Trinity College Dublin
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Sigmedia
Signal Processing for Media Applications

Introduction to HDR Playback 4C8 2023

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* *Trinity College Dublin,*
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Loosely based on FOSDEM'23 Talk
4K HDR video with AV1 : A Reality Check
FOSDEM 2023

Who am I?

Vibhoothi

- PhD Student and Research Assistant@Trinity College Dublin (TCD), circa ~2020.
    - *Research on optimising video codecs for streaming and internet use-cases*.
- Involved in Open-source multimedia, circa ~2018.
    - *VideoLAN Association*, Xiph. org Foundation, and Alliance for Open-media (AOM).


What are we going to do today?


Main motivation is to talk about the technical challenges for optimal HDR playback !!

History of HDR Imaging

1850s -> Stacking multi-exposure images for extreme range of luminance - Gustave Le Gray (French Photographer).

This was for capturing both Sea and Sky at the same time.

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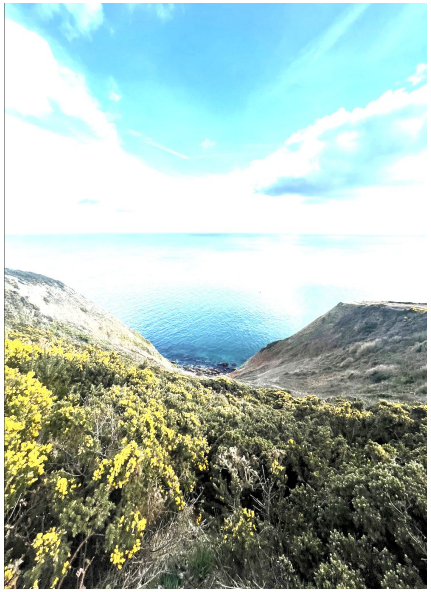
Idea is similar, capture multiple image with different exposures

Varying Brightness across the scene

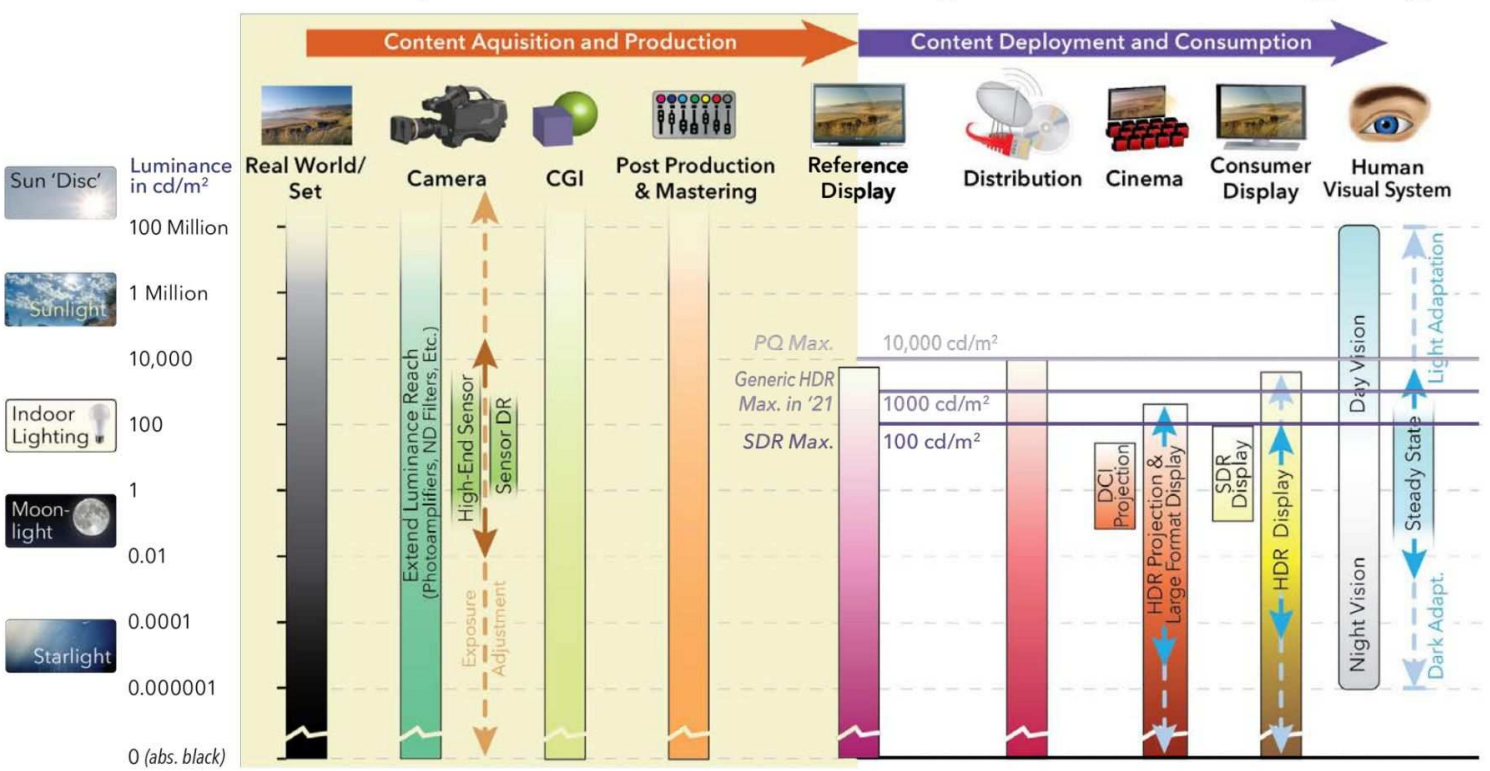


Single image with different lighting conditions during capture,
Problem here is, it is ***difficult to capture different lighting*** conditions correctly. Modern cameras including mobile photography is pretty good now!!

Somewhere in Howth in March 2023

This is due to the fact that, the real-world luminance is varying a lot, how much is it ->?

How bright are we talking



Dolby 2022

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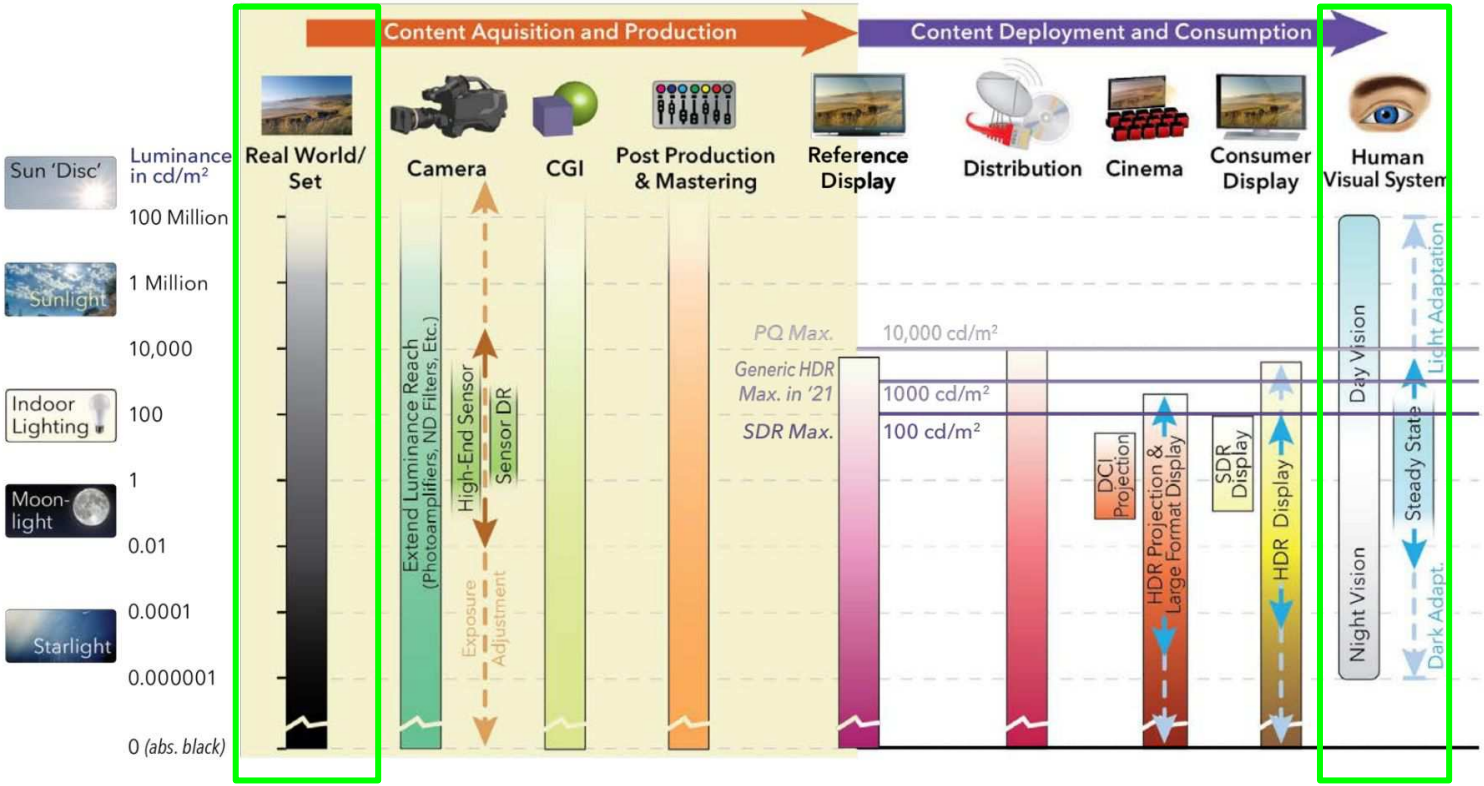

