Multi-view 3D CG Image Quality Assessment for Contrast Enhancement Including S-CIELAB Color Space in case the Background Region is Gray Scale

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Abstract: In this paper, we experimented the subjective evaluation for 3D CG image including the gray scale region with 8 viewpoints parallax barrier method, and we analyzed this result statistically. Next, we measured about the relation between the luminance change and the color difference by using S-CIELAB color space and CIEDE2000. As a result, we obtained knowledge about the relation among the coded image quality, the contrast enhancement, and gray scale.

Keywords— **Contrast Enhancement, H.265/HEVC, Gray Scale, S-CIELAB Color Space, CIEDE2000**

1. Introduction

Thus far, there were studies for image quality assessment based on S-CIELAB color space including the spatial frequency characteristics of human vision system [1], [2]. We also carried out the quality assessment of multi-view 3D image [3], multi-view 3D image for contrast enhancement [4], and multi-view 3D image for contrast enhancement of the object region [5] based on S-CIELAB color space. As contents creators, we consider that they need not only to consider the coded degradation but also not stand out the background. We consider that it is possible for these to achieve by using gray scale in the background. In the 3D images including the luminance that affected to both the stereoscopic effect and the evaluation result, it is not clear that assessors are able to accept how degradation or luminance by whether background region is gray scale or not. Therefore, we need to verify about these problems. In this study, first, we carried out the quality evaluation experiment of 3D CG image encoded and decoded by H.265/HEVC for contrast enhancement in case the background region is gray scale, and then, we analyzed these results and classified for the luminance change and the coded image quality (Exp. 1). Next, we measured the luminance L^* objectively by transforming to S-CIELAB color space (Exp. 2). Finally, we measured the color difference objectively by using CIEDE2000 (Exp. 3), and compare among results.

2. Image quality evaluation experiment

2.1 3D CG images used in this study

In this study, we used 3D CG contents “Museum,” “Wonder World” provided by NICT [6] for free of charge as shown in Fig. 1 (a)-(f) in order to carry out the image quality evaluation experiment. As a generation procedure, we constructed CG cameras by the number of viewpoints on the virtual space generated the HD quality still image by 8 viewpoints. And then, we carried out the region division for the object and the background in still images by 8 viewpoints, and processed

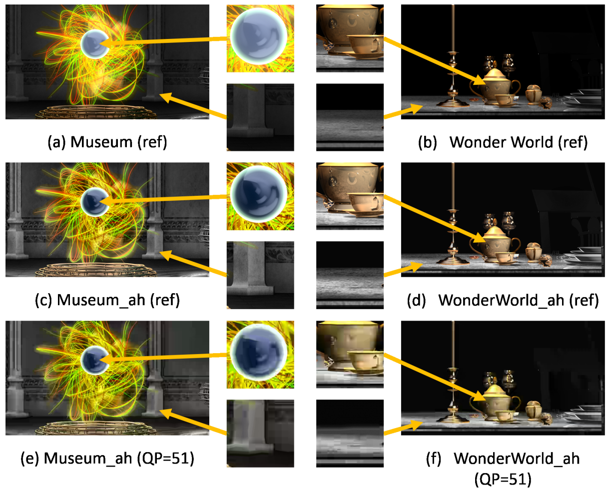

Figure 1. 3D CG images used in this study

gray scale transformation to the background region image. After that, we composed each regions again. Next, we carried out the contrast enhancement for generated images by carrying out the processing of Adaptive Histogram Equalization (AHE). On the other hand, we prepared 60 patterns of image sequences including the Quantization Parameter ($QP = 0(ref), 20, 30, 40,$ and 51) by H.265/HEVC, the Luminance change parameter ($Lum = 0(ref), 0.25, 0.5, 1, 2, 4$), and 3D CG contents.

