Hyper-Realistic SDR/LDR Image Reproduction Proposal Needing Just Approx. 1/30th Exposure of Conventional SDR Image and Global-Tone-Mapping, or 1D-LUT, in UHDR Environments Regardless of Time of Day

Sakuichi Ohtsuka, Michihiro Hayashi
International College of Technology, Kanazawa, Kanazawa, Japan

Abstract

Perceptually natural SDR (Standard-dynamic-range) / LDR (Low-dynamic-range) images should retain enough information for the human observer to estimate the visual environment in which the UHDR (Ultra-high-dynamic-range) scene was captured in not only daylight, but also twilight (mesopic) vision. Our current proposal brings two significant achievements: (1) only conventional SDR images, not HDR ones, need be captured, and (2) realizes antinomy of incomparable sensitivity (approx. 30 times) and yields hyper-realistic reproduction quality.

Author Keywords

High-dynamic-range (HDR); normalized visual percept (NVP); visual perception; cSDR; hSDR; twilight vision.

1. Introduction

We previously tried to reproduce NVP (normalized visual percept) SDR images from HDR images and demonstrated some successful results in daylight. For application to vehicle displays, characterized as low contrast environments, it is also important to support LDR images (See Fig.1[1], [2]).

Nighttime is very problematic for image capture unlike daytime. It was found impossible to reproduce the twilight vision of humans, even though we could estimate the physically-accurate dynamic range. The bottleneck was the inability to reproduce true dark or black situations. Therefore, SDR images, let alone LDR images, were found to be problematic [3], [4].

We overcame this barrier by thinking outside the box. The key idea was to assume that “the darkest part does not become 0, but has a finite pedestal”. In other words, the human observer perceives the darkest part as having a certain luminance [5]. As detailed in the next chapter, this idea made it possible to generate realistic SDR/LDR images for nighttime situations.

In this paper, in addition to the above, we demonstrate that input images need just a bit resolution of gamma-corrected 8bit (i.e., sRGB etc.) rather than 16bit; at the same time, we maintain perceived naturalness of brightness and color tone. Note that we ignore the reproduction of moon texture [4]-[6] because the main target of this proposal is the output of monitoring cameras.

2. Newly derived SDR/LDR curves

2.1 Experimental setup

Nikon Z9, for almost, and Z-fc, for partially, mirrorless cameras, were used to capture all original images. The images were recorded in Nikon-RAW format. The Nikon-RAW data were processed by “NX Studio” with a sensitivity correction of between approx. -3EV (Exposure value) and +5EV to create original 16bit TIFF images. The 8bit images were truncated to 8bit TIFF images by Photoshop CS6, for producing conventional SDR (cSDR) or original SDR images as inputs for our proposal.

2.2 Obtained SDR/LDR curves

Figure 2 shows proposed hyper-realistic SDR (hSDR) tone mapping curves with modification for 8bit input and LDR.

For SDR images, maximum contrast ratio (CR) was assumed to be approx. 80:1, for reproduction on Epson semi-glossy paper (KA420MSHR). For LDR images, CR was set to 10:1.

Commonsense suggests that the pedestal should be the convergence of these assumed values, i.e., 1/80 or 1/10. In this situation, the lowest luminance value of an image approaches to real “Zero”. However, the offset of the obtained curves (i.e., pedestal) is higher than that value. This means, in other words, “the darkest part does not become 0, but has a finite pedestal” sufficiently larger than the reflections from ambient light on the display.

These curves raise several issues. First, for either SDR or LDR, the pedestal values were higher at nighttime than at daytime. In addition, the pedestal of LDR at nighttime is higher than 1/10, where total dynamic range was limited to just 1/10.

Second, in the case of SDR images, the range used to reproduce medium tone was approximately 30 (i.e., 2^5). This is similar to the dynamic range of conventional SDR, e.g., color checker chart has 5 steps [7]. In addition, γ is smaller at nighttime than at daytime, everywhere. This suggests that color saturation is lower at nighttime than daytime. In other words, we perceive all colors to be pale at night.

