DELIVERY OF HIGH DYNAMIC RANGE VIDEO USING EXISTING BROADCAST INFRASTRUCTURE

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ABSTRACT

High dynamic range (HDR) video can offer consumers a much improved viewing experience compared to current broadcast video. The dynamic range of current television images, referred to as standard dynamic range (SDR), is governed by cathode ray tube physics first documented about eighty years ago. The standards include the Electro-Optical Transfer Function (EOTF) and the Opto-Electrical Transfer Function (OETF), as defined in Recommendations ITU-R BT.1886 and ITU-R BT.709, respectively.

Alternative transfer functions have been defined to support the transmission and rendering of HDR video signals. These transfer functions aim to provide perceptually uniform mapping of video signals to the higher luminance range of future HDR displays while maintaining video signal bit depths used across current broadcast infrastructures. In consequence, these new transfer functions exhibit much higher non-linearity compared to the transfer functions used in today's SDR systems. This could lead to several implications, such as an increase in bitrates required to transmit HDR services; changes to the existing broadcast infrastructure, including graphics equipment and vision mixers; and the compatibility of HDR services with existing SDR displays.

This paper studies the impact of such transfer functions on the efficiency of the video compression used for content exchange as well as delivery to the final user. Results, in terms of compression efficiency and subjective picture quality, using single-layer High Efficiency Video Coding (HEVC, also known as H.265 and MPEG-H Part 2) video compression algorithms are presented. This seeks to answer the question of what bitrates will be required to provide HDR services using existing video compression technology.

INTRODUCTION

4K Ultra High Definition (UHD) TV displays were introduced in 2012, with the promise of fundamentally changing television through having four times the spatial resolution of High Definition TV (HDTV), with 3840x2160 pixels. Since perception of spatial resolution is strongly linked to screen size and viewing distance, research suggests increasing resolution alone will have limited consumer impact on today's TV sizes viewed at today's viewing distances. Therefore, other enhancements are increasingly under study to improve the viewing experience. These include standardizing on progressively-scanned 50 and 60 frames per second (fps), or possibly higher frame rates, to improve motion representation; and a wider colour gamut, which allows the representation of colours to be closer to that of the human visual system (HVS). Over the past year, however, one aspect has arguably stood out above all others as having the largest impact on advancing the viewing experience or TV realism and that is High Dynamic Range (HDR).

HIGH DYNAMIC RANGE: IMPACT ON THE TV VIEWING EXPERIENCE

The Human Visual System (HVS) has a very wide dynamic range, being able to discern luminance levels ranging from bright sunlight at 10^5 cd/m^2 (candelas per square meter or "nits") to starlight at 10^{-4} cd/m^2. It is highly complex, adaptive and not fully understood in terms of television viewing. Unlike increasing resolution, which consumer research by CableLabs [1] and EBU [2] has shown to have limited viewer perception of an increase in picture quality at today's screen sizes and viewing distances, increasing the dynamic range that a viewer can see is equally applicable to a wide range of screen sizes and viewing distances and appears to have strong consumer appeal. For example, the benefit of HDR in high definition (HD) services is clearly evident.

The production standard for consumer video, however, has not been changed since the physics of cathode ray tubes (CRTs) were first documented in the 1930s, including setting the peak white level to 100 cd/m^2. Although modern video cameras can capture a very wide dynamic range and the very latest HD and UHD TVs claim maximum peak output in the range 400-1,200 cd/m^2, TV production standards have not been updated as of yet.

Reduced dynamic range translates to the inability to see both lowlights (e.g., details in deep shadows) and highlights (e.g., clouds in a bright sunny day) simultaneously; one or the other will be "lost". The impact of reduced dynamic range particularly is noticeable for specular reflections, such as sunlight reflecting off of the surface of water or metal; with HDR, such light usually causes a physiological response in the viewer ("feeling" the light, including squinting of the eyes, for example).

Demonstrations of the benefit of HDR over the past two years have convinced standards development organizations to study how to specify this new dimension of immersion into the TV viewing experience. Significant benefits have been shown for not only UHD but also HD resolutions, resulting in many believing that HDR is arguably the most important new development for TV.

For more detailed explanations of proper TV viewing distance, motion artefacts, the need for higher sample bit depths, Wide Colour Gamut (WCG), and HDR, refer to [3].

HDR INVESTIGATIONS IN THIS PAPER

Details of the transmission format for HDR video are yet to be standardised. There is currently work in the ITU-R (under the auspices of Working Party 6C) to consider a new recommendation which would include the transfer functions for an HDR system (the ITU-R uses the term Enhanced Image Dynamic Range TV, EIDRTV). Also International Standards Organization's Moving Picture Experts Group (MPEG) issued a Call for Evidence in February 2015 to study whether extensions to the High Efficiency Video Coding (HEVC) standard (Rec. ITU-R H.265 or ISO/IEC 14496-2 MPEG-H) could improve its coding efficiency, or functionality, for HDR and WCG content.