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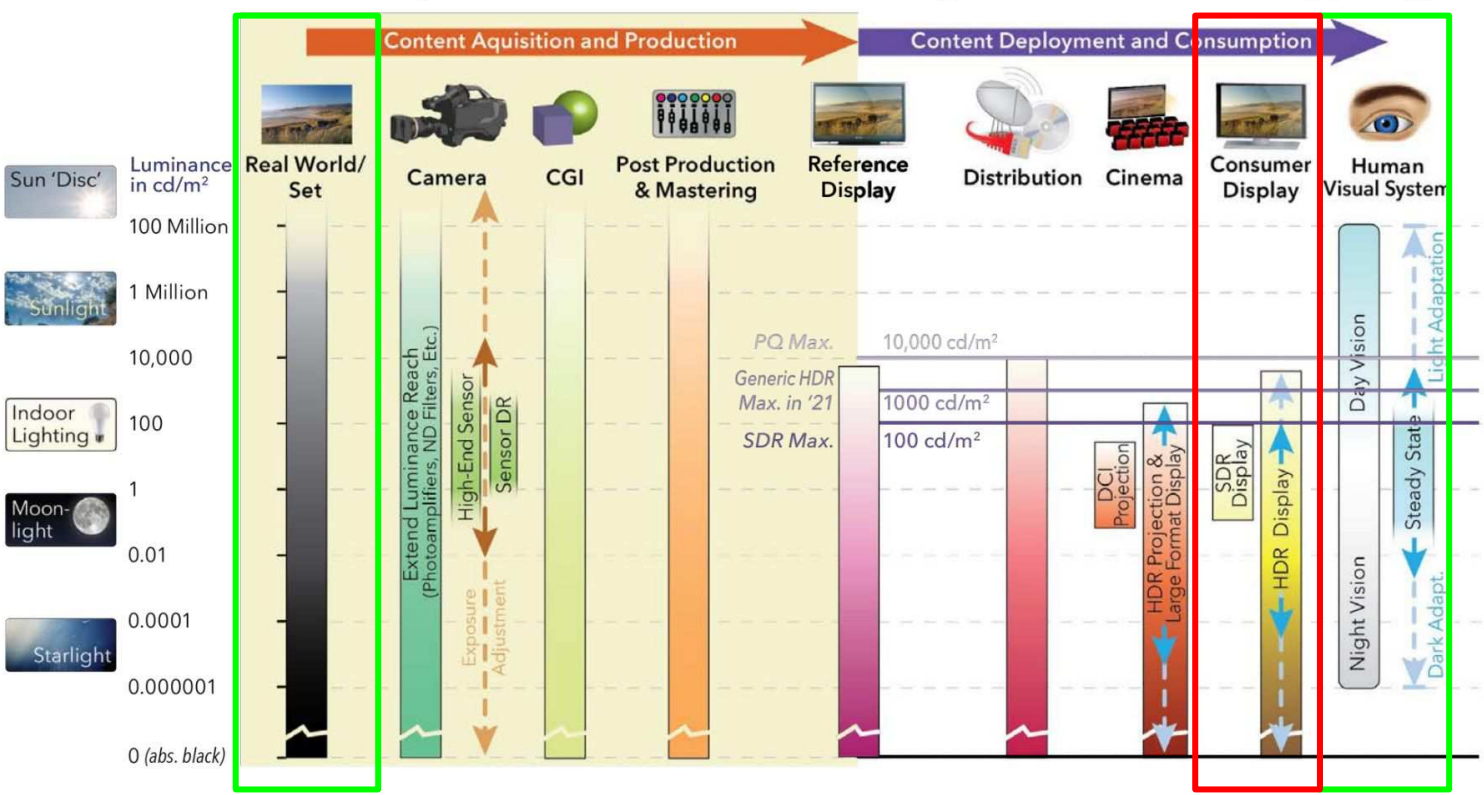
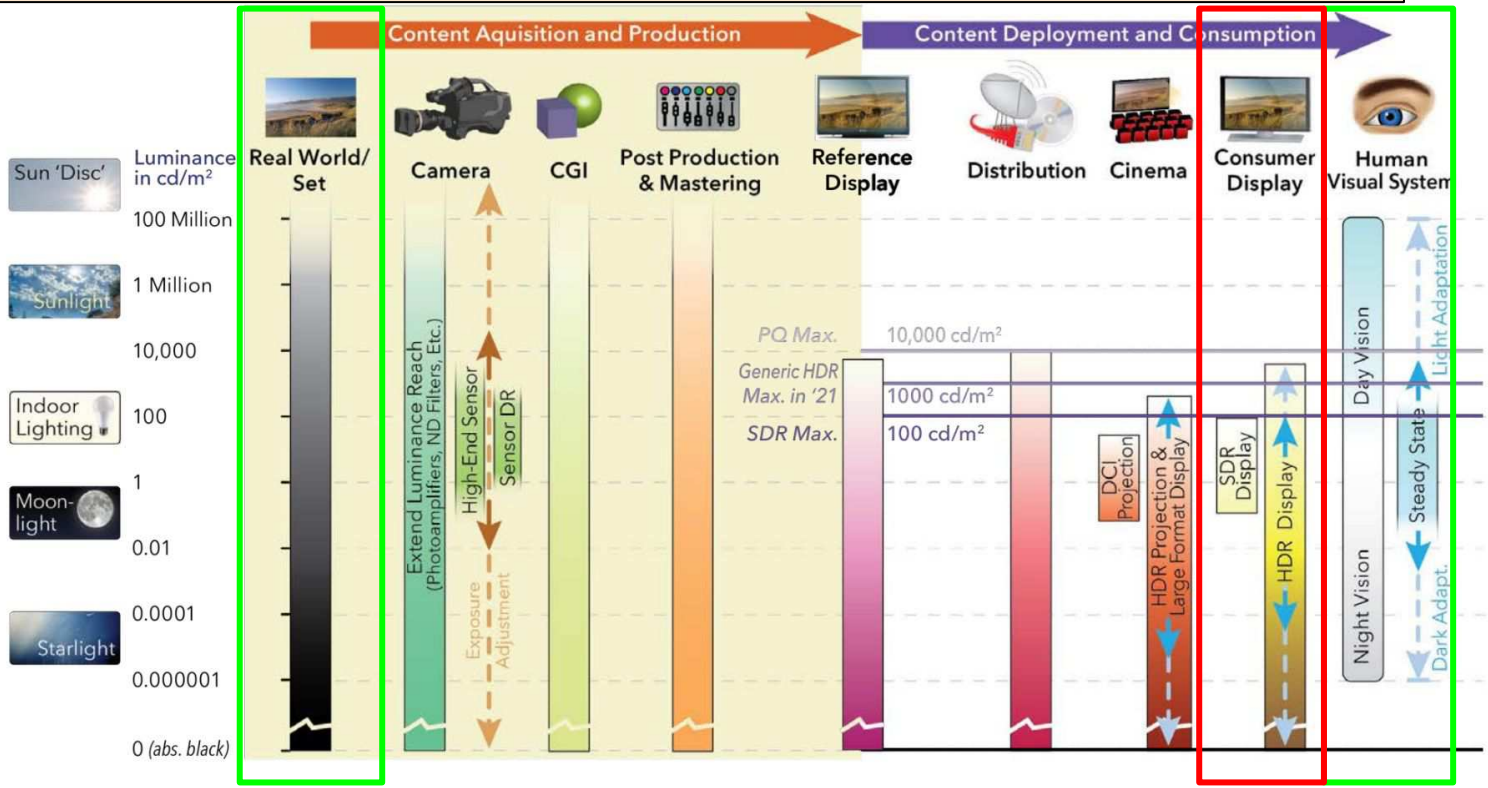


Dolby 2022

How bright are we talking

The range of brightness from real-world to your screen you see or your eyes you see is drastic!!



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In big-picture, HDR Imaging is stacking multiple images at different exposure. This is available in your smartphones.

