-trip using dynamic solutions

Round-trip feature

• Coupling ITM and SL-HDR using SL-HDR1 metadata
  • ITM applies a dynamic tone expansion curve that is specified in the SL-HDR1 metadata
  • SL-HDR applies the corresponding inverse tone compression curve specified in the SL-HDR1 metadata

=> Preserves full flexibility on HDR content creation and guarantees that the SDR-HDR-SDR round trip is perceptually identical
Plan

Tone Mapping in Live Production

SDR-HDR-SDR round-trip using dynamic solutions

SDR-HDR-SDR round-trip conversion performance
SDR-HDR-SDR round-trip conversion performance

Test set-up: compute objective metrics between Source SDR content and output SDR

For each content, 3 different HDR grades are used: one Dim grade, one Medium-balanced grade and one Bright grade
SDR-HDR-SDR round-trip conversion performance

Test content

2 SDR test patterns (Sarnoff / SRI International) for characterization

1 SDR video for testing in real conditions: “ASC StEM2: The mission”

1 StEM2 – Copyright 2022 – American Society of Cinematographers – All rights reserved.
SDR-HDR-SDR round-trip conversion performance

Objective metrics

• Test patterns: ΔEITP metric defined in ITU-R Rec. BT.2124
  ΔEITP below 1 ensures that the color difference is not visible
  ΔEITP just above 1 does not mean that the color difference is visible

• Video: based on PSNR as defined in ITU-T Rec. J.340:
  Weighted average \( \text{PSNR}_{\text{YUV}} = \frac{6 \times \text{PSNR}_Y + \text{PSNR}_U + \text{PSNR}_V}{8} \)
  \( \text{PSNR}_{\text{YUV}} \) above 45 dB means imperceptible difference
SDR-HDR-SDR round-trip conversion performance

ΔEITP metric results on ColorChip test pattern

⇒ color difference for the 24 patches is not perceptible or hardly perceptible whatever the HDR grade
SDR-HDR-SDR round-trip conversion performance

$\Delta$EITP metric results on Yellow Brick Road test pattern

→ color difference for the 624 patches is not perceptible or hardly perceptible whatever the HDR grade
SDR-HDR-SDR round-trip conversion performance

$$\text{PSNR}_{YUV} = \text{metric results on video content}$$

$$\Rightarrow$$ difference between the source video and the output video is imperceptible whatever the HDR grade
Conclusion

HDR live production is in its early years and represents a big challenge

Need for **Tone Mapping** tools that are **dynamic**, **AI-driven**, **tunable**, and with **imperceptible Round-trip** performance

The round-trip performances of a system handling all these features, the Advanced HDR by Technicolor suite, have been analyzed

The **round-trip** feature exhibits results that are **objectively imperceptible** on both challenging test patterns and real video content

=> Demonstrate a “no compromise” round-trip feature applicable to live-TV and post-production operations, ensuring that flexibility in HDR content creation and conversion processes do not alter the original creative intent of SDR sources
Thank you!

Advanced HDR by technicolor

PHILIPS

interdigital.

www.advancedhdrbytechnicolor.com

Josefilipe.ferrazvalente@philips.com