For future HDR services, there is a commercial desire in some markets to provide a solution that offers backward compatibility with existing standard dynamic range (SDR) receivers. To achieve this, dual-layer systems have been proposed by various companies, and while these are suitable for off-line content creation or delivery, industry and standards setting group participants have stated that for live broadcast a single-layer system is more practical for the workflow. For simplicity, this paper is considering the most straightforward case of a single layer non-backward compatible system.

This does not mean, however, that current infrastructure can be used without modification. The transmission of HDR data encoded using the current Rec. ITU-R BT. 709 [4] transfer function has a tendency to result in visible "banding" in regions of lower luminance, particularly when the luminance is spatially slowly varying. This is due in part to the higher sensitivity of the human visual system (HVS) to contrast changes at lower luminance levels [5]. One way to avoid this artefact is to increase the number of bits, and therefore the number of quantisation levels, used to encode the data. This is relatively inefficient, however, since it results in more data and an excess of quantisation steps at high luminance levels where the HVS cannot perceive the difference between them. A more efficient approach that exploits the response of the HVS to contrast changes is to use a non-linear mapping of the code words used to represent the video data to the display output. One such transfer function is defined in SMPTE Standard ST 2084 (hereafter referred to as ST 2084) [6]. Figure 1 shows how the code words of the current (for HD) Electro-Optical Transfer function (EOTF) defined in Rec. ITU-R BT.1886 [7] and the ST 2084 EOTF map to screen output luminance levels.

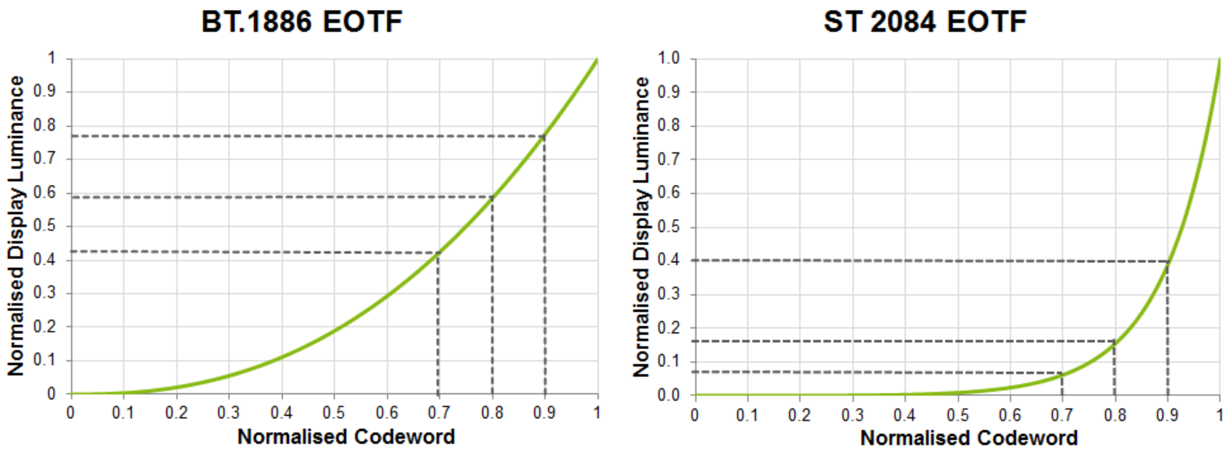

Figure 1 – Comparison of EOTFs. BT.1886 is used in SDR systems. ST 2084 is a proposal for HDR systems

The question of most interest to the industry, and yet to be answered, concerns what impact (if any) the additional dynamic range of the source content and the transfer function will have on the bitrates required to transmit HDR content to the home. This comparison between SDR and HDR bitrates is complicated by several factors including the availability of equivalent HDR / SDR displays and the need to 'grade' any given source clip differently for SDR and HDR. A direct subjective comparison is also complicated by the different appearance of compression artefacts and the "wow" factor induced by observing high dynamic range content, potentially for the first time.

We attempt to gain some insight into the question by running independent HDR and SDR subjective evaluations in which compressed sequences are compared to uncompressed references. This offers some indication of the relative impact of reducing the bitrate on HDR and SDR.

Previous experiments on the compression of HDR video [8] indicated that the assumed EOTF of the display has a significant impact on the compression efficiency. Specifically, for some content, the degree of non-linearity of the transfer function correlated with the bitrate for a fixed encoder quantisation parameter (QP). This paper investigates the perceived impact of the highly non-linear transfer function described in ST 2084 on different content by comparing it with a more linear transfer function.