History of HDR

Wet Plate Camera

1850s

iSight Camera for Dual exposure

1990s

Arri Alexa camera

2010s

History of HDR

Wet Plate Camera

1850s

iSight Camera for Dual exposure

1990s

Arri Alexa camera

2010s

2015

Sony Reference monitor

2016

Samsung TVs converts SDR to HDR

2021

Consumer level HDR OLED laptops

Introduction to modern HDR

Capture HDR -> It is working now
HDR Display Panels -> It is starting to be available now,

Now in modern production, HDR pipeline is with 4 elements,

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Capture HDR -> It is working now
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Now in modern production, HDR pipeline is with 4 elements,

1. ***Brighter Pixels***
2. ***More bits*** *(8bit->10+bits per channel)*
3. ***Standardised Transfer Functions:*** *For mapping captured values to display values (OOTF/EOTF etc)*
4. ***More Colours***

Sequence: sparks_aom_11198-11570, Luminance measured with JETI Spectravel 1511 Spectroradiometer on Sony BVM-X300 (1000 nits)

2. HDR = More Bits

SDR = typically 8-10 bits

HDR = typically 10+ bits

Visual representation of dynamic range

3. HDR = Different Transfer Function

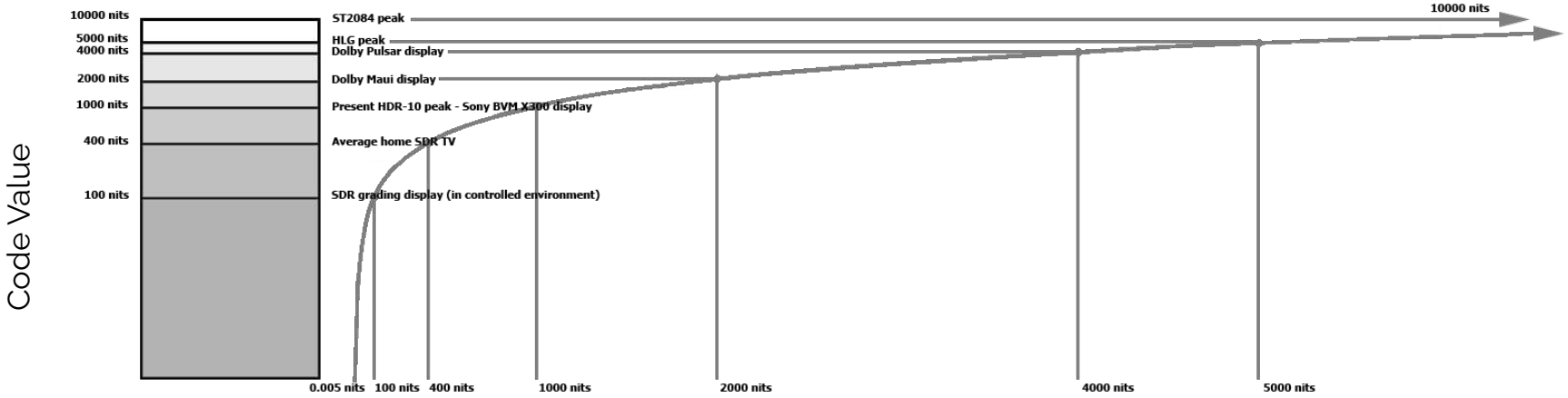
Now,

More Nits, More Bits…

Now,

Different mapping for Nits to Bits.

Black -> White, Modified Barten Model based on “banding” (“Perceptual Quantization” (PQ)),

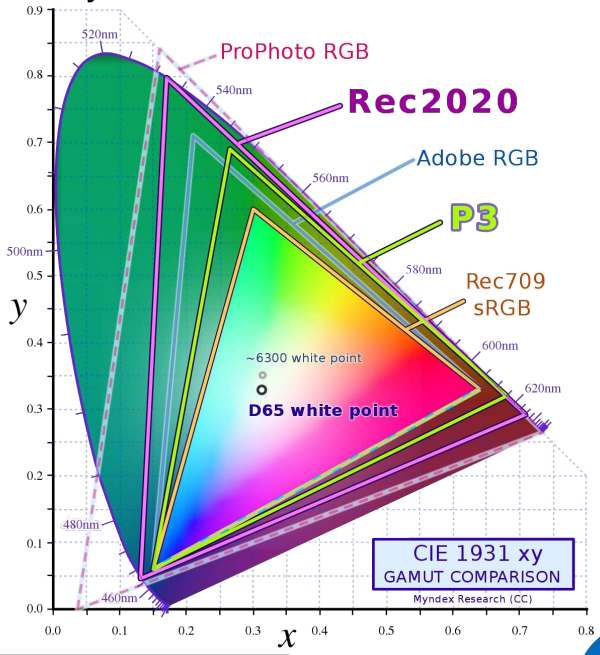


Source

4. HDR = Wider Gamut

The display technology have been improved since SDR standardisation (Rec 709). Rec.2020 proposed wider color gamut using primary colors closer to spectral locus.

BT.709 for SD TVs,
BT.2020 for UHD 4K, 8K HDR,
sRGB, *REDLog* for Post-production
CIE XYZ a perceptually uniform colour space



Wide Color Gamut (WCG.)

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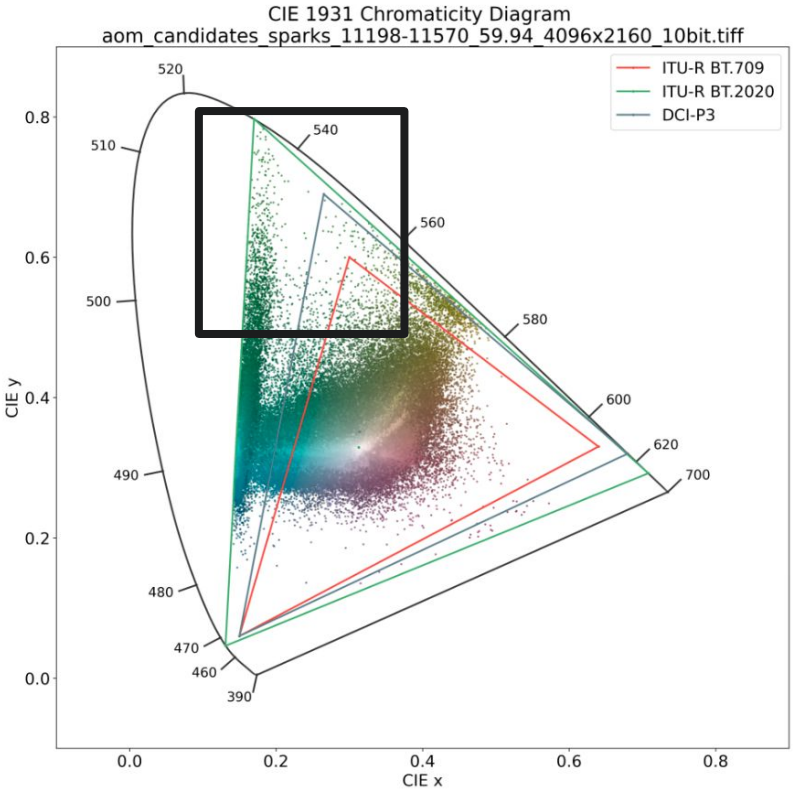
Reds *and* ***Greens****, have wider range,*
Blues*, do not change much.*



Wid… …(Wcg)

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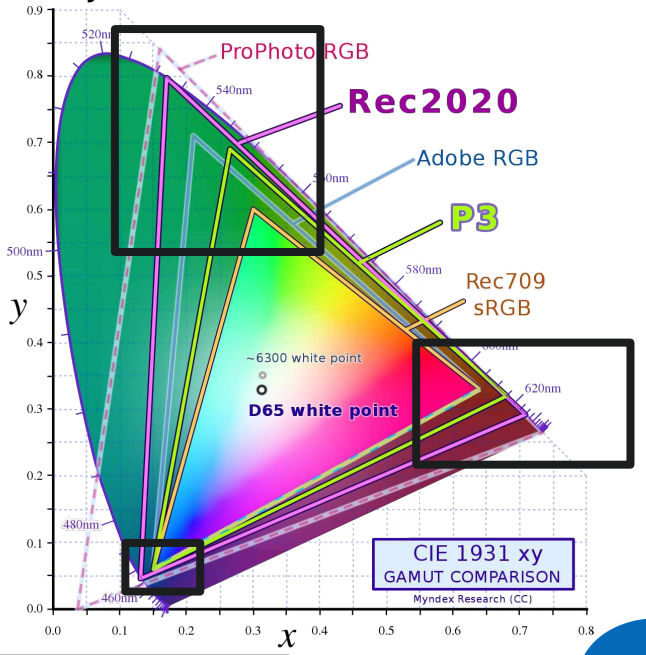

Wide Color Gamut (WCG.)

Video Codecs 101: HDR Encoding

Encoding process is **same** as any other videos in the **current** implementation, only difference is, for correct *playback*, we have to signal,

- *Color primaries*: BT.2020 (Color space)
- *Transfer characteristics*: SMTPE2084 (PQ)
- *Matrix coefficients*: BT.2020NCL (Non-constant Luminance)
- *Chroma sample position*: Colocated

Some encoders have *optional* flags (disabled by default) which can assign *different chroma quantizers* when these options are signalled.

What is the story here??

