High Dynamic Range Television (HDR-TV)

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Outline of the talk

• What is HDR?
• Parameters of Video quality
• Human Visual System relation to Video
• Colour gamut
• Opto-Electrical & Electro-Optical Transfer Functions
• Perceptual Quantizer
• Hybrid Logarithmic Gamma function
• Various HDR formats
• Which one will succeed?
How does a normal TV in a stadium look like?
We like to see it like this!
Display parameters defining video quality

• Luminance
• Contrast
• Colour
  • In CRT
    • 0.1 < Lum < 100 nits
  • In LCD
    • 0.001 < Lum < 1000 nits

But Colour remains the same as BT. 709 standard

HSV
Luminance range of CRT vs LCD
# Human Vision response to Luminance Dynamic Range

<table>
<thead>
<tr>
<th>Luminance Levels [cd/m²]</th>
<th>Luminance Value</th>
<th>Real World</th>
<th>Human Vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun Direct</td>
<td>$10^9$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sun light</td>
<td>$10^6$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor light</td>
<td>$10^4$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moon light</td>
<td>$10^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Star light</td>
<td>$10^{-2}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$10^{-6}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Day Vision**: Typical Range w/o adjustment $\approx 10^5$
- **Night Vision**:
Impact of Contrast on Picture resolution

Pelli-Robson chart:
Impact of contrast on resolution
Scene of objects with various light intensity
Opto-Electric/Eletro-Optic Transfer functions in Normal TV

- At display: Electro-Optic Transfer Function: EOTF
- At the camera: Opto-Electric Transfer Function: OETF
- System Transfer Function= Opto-Optic Transfer Function= OOTF
HDR/SDR Luminance response

![Graph showing luminance response for Standard Dynamic Range Image and High Dynamic Range Image.](image-url)
Comparison between BT.709 /BT.2020
Barten Ramp: Quantization Noise visibility @ 0.1 – 100 Nits
Contouring Noise

8-bit (up to 256 samples)  10-bit (up to 1024 samples)
Human Visual Colour Response
CRT vs LCD colour response

CRT

LCD
CIE-Diagram
709/2020
Luminance and Colour
BT.709/BT.2020
Cumulative distribution functions for a. black stimuli, b. reflective white stimuli and c. emissive and highlights. For comparison, the dynamic ranges of common displays are given.
Emissive light sources, specular reflections, and diffuse white
Opto-Optical Transfer Function (OOTF) = Systems transfer function

System transfer function for CRT

$$\text{OOTF}_{\text{SDR}} = \text{OETF}_{709} \times \text{EOTF}_{709}$$

System transfer function for LCD

$$\text{OOTF}_{\text{SDR}} = \text{OETF}_{709} \times \text{EOTF}_{1880}$$

System transfer function for HDR

$$\text{OOTF}_{\text{HDR}} = \text{OETF}_{\text{PQ}} \times \text{EOTF}_{\text{PQ}}$$
Perceptual Quantizer

Contrast step size vs. display luminance for 12 bit signals

- Visual Difference Threshold
- 12 bit BT.1886 - 100 cd/m²
- 12 bit BT.1886 - 10,000 cd/m²
- 12 bit PQ - 10,000 cd/m²

Contrast step [N] vs. Luminance [cd/m²]
## Metadata

| Video standard | HEVC  
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Main 10 Profile/ Main Tier/ Level 5</td>
</tr>
<tr>
<td>HDR Info</td>
<td>UUID:-427fcc9bb89248219561c292e3a1fd3</td>
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<tr>
<td></td>
<td>Mastering display color primaries:</td>
</tr>
<tr>
<td></td>
<td>R:x=(0.708)y=(0.292)</td>
</tr>
<tr>
<td></td>
<td>G:x=(0.17)y=(0.797)</td>
</tr>
<tr>
<td></td>
<td>B:x=(0.131)y=(0.046)</td>
</tr>
<tr>
<td></td>
<td>White point:x=(0.3127)y=(0.329)</td>
</tr>
<tr>
<td></td>
<td>Mastering display luminance:</td>
</tr>
<tr>
<td></td>
<td>Min:0cd/m2,</td>
</tr>
<tr>
<td></td>
<td>Max:1000cd/m2</td>
</tr>
<tr>
<td></td>
<td>Maximum Content Light Level(MaxCLL):800cd/m2</td>
</tr>
<tr>
<td></td>
<td>Maximum Frame-Average Light Level(MaxFALL):400cd/m2</td>
</tr>
<tr>
<td></td>
<td>Color primaries:Rec. ITU-R BT.2020</td>
</tr>
<tr>
<td></td>
<td>Transfer Characteristics:SMPTE ST 2084</td>
</tr>
<tr>
<td></td>
<td>Matrix Coefficients:ITU-R BT.2020 non-constant luminance system</td>
</tr>
</tbody>
</table>
Opto-Electrical Transfer Function
Opto-Optical Transfer function
Display mapping
Hybrid Log-Gamma (HLG)