EXPERIMENTAL FRAMEWORK

Figure 2 presents the block diagram of simulated, single-layer HDR and SDR broadcast systems. In both cases, image sequence coding is based on existing non-constant luminance transfer function framework as defined, for example, in BT.709 or Rec. ITU-R BT.2020 [9].

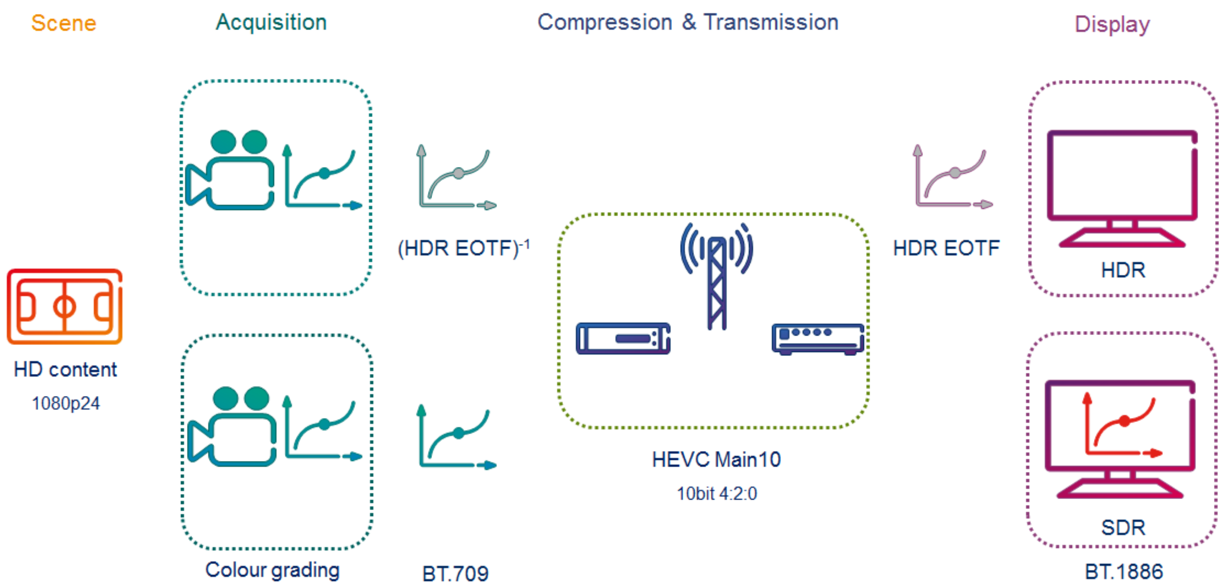

Figure 2 – Diagram of simulated HDR and SDR broadcast systems

In encoding, tristimulus (RGB) image data coming from the camera are first subject to some form of grading. This may be a simple look-up table (LUT) in the case of live broadcast or more complex image manipulation in the case of off-line production. The output of the grading process is then subject to a transfer function before conversion to the YCbCr domain in which the data is quantised to 10 bits per channel. In the current (SDR) broadcast chain, this process is defined in BT.709, in which the transfer function is referred to as the Opto-Electrical Transfer Function (OETF). The YCbCr data is then subject to compression, for which we use an HEVC encode with the Main 10 Profile (10-bit 4:2:0).

In our model, compression is applied just once, simulating the final delivery stage to the end customer. This is a simplification of real-life broadcast systems where final delivery is usually preceded with multiple stages of compression during acquisition/contribution and primary distribution. Depending on quality of the links, those stages may have a significant impact on the end quality of video services [10]. Our experiments assumed that high quality mezzanine links were used.

Content

In total four sources were used for the subjective evaluation; MagicHour coming from the Digital Cinema Initiative 2014 Standard Test Material [11], BalloonFestival coming from CableLabs [12] and the ShowGirl, and BeerFest sequences coming from Hochschule der Medien, Stuttgart [13].The MagicHour sequence represents scanned film content and was stored as 12-bit RGB data in TIFF format. The BalloonFestival, ShowGirl and BeerFest sequences were stored as 16-bit floating point data in EXR format [14]. Screenshots of the sequences are given in Figure 3 and histograms of the representative frames are given in Figure 8.

Figure 3 – Test content used in experiments

Colour Space

The SIM2 HDR47 display colour gamut is quoted as >90% of BT.709. As such, the decision was taken to limit source material to the BT.709 colour space before grading. For sources not already in this colour space, conversion was achieved by pre-multiplication of the RGB column vector by a 3 × 3 matrix derived from the chromaticities and white points of the source and BT.709 colour spaces. Colour values outside of the interval [0,1] were hard clipped. For SDR sources, the BT.709 colour space was maintained throughout. For the HDR sequences prepared for compression, however, the BT.709 data was stored in a BT.2020 container. It has been observed that using an oversize colour space container serves to mitigate the chroma distortion artefacts observed in [8]. This does not represent a complete solution, however, since in this case the chrominance is effectively over-quantised and, in the case where source material occupies the entire BT.2020 colour space, problems will still exist.