We want a **“subjective study”** for evaluating HDR compression.

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How do we know whether video is **actually HDR?**

Equipments you need now!

Reference monitor, Sony BVM-X300-V2 (32" OLED)

This is a **Gold** standard for picture quality.

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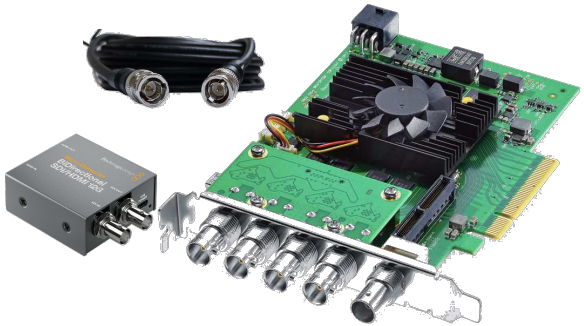
And video playback card, adapters, and cables to send the video signals to TV



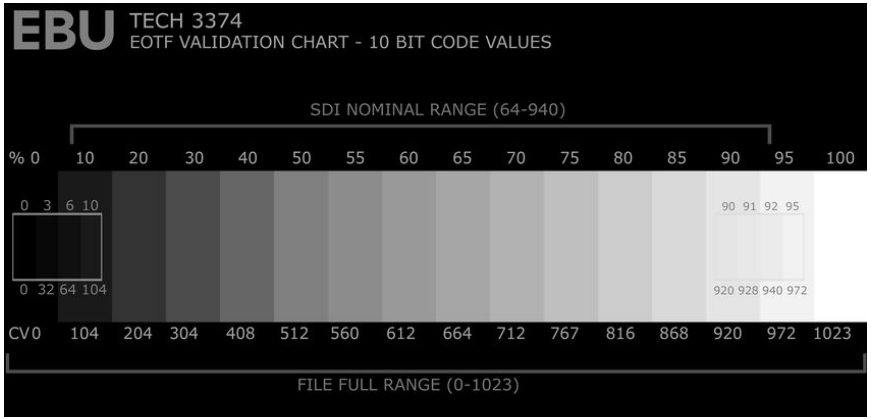
Playback of HDR: Scientific Testing

How to check if the HDR playback link respects REC.2100 standard?

Brightness

Conform using multiple methods,

- **Use a PQ EOTF Chart from EBU**

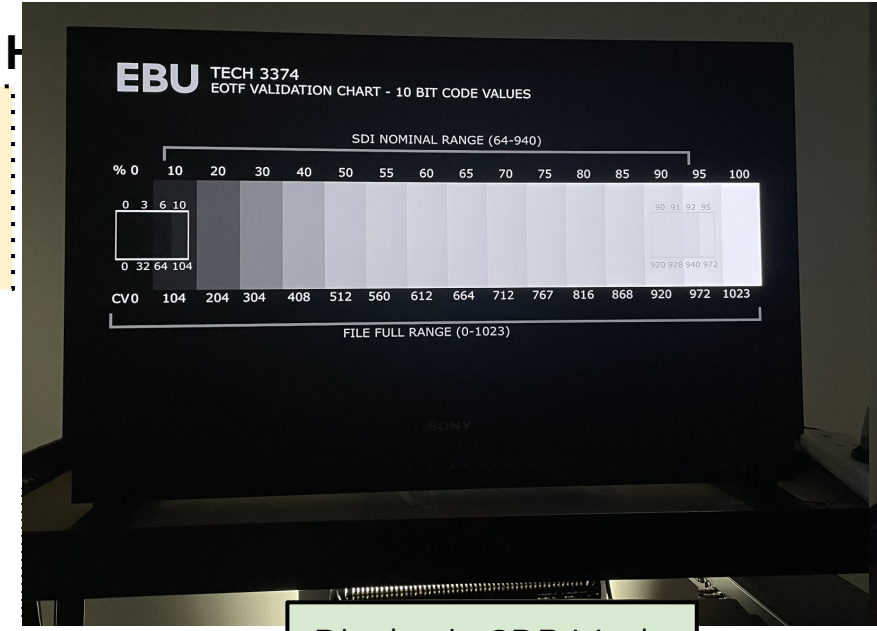


*This can help to **find the peak brightness**.*

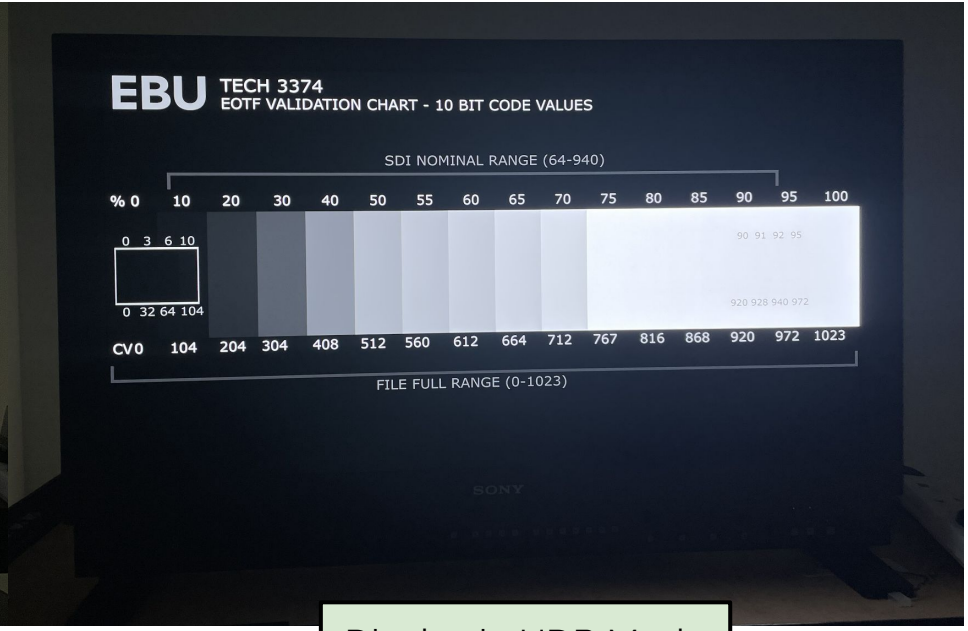
Peak Brightness of the TV is maximum light output (brightness) it can display

Playback of HDR: Scientific Testing

Brightness



Display in SDR Mode



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*HDR Displays: **Cannot display** full peak brightness **everywhere** in the display for long time (1. Energy savings, 2. Can harm the panel).*

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If you send a image with full brightness everywhere, then ***display will drop brightness*** *to 100 nits.*

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If you send a image with full brightness everywhere, then ***display will drop brightness*** *to 100 nits.*

So we need to ***know maximum area*** *that can display at peak brightness. So, the content will be* ***still****@HDR.*

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Signal

Conform using multiple methods,

- **Use HDR cross-converter monitor (Atomos Shogun 7) for pass-through of video to the TV**

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Signal

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*This can help to check **existence** of the **signal.***

Verify Cable and signal integrity, and check if the signal from source is reaching destination correctly.

Playback of HDR: Scientific Testing

How to check if the HDR playback link respects REC.2100 standard?

Brightness

Signal

COLOR

Conform using multiple methods,

- **Turn on Gamut Marker on Reference Monitors.**

*This can show pixels which is **beyond SDR colorspace** (BT.709) in Reference monitor.*

Only available in $$$$ expensive reference monitor.

Playback of HDR: Scientific Testing

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Brightness

Signal

COLOR

Conform using multiple methods,

+ **Use a Spectroradiometer**

*This can help to **measure color volume** (Color-space, brightness) of patch in the screen.*

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That is CIE 1931 Chromaticity, Color distribution of a point

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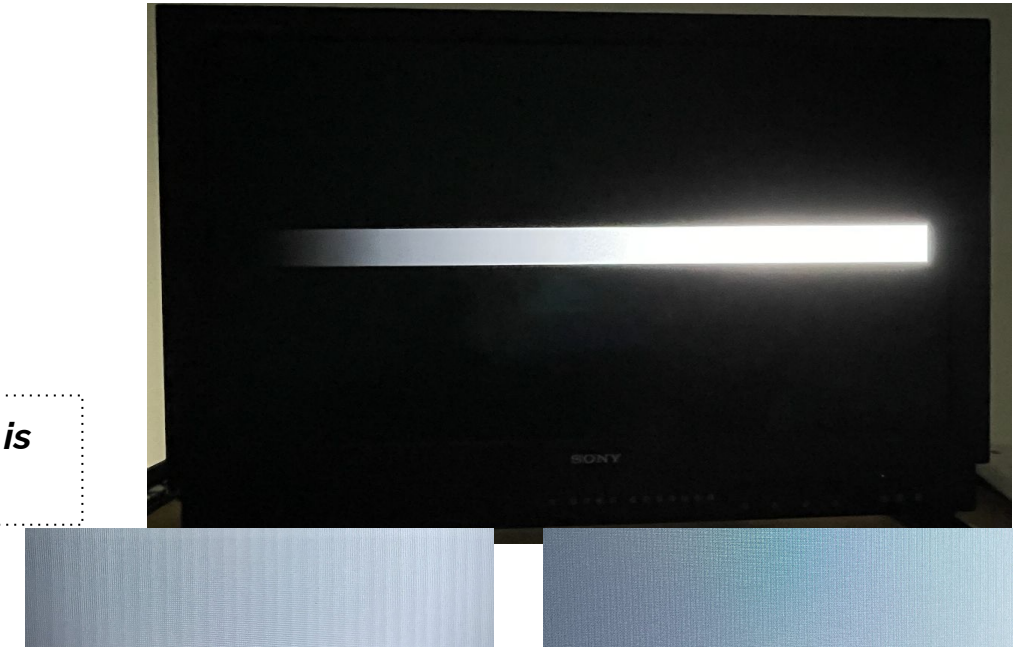
COLOR