2.2 S-CIELAB color space and CIEDE2000

Figure 2 shows the flowchart for the process from loading an image including gray scale background to transforming the S-CIELAB color space and CIEDE2000 [1]. We have explained the S-CIELAB color space and CIEDE2000 in Appendices A and B, therefore, please see the explanation of Appendices A and B in detail [1]. We show briefly from the following. Finally, L^*, a^*, and b^* are shown in Eq. (1)–(3).

$$L^* = \begin{cases} 116\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16 & \left(\frac{Y}{Y_n} > 0.008856\right) \\ 903.3\left(\frac{Y}{Y_n}\right) & (otherwise) \end{cases} \quad (1)$$

$$a^* = \begin{cases} 500\left[\left(\frac{X}{X_n}\right)^{\frac{1}{3}} - \left(\frac{Y}{Y_n}\right)^{\frac{1}{3}}\right] \left(\frac{X}{X_n}, \frac{Y}{Y_n} > 0.008856\right) \\ 500 * \left[\left[7.787\left(\frac{X}{X_n}\right) + \frac{16}{116}\right] - \left[7.787\left(\frac{Y}{Y_n}\right) + \frac{16}{116}\right]\right] \\ (otherwise) \end{cases} \quad (2)$$

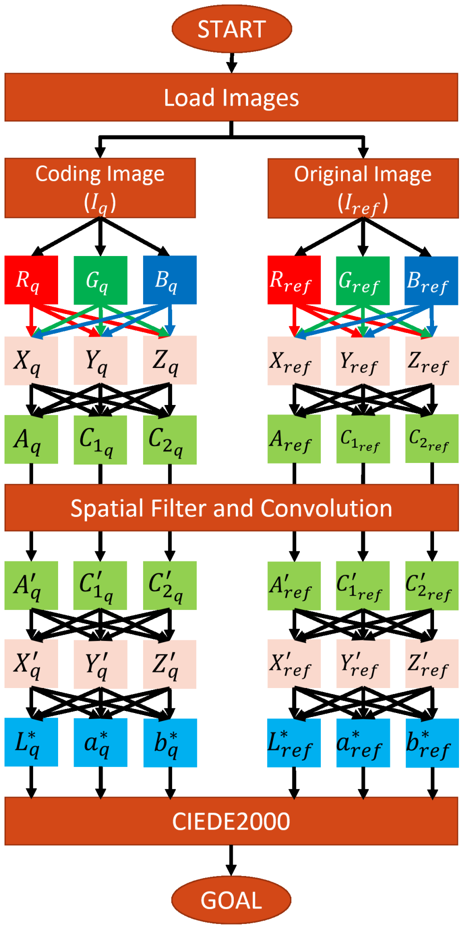

Figure 2. Flowchart from transformation of S-CIELAB color space to CIEDE2000

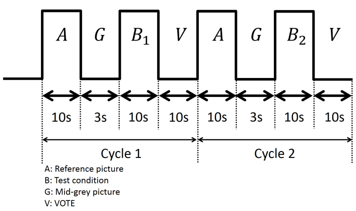

Figure 3. DSIS method

Table 1. EBU quality scale

Score	Quality
5	Imperceptible
4	Perceptible, but not annoying
3	Slightly Annoying
2	Annoying
1	Very Annoying

$$b^* = \begin{cases} 200\left[\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - \left(\frac{Z}{Z_n}\right)^{\frac{1}{3}}\right] \left(\frac{Y}{Y_n}, \frac{Z}{Z_n} > 0.008856\right) \\ 200 * \left[\left[7.787\left(\frac{Y}{Y_n}\right) + \frac{16}{116}\right] - \left[7.787\left(\frac{Z}{Z_n}\right) + \frac{16}{116}\right]\right] \\ (otherwise) \end{cases} \tag{3}$$

Finally, ΔE_{00} is shown in Eq. (4), (5).

$$\Delta E_{00} = \sqrt{L^2 + C^2 + H^2 + (R_T CH)} \tag{4}$$

$$L = \frac{\Delta L'}{K_L \cdot S_L}, C = \frac{\Delta C'}{K_C \cdot S_C}, H = \frac{\Delta H'}{K_H \cdot S_H} \tag{5}$$

2.3 Experimental content and assessment method

In this experiment, we used "Newsight" 3D display developed by Newsight Corporation [7].