Colour Grading

For each source sequence, two different gradings are sought, one maximising the capabilities of the SDR display and another the HDR display. For the MagicHour and WarmNight sequences, professionally graded variants for both 4000 and 100 cd/m^2 peak luminance displays were available. Therefore, no additional grading was performed on these sources. The BalloonFestival sequence was already graded for 4000 cd/m^2 requiring only a new grade for SDR. The ShowGirl and BeerFest sequences were provided ungraded and so required both HDR and SDR gradings. Grading was performed using a simple manipulation of the source data in floating point representation. The manipulation in each case comprised a gain and power function. Whilst this does not represent a fraction of the tools available to the professional colourist, it produced quite acceptable results. In all cases, the exact same workflow used in the subjective evaluations was used to perform the grading.

HDR OETFs

For the HDR sequences the graded content was subject to one of two transfer functions being the inverse EOTF defined in ST 2084 or a power function with index 1/0.45 hereafter referred to as the power function. This power function is similar to BT.709, as it has the same index, but without the linear portion at lower luminances. As can be seen in Figure 4, the power function is considerably more linear than ST 2084. The transfer function in each case is applied using the non-constant luminance method in which the individual tristimulus pixel values are transformed before conversion to YCbCr and subsequent quantisation.

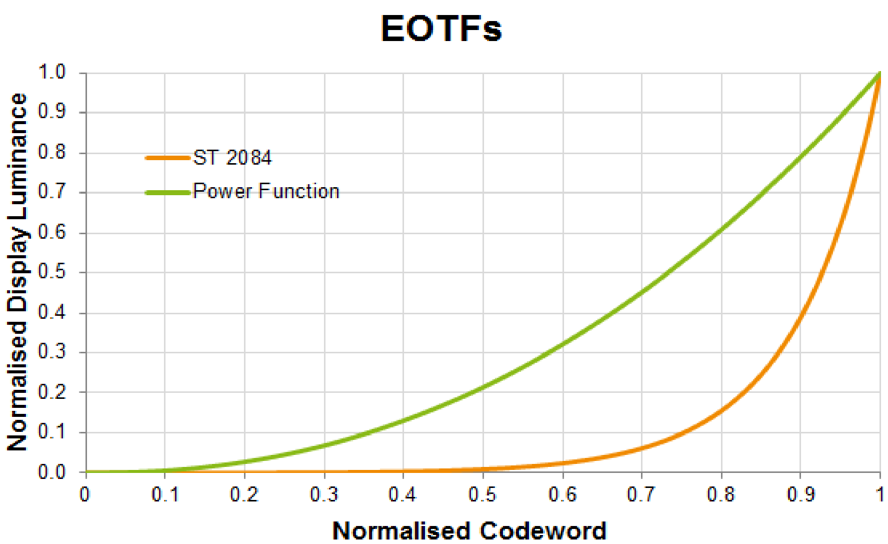

Figure 4 – EOTFs for experimental HDR systems

Note that the EOTF maps to the normalised display brightness (this follows the methodology used by the MPEG Call for Evidence on HDR). ST 2084 maps to absolute luminance values from 0 up to 10,000 cd/m^2; however, the peak luminance of the display used here is 4000 cd/m^2.

Compression

Video compression was performed using the HEVC Test Model (HM) [15] with source content encoded using the Main 10 Profile, in 10-bit 4:2:0 format. Chroma down-sampling was performed using short filters with no negative values, specifically those defined in the MPEG HDR Call for Evidence [16]. Compressed streams with bitrates of 1, 3 and 5 Mbps were produced using fractional QP values to provide bitrate accuracy of < 3%.

Decoding

Following transmission, the encoding operations are inverted producing tristimulus (R'G'B') data which are subject to the EOTF before display. In the SDR broadcast chain, this EOTF is specified in BT.1886 and is assumed to be applied by the Samsung UE46A display. In the HDR case, the EOTF is applied after colour space conversion from BT.2020 to BT.709. The resulting linear RGB signal is communicated to the SIM2 display using the proprietary HDR DVI interface.

Experiments

Ericsson has conducted subjective assessment tests to investigate the impact of compression on perceived picture quality of HDR and SDR services. Tests were carried out using 36 viewers, who were randomly selected from Ericsson employees. The group consisted of a mix of expert and non-expert viewers, where the former had some professional experience of assessing quality of video.

Test Method

The subjective assessment was done according to Rec. ITU-R BT.500 [17]. The recommendation provides several types of methods, from which the Double-Stimulus Continuous Quality Scale (DSCQS) method was selected. In this method, each viewer is asked to assess a pair of videos (originating from the same source), one referred to as 'reference', and the other referred to as 'test', and to score the quality of both sequences. The result is the difference between scores, referred to as the Difference Mean Opinion Score (DMOS). This test method was used since it is thought to be useful when sequences do not cover the whole range of quality. In the experiment, the test sequences were compressed at bitrates that are expected to be used for final delivery transmission to the consumer.