BIT DEPTH

Conform using multiple methods,

+ **Use 10 bit gray ramp**



*This can help to validate if your **full pipeline is 10 bits** or any decimation happening.*

https://people.videolan.org/~mindfreeze/grayRamp.tiff
https://people.videolan.org/~mindfreeze/grayRampWithNoise.tiff

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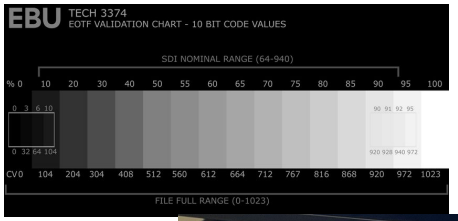

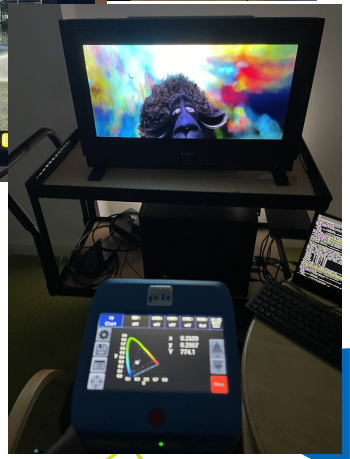

Setting up scientific testing environment

Conforming video playback is not only enough for HDR videos,

The **viewing environment** has a big impact on perception of colors

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Depends on

- *Display panel technology* (Peak luminance, and color temperature)
- ***Surrounding lights*** and light reflection from screen
- *Video materials*
- *Perception* of compression *artifacts*

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ITU BT.500-14: Methodologies for the subjective assessment of the quality of television images, explains the testing environment

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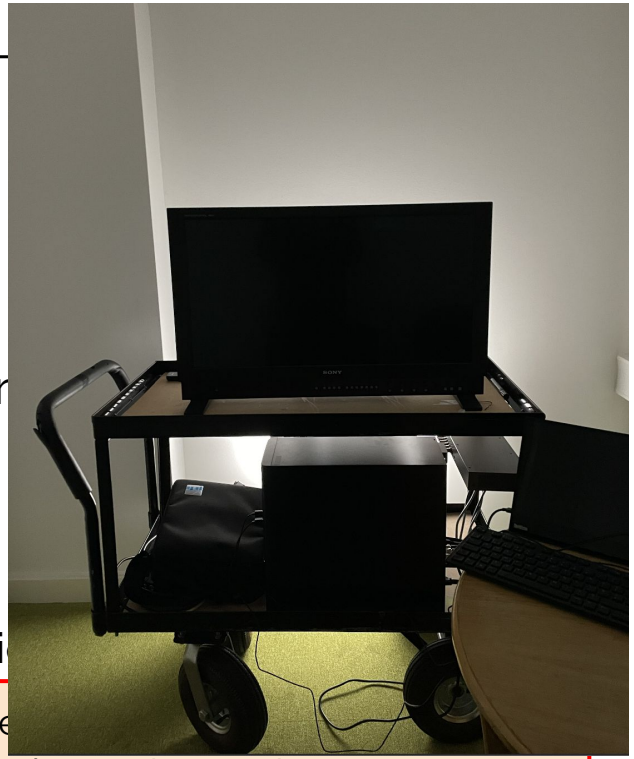

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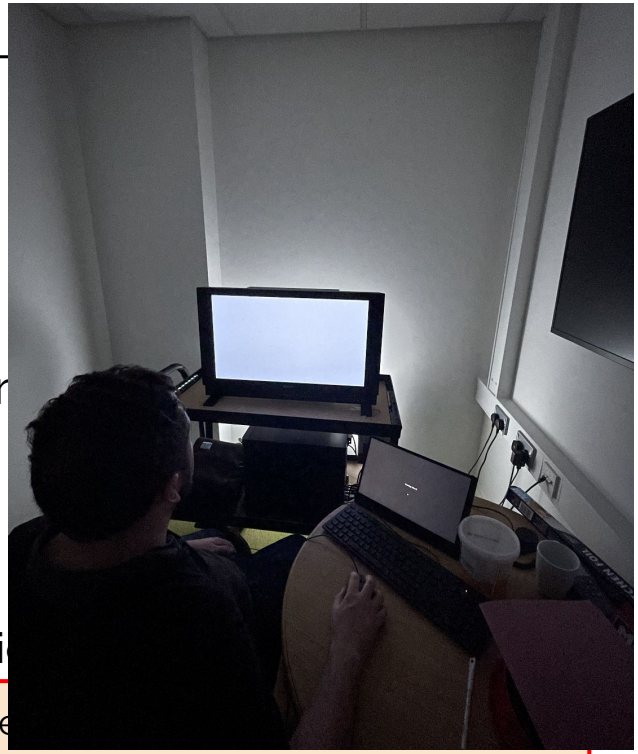

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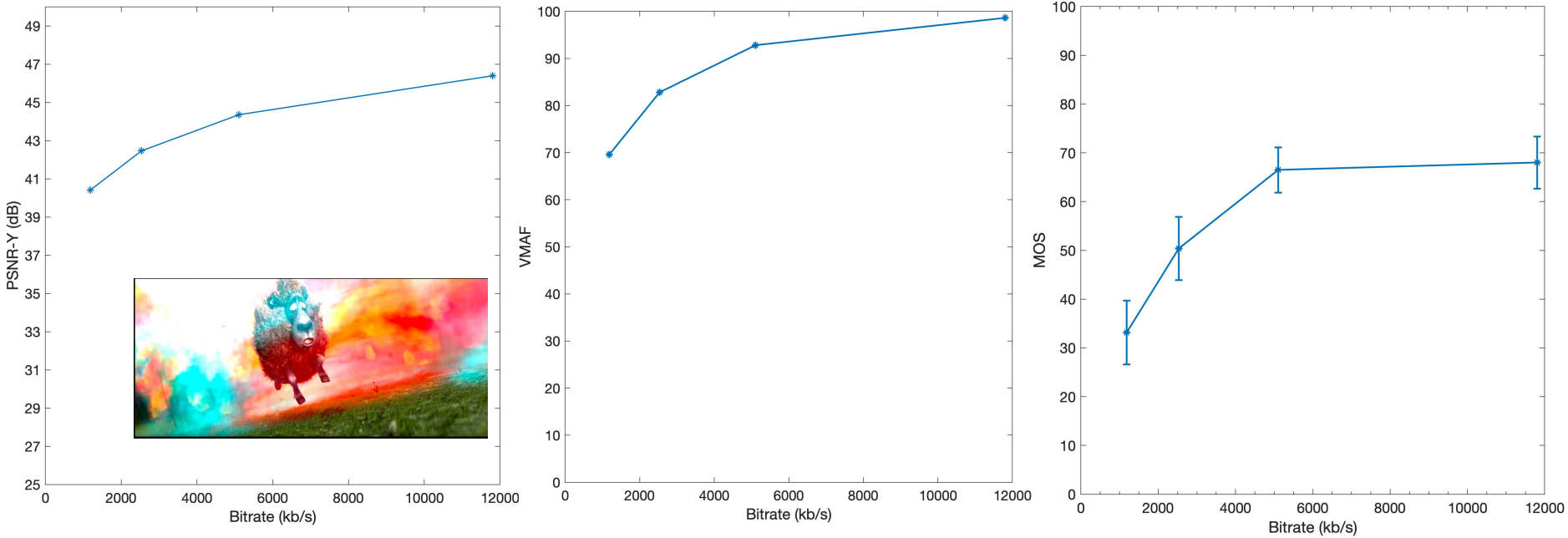
A quick glance over mean opinion scores



Comparison of PSNR, VMAF, and MOS score,

Comparison of MOS score with Objective metrics from 42 Subjects with Age 22-55, (30M, 12F) with 11 Experts and 31 Non-Experts.

CosmosSheep Encoded with libaom-av1@cpu-used 2 with 4 QPs 27, 39, 49, 59, MOS recovery carried out with Netflix Surreal Toolkit; Subjective study carried out with DSCQS protocol@TCD.