Comparison of SDR and HLG HDR OETFs

- SDR gamma curve
- SDR gamma with knee
- HDR Hybrid log-gamma
Conversion between PQ and HLG
Comparison between OETF of PQ/HLG
Dolby vision HDR

- ITU-R BT.2020 colour diagram
- 12 bit Perceptual Quantizer (PQ)
- Adaptive (frame by frame) metadata (can also be static)
- Is not free
- Applications: UHD-HDR on Blue-Ray & Streaming
- With 12 bits it can produce 10,000 nits, but in practice is about 4,000 nits
- Supporters: 4k-HDR manufacturers; LG, TCL, Vizio
Hybrid Logarithmic Gamma HDR

- Hybrid Logarithmic Gamma (HLG) quantizer
- ITU-BT 2020 Colour diagram
- 10 bit resolution
- BBC and NHK Joint work
- Compatible to SDR (EOTF is similar to SDR up to 100 nits) (note: new LCDs also use BT.2020 colour, specially UHD-TV)
- No metadata
Other standards

**HDR10**
- ITU-R BT.2020
- 10 bit colour
- PQ
- Fixed Metadata
- Supported by: Dell, LG, Samsung, Sharp, Sony, Vizio, Microsoft and Sony

**HDR10+**
- ITU-R BT.2020
- Could be more than 10 bits
- PQ
- Metadata change fr/fr
- Supported by Samsung and Amazon (free)
Single Layer Directly Standard Dynamic Range = SL-HDR1

- Also called advanced HDR
- It sends SDR + supplement Enhancement Information for HDR (supported by H.264 and H.265)
- Easy compatibility with SDR
- Also supported by ETSI in 2016
- Supporters: STMicroelectronics, Philips, CableLabs & Technicolour research Centre (France)
Transmission of Quality Scalable HDR
Transmission of SL-HDR1
Relative Bandwidth Demands Of 4K, HDR, WCG, HFR

Bandwidth Increase

- 4K UHDTV
- High Frame Rate - 120FPS
- High Frame Rate - 60FPS
- HDR
- Color Gamut
- 10-Bit Bit Depth
4K-HDR Trial via Satellite

- 10 bit 4k-video
- HOTBIRD (13° East)
- Frequency: 12015 MHz
- Horizontal polarization
- Symbol rate: 30000
- DVB-S2, 8PSK, FEC 5/6
- HEVC encoding at 30 Mbit/s
- 2 Samsung receivers with 1000 nits (HDR and SDR)
Added Value

• Expected satisfaction from one TV format to another?
• Black & White to Colour TV (High)
• SD to HD (medium)
• HD to UHD (medium)
• HD to HD-HDR is higher than HD to UHD
• HD to UHD-HDR (high)
How to make HDR-TV successful

• Lessons learned from the failure of 3D-TV.
  • The main failure was lack of 3D content
  • They had to use up-converted 2D (worse than normal 2D)

• HDR and UHD are so mixed that one without the other is meaningless

• Broadcasters should now start producing UHD-HDR content (at least 5 years ahead of distribution/broadcast)

• Today, cost of 6 hours of 4K-HDR content is $300,000 more than HD production
HDR Studio Products

- Camera
  - Arri, Red, Panavision, Canon, Panasonic & Blackmagic Design
  - Sony UHD-HDR (HLG type) HDR: HDC-4800 & HDC-4300
  - Panasonic, UHD-HDR (10 bit, 1500 nits): EVA1
  - Canon (HLG type): C200, C300, C700

- Video Recorders:
  - Apple ProRes & Avid DNx
  - Canon Cine EOS family: C300MKII, C500
  - Panasonic: GH4, DVX200, Varicam 35, Varicam LT
  - Sony: FS7, FS700 & FS5
Editing

Adobe Premier Pro:
  BT.2020 colour processing

Mistika:
  Colour grading

DaVinci Resolve:
  Colour grading
Which HDR format?

• All 4 formats are under study by the standard groups
• Dolby vision:
  • Will be most used in Blue-rays
• HDR10
  • Most likely to be used in North America
• HLG
  • Most likely to be used in Europe and Asia
• SL-HDR1
  • Most likely to be used as format convertors
Images @ Sunset
4K Non-HDR

4K HDR