Test Environment

Viewings were done in an enclosed room in a typical office environment. Ambient light level at the viewing position was measured to be ~65 lux. HDR and SDR viewings were done in the same room. The viewing distance for both HDR and SDR tests was "3H" (3x picture height of the display). When used with the proprietary HDR input, which results in no EOTF being performed in the display, the SIM2 HDR47 display also deactivates settings for Brightness, Contrast and Sharpness as normally would be available in commercial displays. Peak luminance of the HDR display was 4000 cd/m^2.

The display used for SDR viewing was a Samsung TV, model UE46A, set to default settings (Backlight: 11, Contrast: 100, Brightness: 45) except for the sharpness setting, which was reduced from 50 to 10 in order to reduce ringing artefacts. All digital noise reduction filters and motion interpolation features were disabled.

Test Scenario

The test duration was ~60 minutes and comprised two sessions: one for HDR and one for SDR. The two sessions were separated with a break and preceded with a training cycle where subjects were shown typical picture quality conditions for each of the sessions. In each training session, five pairs of video sequences were shown to subjects. The sequences shown were not used in the main test. Half of subjects started tests with the HDR session followed by the SDR session and the other half vice versa. The HDR session was comprised of 28 pairs of sequences. The SDR session was comprised of 16 pairs of sequences. The test was split into following three test cases (Table 1):

№	Reference	Test case under the assessment
1	Uncompressed HDR	Compressed HDR based on ST 2084 EOTF
2	Compressed HDR based on ST 2084 EOTF	Compressed HDR based on power function EOTF
3	Uncompressed SDR	Compressed SDR

Table 1 – Description of test cases

All videos were played twice before voting. Sets of video pairs were presented in random order. The positions of reference and test sequences were swapped randomly. The subjects were not told which one of the clips was the reference and assessed the overall picture quality of each video clip in the pair using the continuous scale guided by five categories: “Excellent”, “Good”, “Fair”, “Poor” and “Bad”.

TEST RESULTS

The DMOS scores were calculated for each reference / test pair. The difference between test and reference sequence was centred on the value of 100. The average value across all subjects was taken to obtain the DMOS scores. The interpretation of DMOS scores is as follows:

- <100: Test video has lower picture quality than reference video
- =100: Test video has the same picture quality as reference video
- >100: Test video has higher picture quality than reference video

In our tests, HDR DMOS results were calculated relative to the HDR reference, while SDR DMOS results were measured and calculated relative to the SDR reference. Therefore, in order to compare the relative quality of HDR vs. SDR, we look at the degree of degradation for a given bitrate point. The interpretation used was as follows:

- DMOS for HDR **lower** than for SDR (for a given bitrate and content)
    - Degradation in picture quality was **greater** than for SDR
    - Suggests a **higher bitrate** may be required for HDR

- DMOS for HDR **higher** than for SDR (for a given bitrate and content)
    - Degradation in picture quality was **less** than for SDR
    - Suggests a **lower bitrate** may be sufficient for HDR

HDR and SDR Tests Results

Figures 5 and 6 show DMOS results for the four tested sequences.

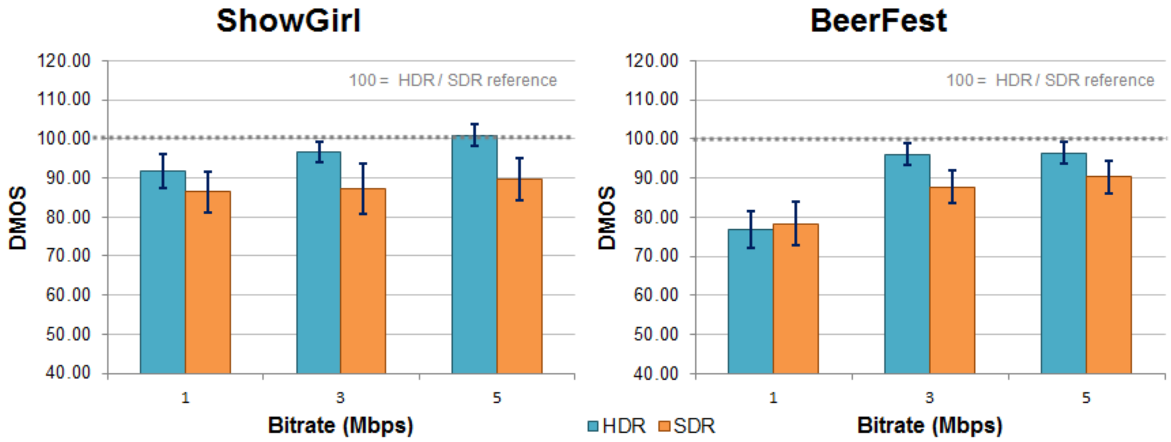

Figure 5– DMOS results for the ShowGirl (left) and the BeerFest (right) sequences. The error bars represent 95% confidence intervals

For the ShowGirl sequence, the DMOS scores were higher for HDR than for SDR. The difference in average scores between HDR and SDR was smallest for the lowest bitrate point (1 Mbps). While for HDR, the DMOS scores increased with the bitrate. This effect was not observed for the SDR scores.