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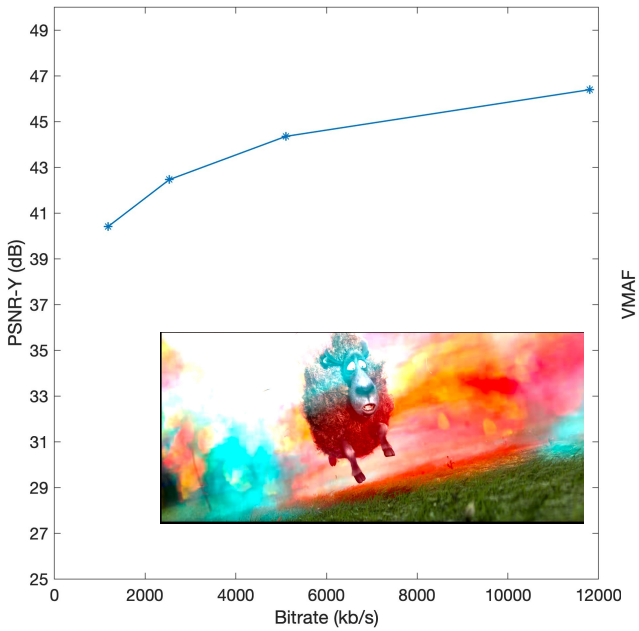

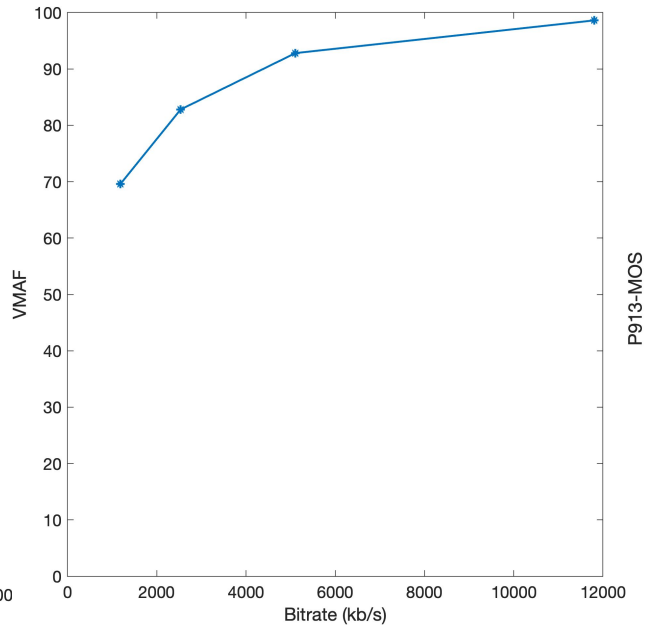

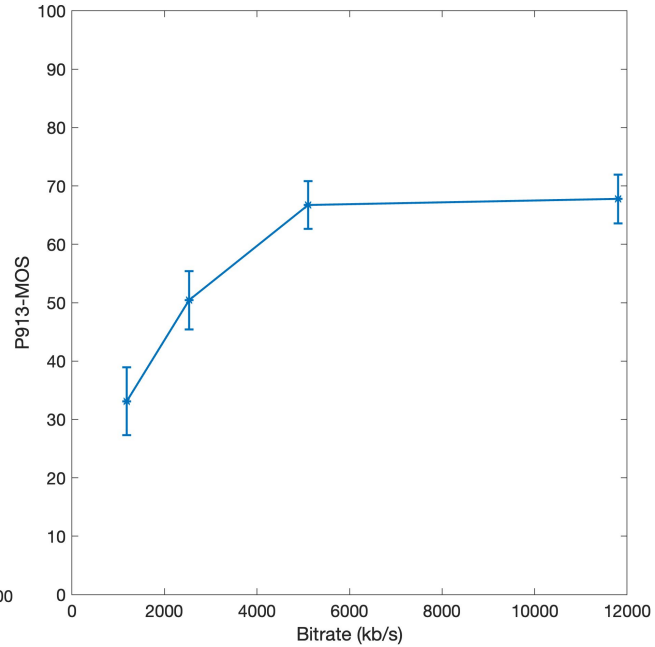

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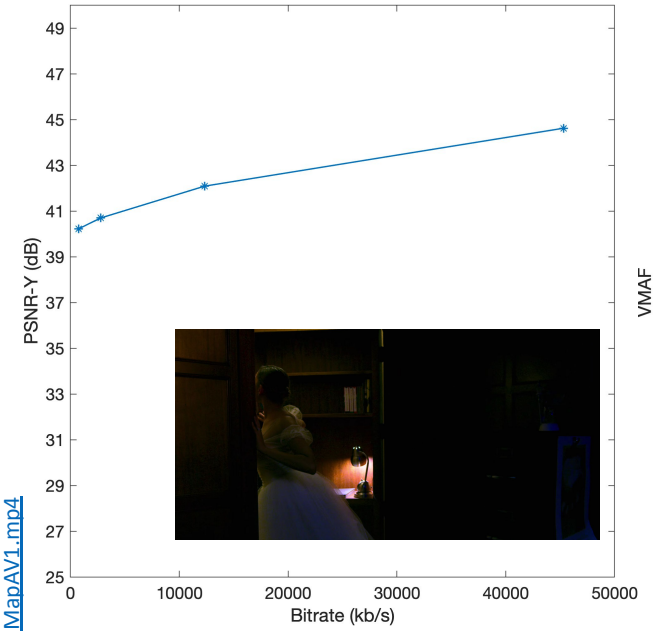

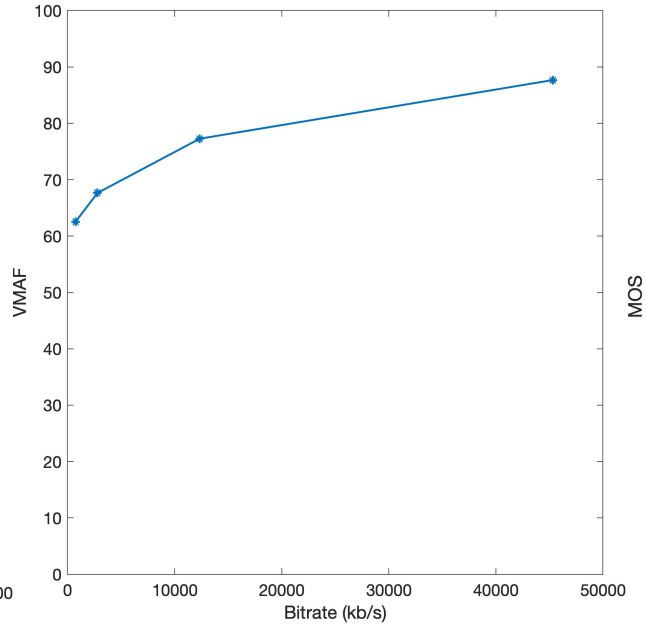

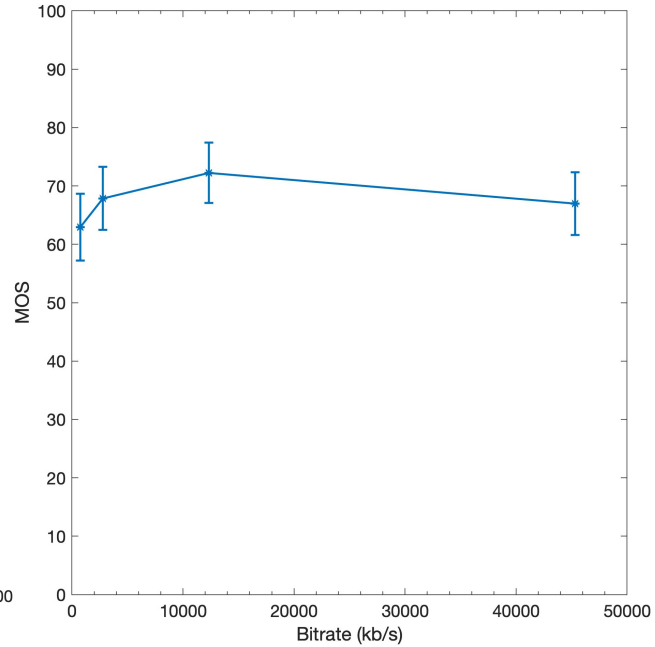

Comparison of PSNR, VMAF, and MOS score,

NocturneRoomToneMapAV1.mp4

- Do not expect MOS to be "**monotonic**" like PSNR, VMAF (Objective Metrics), as perception of quality across people varies
  - You may not be able to able to compare like objective metrics using BD-rate (%)

NocturneRoom Encoded with libaom-av1@cpu-used 2 with 4 QPs 27, 39, 49, 59, MOS recovery carried out with Netflix Surreal Toolkit; Subjective study carried out with DSCQS protocol@TCD.