As an assessment method of subjective quality evaluation experiment, from Fig. 3, first, we displayed reference image A for 10 seconds, and then mid-gray image G for 3 seconds. Next, we displayed test condition image B for 10 seconds. Subsequently, the assessor evaluated this cycle and inputted the assessment value into the computer application, which required 10 seconds. This cycle was defined one set, we repeated for an assessor until finishing the last set (five sets). As an experimental environment, we carried out the experiment based on ITU-R BT.500 [8], [9]. From Table 1, the assessor assigned evaluation scores according to five ranks (MOS (M_{MOS}, W_{MOS})). Here, we defined $MOS = 4.5, 3.5$, and 2.5 as "DL (Detective Limit)," "AL (Acceptability Limit)," and "EL (Endurance Limit)," respectively. For the objective assessment, as shown in Fig. 2, first, we decomposed the reference image and the coded image into R, G, and B components. Next, we transformed these component images to S-CIELAB color space, and we measured the luminance of each image sequences and the color difference by using CIEDE2000.

3. Experimental results and discussion

3.1 Result of Exp. 1

Figure 4 shows MOS in the vertical axis, QP in the horizontal axis. The error bar is extended vertically from the plot points in Fig. 4, which shows 95% confidence interval. From experimental result, we can verify the same tendency in $L = 0.25, 4.00$. In $L = 1.00$, M_{MOS} and W_{MOS} shifted before and after "AL" except for $L = ref$ since they are more than 3. On the other hand, when $QP \geq 40$ is satisfied, we can verify the decline of assessment value rapidly.

3.2 Statistical analysis by using Support Vector Machine

From results of subjective assessment, Table 2 and 3 show SVM result by using SMO algorithm of Weka 3.6 [10]. "Precision," "Recall," and "F-Measure" values greater than 0.7 are denoted in boldface font. Table 4 shows SVM correctly classified percentage. From Table 2, for Class (Lum), Precision of "lum_2," "lum_ref," Recall of "lum_0.25" are more than 0.7, however, correctly classified percentage in Class (Lum) is less 40%. Therefore, we can judge as "not classified." On the other hand, from Table 3, for Class (QP), most of "QP_ref," "QP_51" are boldface font because of more than 0.7, and correctly classified percentage in Class (QP) is also more than 0.7. Therefore, we can judge as "Classified."

3.3 Result of Exp. 2 and 3

From Fig. 5, as a whole, in "Museum," L^* shifted between 75 and 93. On the other hand, in "Wonder World," L^* shifted between 24 and 32. Therefore, the luminance difference among L^* in "Museum" is larger than those in "Wonder World." From Fig. 6, as a whole, the color difference ΔE_{00} in "Wonder World" are larger than those in "Museum."