For the BeerFest sequence, the DMOS scores were higher for HDR than for SDR, apart from the lowest bitrate point (1 Mbps). Similar to the ShowGirl sequence, the DMOS scores for HDR achieved higher values at higher bitrates than the SDR scores. For the HDR scores, a sharp drop between 3 Mbps and 1 Mbps was observed.

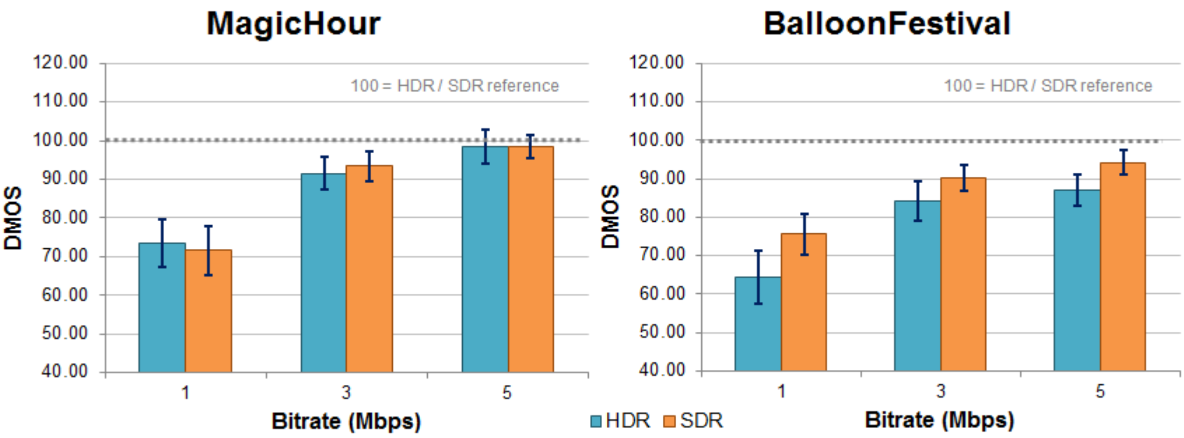

Figure 6– DMOS results for the MagicHour (left) and the BalloonFestival (right) sequences. The error bars represent 95% confidence intervals

For the MagicHour sequence, the DMOS scores for HDR and SDR were very similar across all bitrates. Both HDR and SDR scores recorded consistent improvement with increasing bitrate. Both HDR and SDR tests recorded a sharp drop in scores between 3 Mbps and 1 Mbps.

For the BalloonFestival sequence, the DMOS scores were consistently higher across all bitrate for SDR than for HDR. The biggest difference in favour of SDR was for the lowest bitrate point, 1 Mbps. Both HDR and SDR tests recorded the sharpest drop in scores between 3 Mbps and 1 Mbps.

HDR and SDR Tests Discussion

The following observations were made from the experiment. For ShowGirl and BeerFest, subjects judged the HDR versions to have relatively fewer artefacts than the corresponding SDR versions.

The examination of the two clips showed that this could be mostly attributed to the amount of blocking artefacts in darker parts of the sequences. For ShowGirl, the blockiness in the SDR version was clearly visible in the black background. The artefacts persisted across all bitrate points and this could explain why the DMOS scores for ShowGirl SDR did not improve with the increased bitrate.

For the BeerFest SDR clips, the blockiness was less pronounced, but banding artefacts were still noticeable. By contrast, the HDR versions were free of banding artefacts. For the ShowGirl HDR clips, no banding in the dark backgorund was visible across all bitrates. For the BeerFest HDR clips, the lowest bitrate clip suffered from blocking artefacts.

For the MagicHour sequence, subjects assessed the degradation in quality vs. bitrate equivalent between HDR and SDR. This seems consistent with the general viewing impression that the sequence looked very similar on HDR and SDR displays.

For the BalloonFestival sequence, subjects judged degradation on HDR to be more substantial than for SDR. This could be mostly attributed to lack of detail across several parts of the sequence, such as the balloon rope or mountains, and noticeable blocking in the sky.