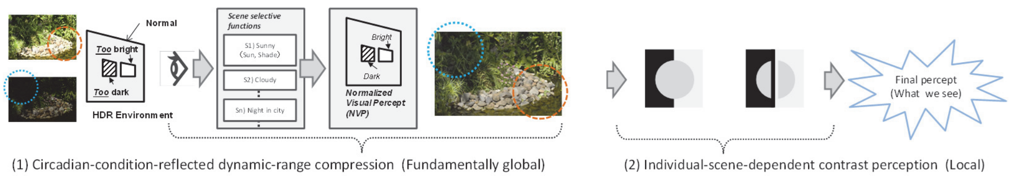
Third, in the case of LDR images, the high contrast areas shrink under daylight. This suggests that the locus of attention of the human observer is focused on the brighter parts in quite low contrast image environments, i.e., visually degraded environments. The reason is thought to be the human observer’s desire to preserve important information. In summary, with LDR images, the observer’s image preservation strategy approaches binarization instead of full gradation information. On the other hand, nighttime images exhibited curves similar in shape to those of SDR images; however, total dynamic range was decreased. Therefore, it is suggested that, in the case of twilight vision, the human observer pays attention widely, from dark to bright areas.

2.3 Realizing antinomy of incomparable sensitivity (approx. 30 times) and reproducing hyper-realistic quality

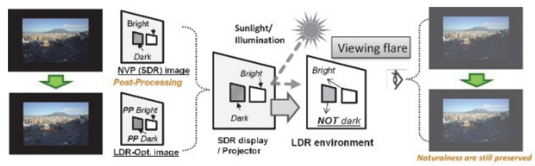
Setting pedestals higher than 1/100 (SDR) or 1/10 (LDR) offers another benefit. The dynamic range of SDR images is approximately 10^3.5. Therefore, if the dynamic range exceeds this value, the conventional approach is to use HDR images. However, this report finds that the darker parts of any original HDR image, less than 10^-3.5, contribute little to reproduced image quality.

This means that our proposal uses original SDR images, instead of HDR images, allowing the use of quite short exposure times, i.e., approx. 1/30 that of conventional SDR. This is described below.

ISSN 0097-996X/25/5603-1670-$1.00 © 2025



(a) Concept of transformation from real HDR scenes to normalized visual percept (NVP) in human visual system. SDR image is fairly good for recording NVP. It is assumed that human visual system executes scene dependent local processing after global processing (i.e., producing NPV) in earlier stage.



(b) Concept of transformation from SDR image (i.e., NVP recorded) to LDR images (e.g., image projected onscreen or image printed on normal paper) by post-processing.

Figure 1. Our hypothesis of two-step human visual perception. Contrast ratio (CR) can be reduced to 10:1 from approx. 10^5:1 while preserving natural tone.

3. Experimental result

3.1 Comparison of reproduced images by different methods

Figure 3 shows examples of image reproduction by hSDR (16bit and 8bit input), HDR-tone (8bit input) and cSDR, respectively. Here, “HDR-tone” is representative of local tone mapping (LTM) and the example shown was reproduced by Photoshop CS6 (setting was default). In case of 8bit input, images were converted to 16bit before GTM or LTM processing in order to prevent cumulation of errors. It is suggested that the tendency of brightness and color reproduction is similar regardless of day and night and independent scenes: (1) images by our proposals, i.e., columns (a) and (b), are natural, (2) HDR-tone is perceived darker in general and highly saturated, and (3) SDR has relatively high-contrast and narrow dynamic range with higher saturation (for more details, see ref [2]).

Figure 4 shows a comparison of histogram distributions (including LDR reconverted image) with partially enlargements for the case of scene D1. Please notice the difference in reproduced tone of two color chats [7] in enlargements, even they were small. First, in relation to the above mentioned (2) and (3), the histograms of (d) and (e) spread from min to max with both HDR-tone and conventional SDR, whereas the population was concentrated from mid to lower in the case of (d); but the population was distributed wider area for the case of (e).