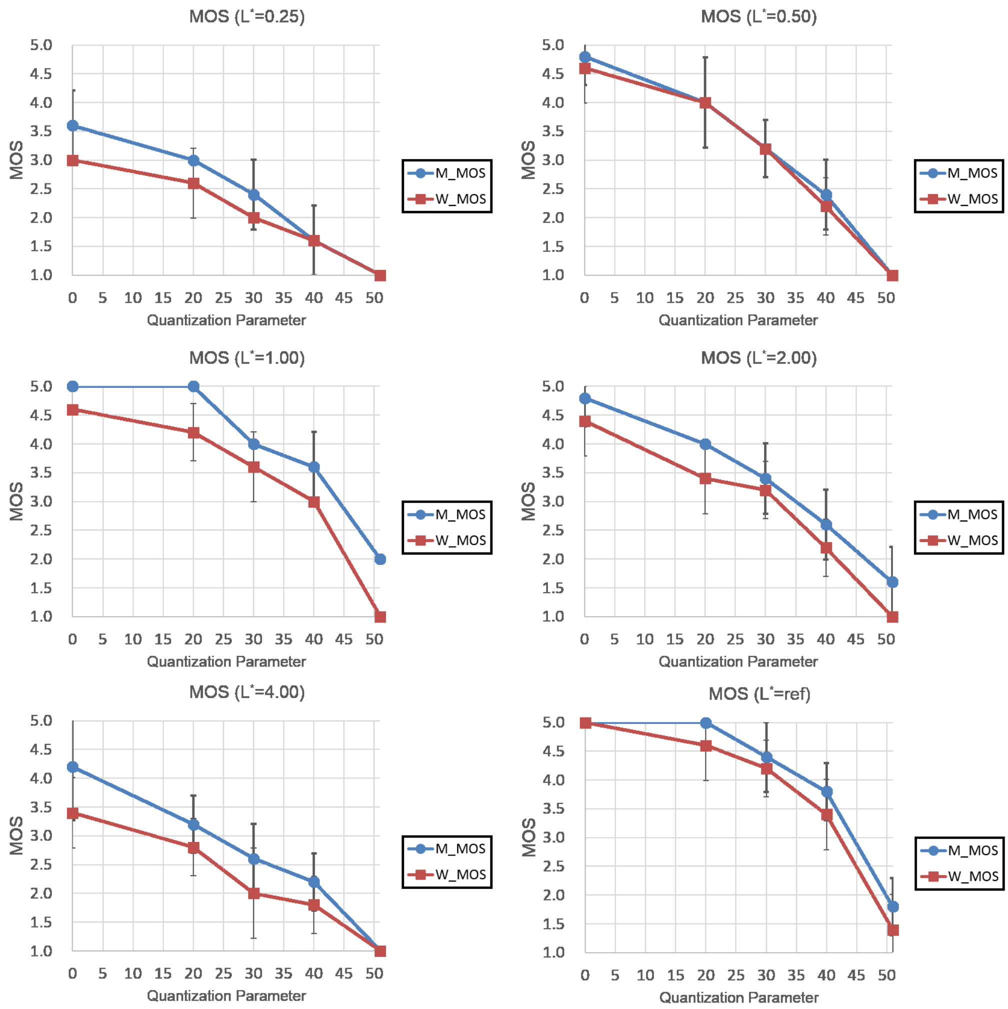

Figure 4. Result of Exp. 1 (MOS)

Table 2. SVM (Lum)

Precision	Recall	F-Measure	Class (Lum)
0.44	**0.87**	0.58	lum_ref
0.33	**0.76**	0.46	lum_0.25
0.56	0.36	0.44	lum_0.5
0.67	0.08	0.14	lum_1
0.75	0.12	0.21	lum_2
0.40	0.24	0.30	lum_4
0.52	0.42	0.36	Weighted Avg.

Table 3. SVM (QP)

Precision	Recall	F-Measure	Class (QP)
0.68	**0.80**	**0.73**	QP_ref
0.58	0.50	0.54	QP_20
0.61	0.63	0.62	QP_30
0.82	0.60	0.69	QP_40
0.86	**1**	**0.92**	QP_51
0.71	0.71	0.70	Weighted Avg.

3.4 Discussion

From experimental result of subjective assessment, in case the luminance parameter is higher or lower, assessment value tends to low, and in the case of nearly $L = 1$, assessment value tends to high. From this, we consider that when the luminance change is more than a few, assessment values are affected. From results of SVM, correctly classified percentage in “QP” is higher than that in “Lum.” From this, we consider that it is easy for the assessor to perceive change of the Quantization Parameter than that of the luminance.