Overall, the results showed there was no consistent bitrate delta between HDR and SDR variants across all test sequences. The HDR system based on the ST 2084 EOTF deals much better with banding in dark parts of ShowGirl and BeerFest than the SDR system, yielding overall better picture quality (less compression artefacts) at the same bitrate. This suggests that a lower bitrate could be sufficient for delivery of HDR services with content of similar properties.

On the other hand, the HDR system based on ST 2084 EOTF suffered from loss of detail in bright parts of the BalloonFestival sequence, yielding overall worse picture quality (more compression artefacts) than the SDR system at the same bitrate. This suggests that higher bitrate would be required for delivery of HDR services with content of similar properties.

HDR EOTFs Test Results

Figure 7 shows average DMOS scores for the HDR system using the power function EOTF relative to the HDR system using the ST 2084 EOTF. The scores were calculated as averages across 3 bitrate points: 1 Mbps, 3 Mbps and 5 Mbps.

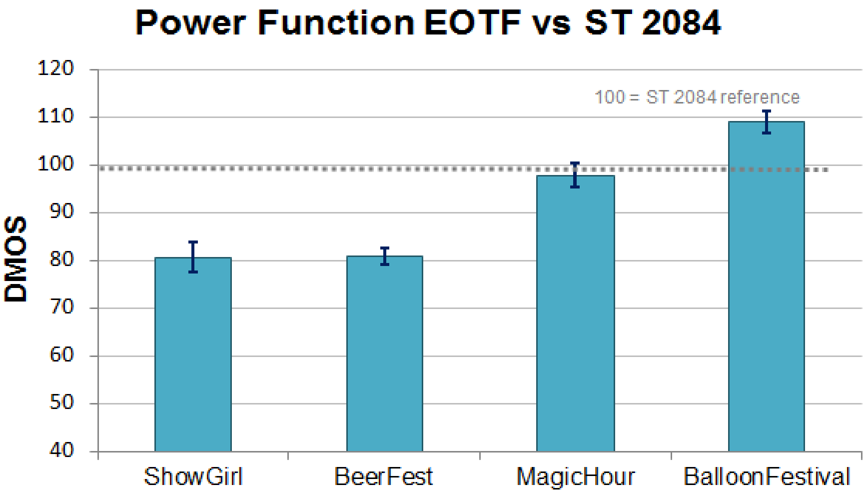

Figure 7 –DMOS results for HDR system using the power function EOTF relative to HDR system using ST 2084 EOTF. The results were averaged across 3 bitrates (1,3,5 Mbps). Error bars represent 95% confidence intervals

For the ShowGirl and BeerFest sequences, the DMOS scores for the HDR system using the power function EOTF were significantly lower than for the HDR system using the ST 2084 EOTF. For the BalloonFestival sequence, the opposite was true: the HDR system using the power function had a higher DMOS score than the reference HDR system using ST 2084. For the MagicHour sequence, the DMOS score for the HDR system using the power function was only marginally lower than for HDR system using ST 2084.

HDR EOTFs Test Discussion

For ShowGirl and BeerFest sequences, subjects clearly preferred the reference HDR system using the ST 2084 transfer function. Examination of the sequences showed severe banding and blockiness, which was present in the test HDR system using the power function EOTF. Interestingly, for the ShowGirl sequence the detail in the bright areas in woman's face and forehead were much better than for the ST 2084 system but this was not reflected in the subjective results as the blockiness in the background seemed far more objectionable. For the MagicHour sequence, the average score suggests viewers had slight preference for the ST 2084 system; however, the upper confidence interval reached beyond 100, which means the difference was not statistically significant.

In contrast, for the BalloonFestival sequence, viewers had a clear preference for the test system using the power function over the reference system with ST 2084. The lower quality of the HDR system with using ST 2084 EOTF could be attributed to loss of detail across parts of video sequence, which was noticeably better preserved in the HDR system based on the power function EOTF.

The analysis of test content properties in Figure 8 is useful in explaining the results. The distribution of luminance values shows that the BalloonFestival sequence is much brighter than other sequences, especially the ShowGirl sequence.