Next, we move on to verification of the 8bit truncation artifact. In case of (a), the distribution shape of histogram was quite smooth, of course, whereas in case of (b) and (d), it had comb-like unnatural distributions in darker area. However, you may be able to find that less artifact was observed in the reproduced image. The reason is the degradation in the histogram was distributed widely in the real image space, similar to dither.

3.2 Discussion of sensitivity

Both our proposals and HDR-tone were reproduced from the original HDR image. However, conventional SDR needed much more exposure (See table 1; average increase was approximately 60 times within the samples). Authors would like to emphasize again that the exposure level needed to obtain high quality images was just 1/30 or so that of conventional SDR. Therefore, up to now, HDR-tone played a significant role from the viewpoint of sensitivity and visibility, whereas perceived naturalness was relatively overlooked. It is suggested, however, that our proposal offers better perceived naturalness while retaining similar visibility. We demonstrated this by the following subjective test.

4. Subjective test

4.1 Requirement placed on the observer

The accuracy of subjective judgments highly depends on personal ability [2]. Therefore, the first author, who made all tone mapping operations alone, chose two subjects, S1, and S2. One of them had special affinity for real space judgements [5]. The other observer exhibited superior performance in a previous experiment [2].

4.2 Experimental setup of subjective test and procedure

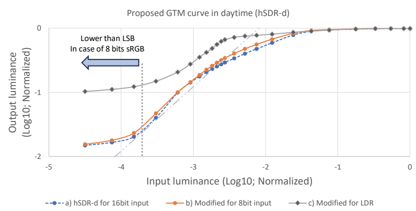
Figure 5 shows the setup. For obtaining stable judgment regardless of ceiling light condition, printed images were used. The illuminance at desk level was approx. 600 to 1000 lx. It was confirmed that observers were not able to perceive any change of brightness in the observing area. The test images were printed on ISO A4 material, and the reference large image, printed on ISO A3, was presented simultaneously. Observers were allowed to hold test images, resulting viewing distance was enough near. First, the experimenter explained the situation as being that the original image was captured, then they were to evaluate images by two criteria (a) perceived naturalness, and (b) visibility, by employing a five-grade quality scale (i.e., 1 to 5).

Observers basically evaluated each reproduced image 4 times (3 times in some sessions) in randomized order. Both ascending- and descending series were employed for canceling the order effect.

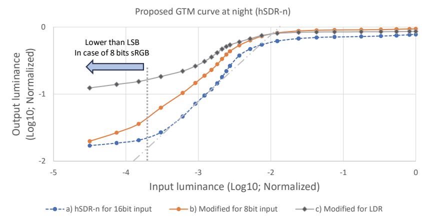
4.3 Experimental results and discussions

Figures 6 and 7 show the results. One-way ANOVA reveled there was no significant differences in all evaluations between 16bit input and 8bit input. Note that only “Not Significant (ns)” pairs are shown to avoid complexity. The same result was established by two post-hoc tests (Tukey and Bonferroni).

These results strongly suggest that our hSDR proposal with 8bit input had high performance in terms of naturalness perception at

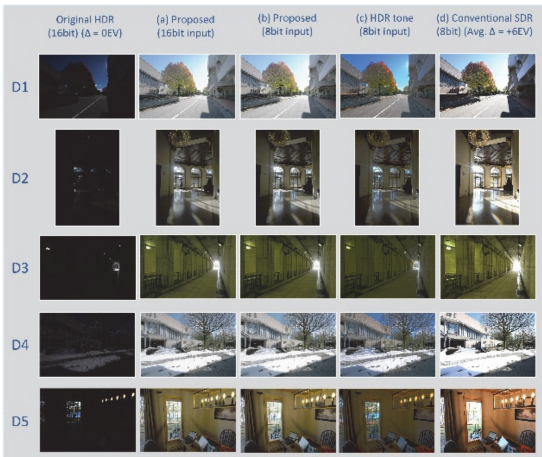


(a) Daylight



(b) Night

Figure 2. Derived hSDR (CR assumed 80:1) and hLDR (CR assumed 10:1) global tone mapping curves



(a) Daylight

(b) Night

Figure 3. Examples of image reproduction by hSDR (16bit and 8bit input, respectively), HDR-tone (8bit input) and cSDR.