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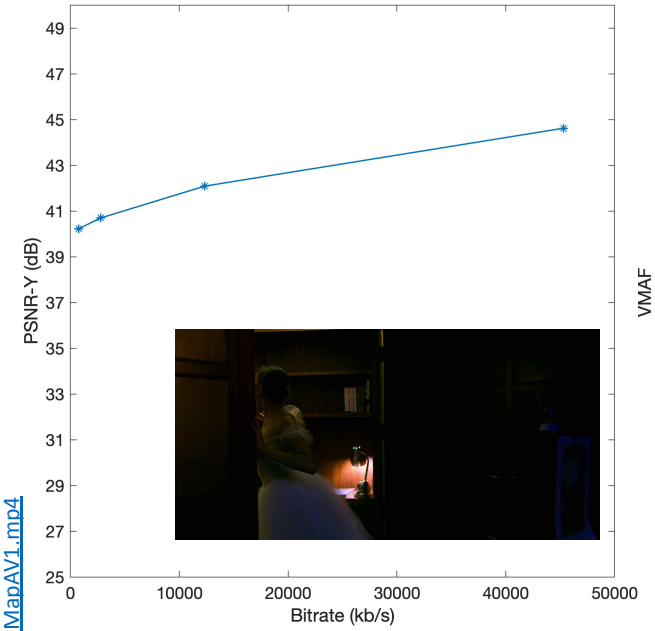

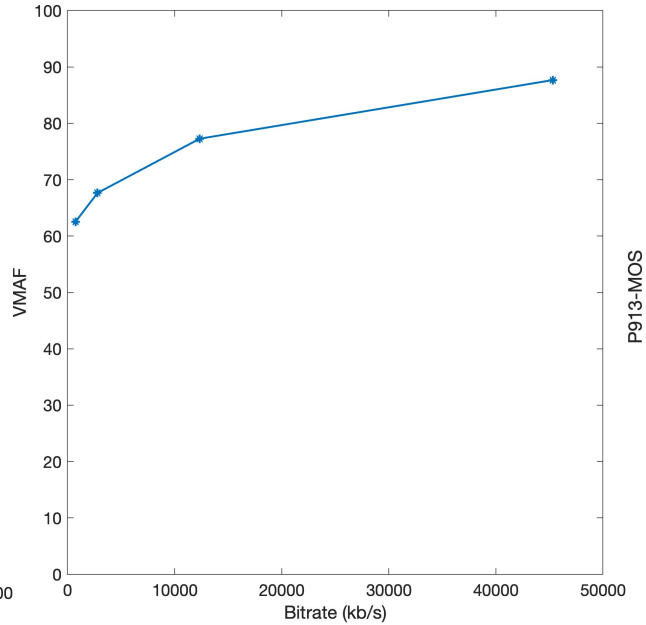

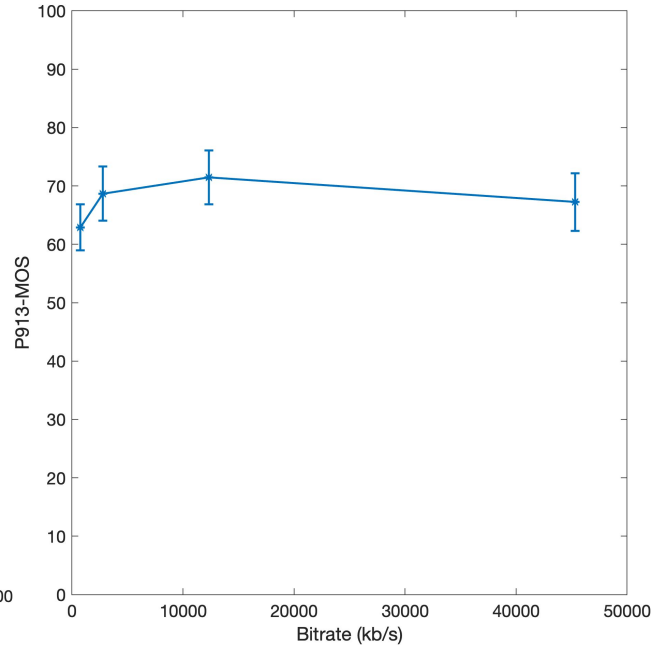

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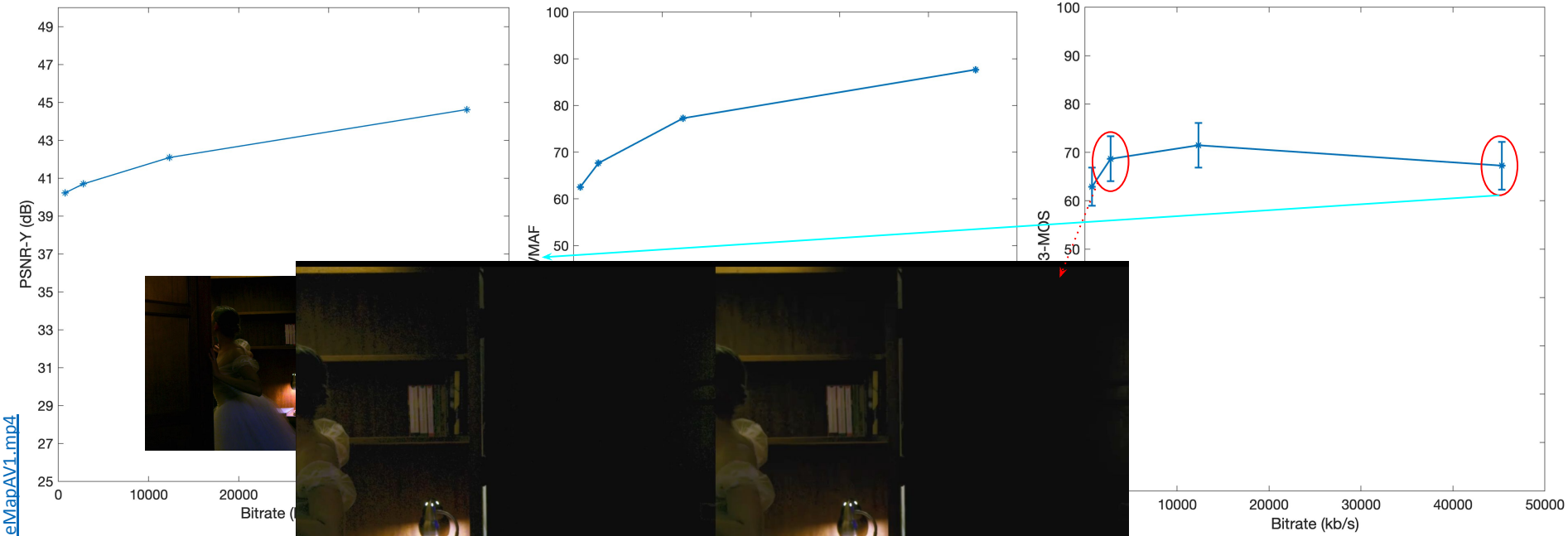
- Do not expect MOS to be "**monotonic**" like PSNR, VMAF (Objective Metrics), as perception of quality across people varies
  - You may not be able to able to compare like objective metrics using BD-rate (%)

NocturneRoom Encoded with libaom-av1@cpu-used 2 with 4 QPs 27, 39, 49, 59, MOS recovery carried out with Netflix Surreal Toolkit; Subjective study carried out with DSCQS protocol@TCD.

A quick glance over mean opinion scores

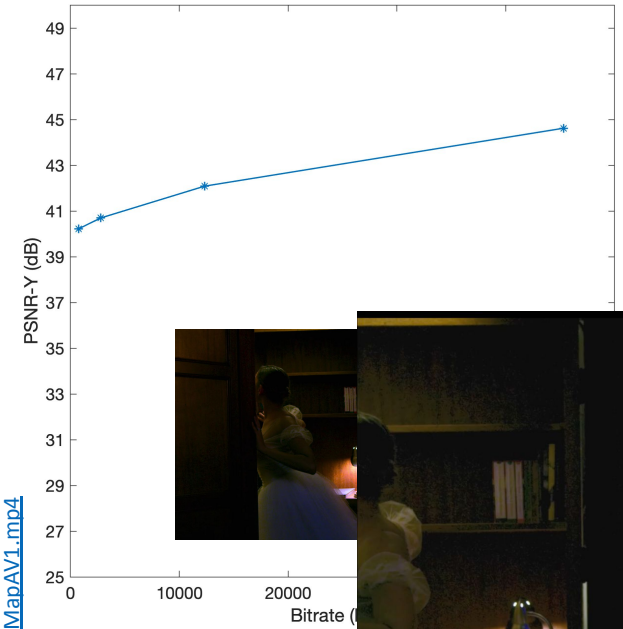


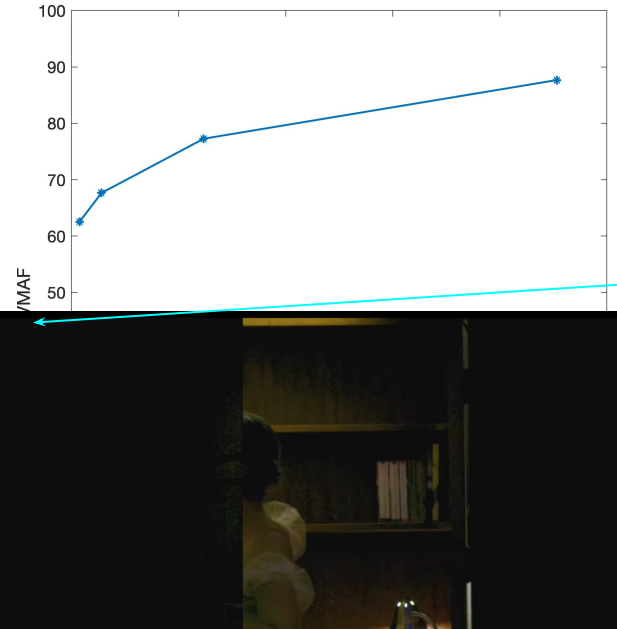
- Do not exp … etrics), as perception of quality acr…
  - You n… sing BD-rate (%)