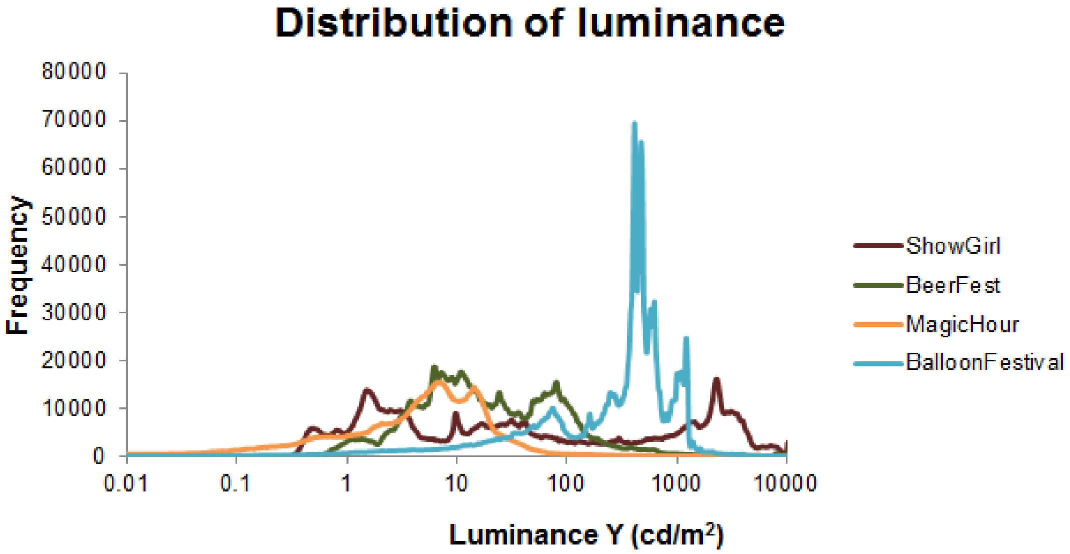

Figure 8 – Distribution of luminance for sequences used in the test

Since the ST 2084 EOTF is highly non-linear, most of code words are allocated to cover lower luminances, with relatively few levels covering high luminance range. In contrast, the power function allocates the code words more evenly across the luminance range (see Figure 4), but overall has more code words to cover the high luminance range. This shows that the shape of the EOTF comes with a trade-off between code words available for low and high luminances.

While for uncompressed sources this may have little overall effect (informal examination of the content did not show any noticeable artefacts), the results showed that the impact of compression can significantly exacerbate the artefacts. It could be argued that for some, such as for mild blockiness, non-normative changes to the encoder might be able to resolve them.

CONCLUSIONS

HDR Video is an important new development that is expected to enhance the television experience for consumers. HDR is unique among other developments for television as it does not strongly depend on content resolution, genre or viewing conditions. Currently, however, how HDR video will be delivered is still not defined, especially in live broadcast scenarios. One area of consideration is the mapping function, called the EOTF, between code words of a transmitted and decoded video signal and luminance levels rendered on a display. It is generally accepted that in order to cover a higher dynamic range of video, the HDR EOTF must be more non-linear than the existing EOTF for SDR systems. The impact of that non-linearity on compression efficiency and, consequently, on bitrates required for delivery of HDR services is not well understood.

In the first experiment presented in this paper, we investigated the degradation of picture quality in HDR and SDR systems for the same original content as a function of bitrate. In this experiment, a single layer HDR system based on the SMPTE ST 2084 EOTF was used. Subjective assessment was conducted with a mixed population of expert and non-expert viewers. In total, four different sequences across three bitrates were tested. The results were mixed. For ShowGirl and BeerFest sequences, the viewers found that at the same bitrate, degradation of sequences in the HDR system was lower than in the SDR system. For the BalloonFestival sequence, the degradation in the HDR system was found higher than in the SDR system. For the MagicHour sequence, the degradation was judged the same.

In the second experiment, we investigated the impact of the EOTF non-linearity on compression performance. The reference HDR system was based on the SMPTE ST 2084 EOTF. The test HDR system was based on the power function (with index 1/0.45) EOTF. The latter is not intended as a proposal for HDR EOTF, but was employed as an example of a significantly more linear EOTF (of similar non-linearity to the SDR systems). The results from subjective assessment showed that for ShowGirl and BeerFest, the quality of the HDR system using ST 2084 was significantly better than for the HDR system using the power function. On the other hand, for the brighter BalloonFestival sequence, the opposite was found, with no difference in picture quality between the systems for the MagicHour sequence.

Based on the two experiments, we conclude that the non-linearity of EOTF has a significant effect on compression performance. The impact is content dependent. For content with low luminance levels, increasing the non-linearity of the EOTF has a positive impact on picture quality and significantly removes banding artefacts present in current SDR systems. The results obtained with the HDR system based on ST 2084 EOTF suggest that, for such content, there would be no bitrate increase required compared to the SDR system. Conversely, for content with a significant portion of high luminance levels, the non-linearity has a detrimental effect on picture quality. In this case, the results for the HDR system based on ST 2084 EOTF suggest that higher bitrates than required for SDR would be necessary.

Current consideration of which EOTF to use does not include the impact of compression. It seems that any choice of a fixed EOTF will result in a trade-off of picture quality between dark and bright content. Another consideration that is relevant in this context is the specification of peak luminance for HDR systems. With a more conservative proposal for peak luminance, the trade-off between the picture quality of dark and bright content might be reduced. Also restrictions on the maximum average luminance and the distribution of luminance values in source content may have a similar effect. Finally, expectations of consumers on picture quality of HDR services quality may differ from the expectations on SDR picture quality which may have consequences for HDR operating point and therefore bitrates.

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