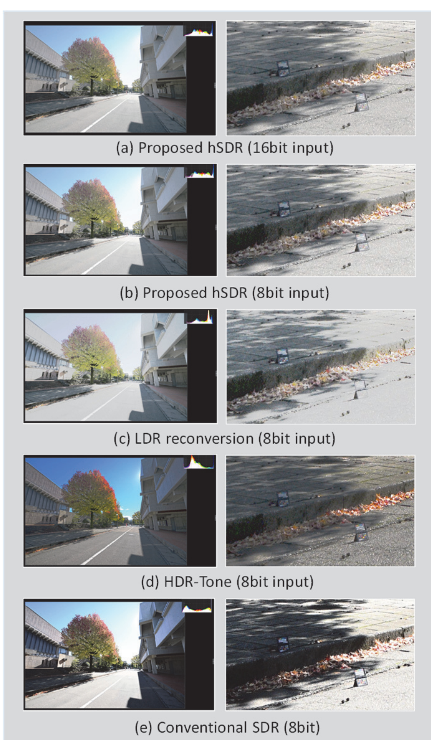


Figure 4. Comparison of histogram distribution (including LDR reconverted image) with partially enlarged in case of scene D1.

least while matching HDR-tone in terms of visibility. It is also suggested that our LDR proposal had relatively good performance as regards naturalness perception even though the reproduced dynamic range was very low.

5. Discussion

Space constraints prevent the disclosure of full detail, but given the chance to submit an extended full paper, more data and a fuller discussion will be provided.

One final note is that this study omits personal differences created by circadian rhythm in daylight [2], to ensure simplicity. We can elucidate this effect easily.

6. Conclusions

Perceptually natural SDR (Standard-dynamic-range) / LDR (Low-dynamic-range) images should retain enough information for the human observer to estimate the visual environment in which the actual UHDR (Ultra-high-dynamic-range) scene was captured, for not only daylight images but also twilight (mesopic) images.

Our current proposal includes two significant achievements. The first is that it employs only conventional SDR (cSDR) images, not HDR ones, with just approx. 1/30th exposure level (i.e., offering incomparable high sensitivity) for reproducing hyper-realistic quality SDR (hSDR) or LDR (hLDR) for both daylight and twilight vision, i.e., realizing antinomy. The second is that it employs only global-tone-mapping (GTM), suggesting that all that is needed for implementation is a one-dimensional look-up-table (1D-LUT).

This enables quite high compatibility with existing cSDR video monitoring systems for both on-vehicle and road systems, and

Table 1. Exposure data and difference between cSDR and hSDR

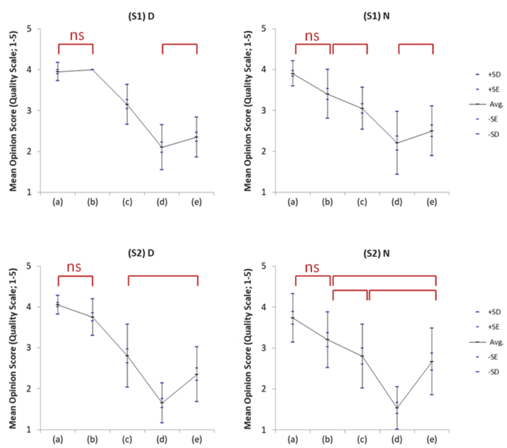
(a) Daylight

#	Short annotation	Exposure Value (EV)		Differences	Sensitivity ratio
		cSDR	hSDR	ΔEV	times
D1	Dazzling landscape with maple tree with autumn colors from building shade	12.0	16.7	4.7	26
D2	Hotel lobby with sunlight in San Jose	10.7	17.7	7.0	128
D3	Tunnel exit direction view from inside	6.3	12.7	6.4	84
D4	Dazzling snow scene	12.7	18.3	5.6	49
D5	Inside room view with extremely bright LED lights and sunset outside landscape	7.3	13.3	6.0	64
				(AM)	(GM)
			Average	5.9	61