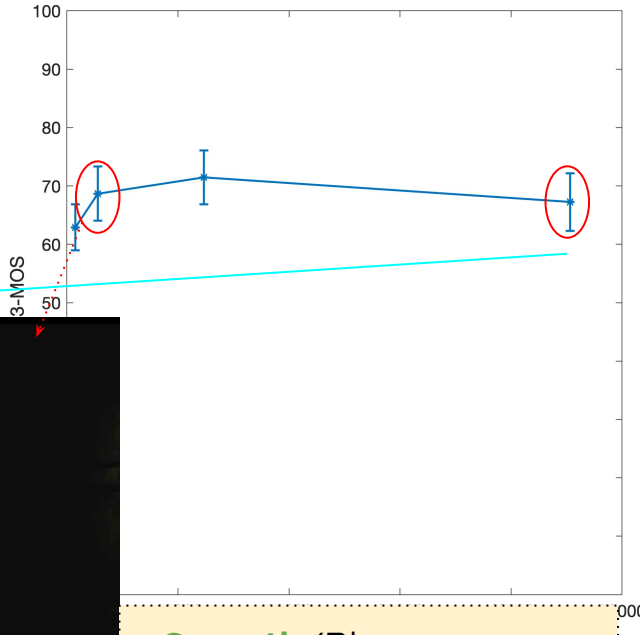
NocturneRoomToneMapAV1.mp4

NocturneRoom Encoded with libaom-av1@cpu-used 2 with 4 QPs 27, 39, 49, 59, MOS recovery carried out with Netflix Surreal Toolkit; Subjective study carried out with DSCQS protocol@TCD.

A quick glance over mean opinion scores







+ Smooth/Blurry

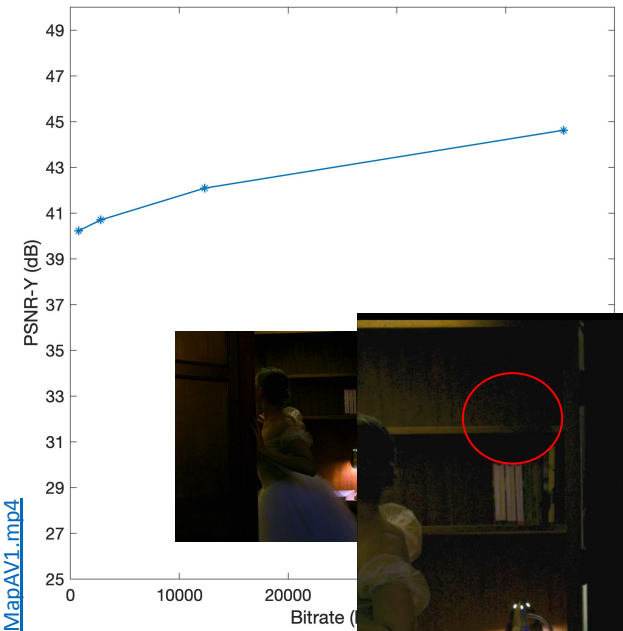
+ Do not exp
quality acr
+ You n

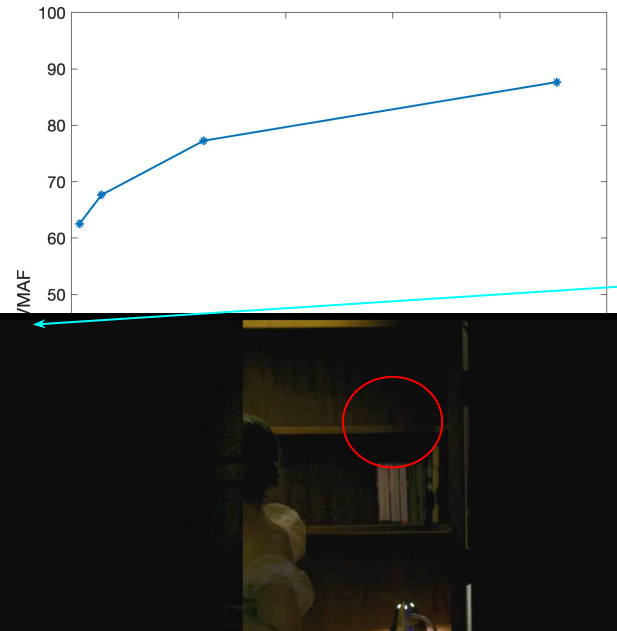
NocturneRoomToneMapAV1.mp4

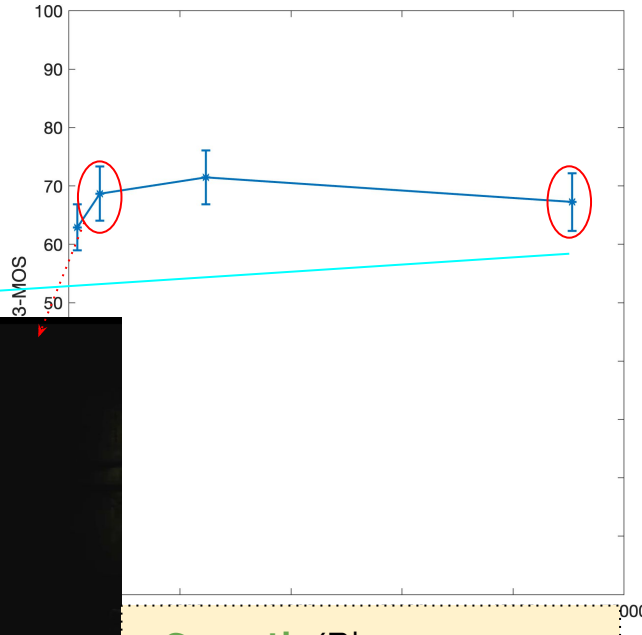
NocturneRoom Encoded with libaom-av1@cpu-used 2 with 4 QPs 27, 39, 49, 59, MOS recovery carried out with Netflix Surreal Toolkit; Subjective study carried out with DSCQS protocol@TCD.

Sigmedia
Signal Processing for Media Applications

A quick glance over mean opinion scores







NocturneRoomToneMapAV1.mp4

- Do not exp
  quality acr
  - You n

+ **Smooth**/Blurry
+ **Different** noise pattern, perceptually same for subjects

NocturneRoom Encoded with libaom-av1@cpu-used 2 with 4 QPs 27, 39, 49, 59, MOS recovery carried out with Netflix Surreal Toolkit; Subjective study carried out with DSCQS protocol@TCD.

Closing Remarks

- Signalling Metadata is **secondary** aspect of HDR, primarily it is,
  - Wide range of **brightness** due to different quantization scheme (**PQ**).
  - **WCG** can enhance viewing experience with more **colors**.

- Setting up playback pipeline of HDR content is **non-trivial** accompanied by **high costs** despite the fact HDR was standardized in **2012**.

- Subjective evaluation of HDR videos is significantly influenced by the **viewing environment**.

References

[1]: `ffmpeg -i input.y4m -vf zscale=tin=smpte2084:min=bt2020nc:pin=bt2020:rin=tv:t=smpte2084:m=bt2020nc:p=bt2020:r=tv,zscale=t=linear:npl=100, format=gbrpf32le,zscale=p=bt709,tonemap=tonemap=hable:desat=0,zscale=t=bt709:m=bt709:r=tv,format=yuv420p image.png`

[2]: https://gitlab.freedesktop.org/pq/color-and-hdr

[3]:High Dynamic Range Video, from Acquisition to Display and Applications https://www.sciencedirect.com/book/9780081004128/high-dynamic-range-video

[4]: https://github.com/Netflix/sureal

[5]; https://aomedia.org/docs/CWG-B075o_AV2_CTC_v2.pdf, AOM-CTC

[6]: https://2019.acmmmsys.org/program/slides/walt-husak.pdf, 2019 HDR presentation from Dolby

[7]: "Direct optimisation of λ for HDR content adaptive transcoding in AV1." In. SPIE, 2022.

[8]: https://www.lightillusion.com/guides.html,

[9]: https://www.colour-science.org/,

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THE END

For questions, please email to vibhoothi@tcd.ie/anil.kokaram@tcd.ie.

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