(b) Night

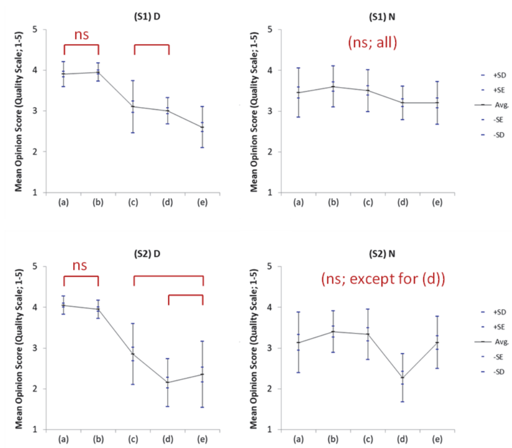
#	Short annotation	Exposure Value (EV)		Differences	Sensitivity ratio
		cSDR	hSDR	ΔEV	times
N1	Twilight city landscape in San Jose	5.7	11.0	5.3	39
N2	Night city intersection with dazzling head lights of cars (Korinbo, Kanazawa)	4.3	10.7	6.4	84
N3	Night city roads in front of San Jose Convention Center (dazzling digital signage)	3.7	10.3	6.6	97
N4	Firework view from dark suburb with rice fields (Nagaoka)	1.7	9.0	7.3	158
N5	Illuminated night cherry blossoms in Kenrokuen park (Kanazawa)	2.3	8.0	5.7	52
				(AM)	(GM)
			Average	6.3	77

Figure 5. Experimental setup



(a) Daylight (b) Night

Figure 6. Subjective test result 1: Perceived naturalness of reproduced brightness and color tone.



(a) Daylight (b) Night

Figure 7. Subjective test result 2: Visibility of reproduced image.

public digital information display systems.

7. Acknowledgements

Authors would thank Mr. KJ. Owaki for a detailed discussion on perceived tone evaluations of our proposal. Authors also would thank Dr. S. Hira and Ms. S. Iwaida for their long-term cooperation.

8. References

1. Ohtsuka, S., et al. (2020), 80-4: Human Visual System Uses Just a Few Transfer Functions Depending on Various Environments to Realize Normalized Visual Percept: Investigation Using Real Photographic Images. SID Symposium Digest, 51: 1202-1205. https://doi.org/10.1002/sdtp.14094
2. Ohtsuka, S., et al. (2024), Next Generation Personalized Display Systems Employing Adaptive Dynamic-Range Compression Techniques to Address Diversity in Individual Circadian Visual Features. J Soc Inf Display. https://doi.org/10.1002/jsid.1277
3. Ohtsuka, S., et al. (2024), 8-4: A New SDR Twilight Visual Image Display System Employing Ultra‐High‐Dynamic‐Range Image Capturing Technology aligned with Human Circadian Behavior, SID Symposium Digest 55(1):68-71. https://doi.org/10.1002/sdtp.17455
4. Ohtsuka, S., et al. (2024), VHF1-3: A New SDR Twilight Visual Image Display System Employing Ultra-High-Dynamic-Range Image Capture Technology Aligned with Human Circadian Behavior (2): Delivering Precise NVPs Regardless of Illumination Fluctuation, Proc. IDW2024, 31:829-932.
5. Ohtsuka, S., et al. (2025), Printing image re-conversion method for adopting to standard dynamic range (SDR) images converted from twilight ultra-high-dynamic-range (UHDR) images, Electronic Imaging Symposium 2025, IQSP-245. https://pcm.secure-platform.com/imaging/solicitations/102002/sessiongallery/94089/application/4380 (Proceedings will be appear later)
6. Thuillard, M. (2021), Analysis of the worldwide distribution of the 'man or animal in the moon' motifs, Electronic Journal of Folklore. 48: 127–144. https://doi.org/10.7592/FEJF2021.84.thuillard
7. X-rite, COLORCHECKER PASSPORT PHOTO 2, https://www.xrite.com/-/media/xrite/files/literature/l11/l11-200_l11-299/l11-293_colorchecker_targets_brochure/l11-293-colorchecker-targets_en.pdf, retrieved Dec. 26, 2024.