Table 4. SVM (Correctly Classified Percentage)

Class	Total Number of Instances	Correctly Classified Instances	Percentage
Lum	155	65	41.9%
QP	155	110	**71.0%**

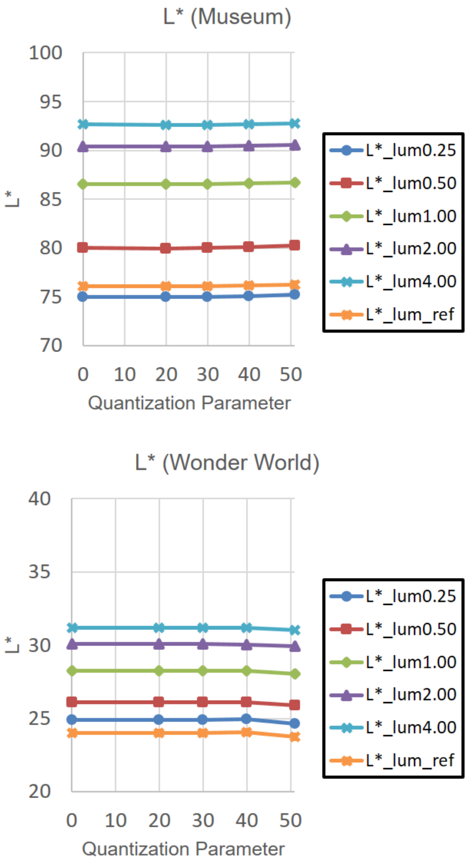

Figure 5. Result of Exp. 2 (L^*)

4. Conclusion

From experimental results in this study, we obtained knowledge that it is easy for the assessor to affect the coded image quality than the luminance change.

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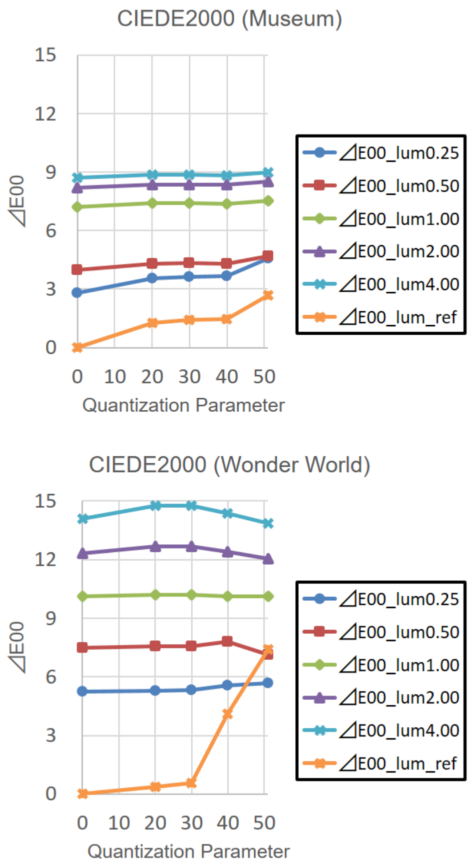

Figure 6. Result of Exp. 3 (ΔE_{00})

References

[1] G. M. Johnson, M. D. Fairchild, "A Top Down Description of S-CIELAB and CIEDE2000," *Color Research & Application*, vol. 28, no. 6, pp. 425–435, June 2003.

[2] J. Bai, T. Nakaguchi, N. Tsumura, and Y. Miyake, "Evaluation of Image Corrected by Retinex Method Based on S-CIELAB and Gazing Information," *IEICE Trans. Fundamentals*, vol. E89-A, no. 11, pp. 2955–2961, November 2006.

[3] N. Kawabata and M. Miyao, "3D CG Image Quality Evaluation Including S-CIELAB Color Space with 8 Viewpoints Glassless 3D," *Proc. of the 2015 IEICE General Conference*, A21-2, pp. 292, March 2015 (in Japanese).

[4] N. Kawabata and M. Miyao, "3D CG Image Quality Assessment for the Luminance Change by Contrast Enhancement Including S-CIELAB Color Space with 8 Viewpoints Parallax Barrier Method," *Proc. of The 1st International Conference on Advanced Imaging (1st ICAI2015)*, T107-01, pp. 632–635, June 2015.

[5] N. Kawabata and M. Miyao, "3D CG Image Quality Metrics for the Contrast Enhancement of the Object Region Including S-CIELAB Color Space with 8 Viewpoints Parallax Barrier Method," *IEICE Tech. Rep.*, vol. 115, no. 48, IMQ2015-4, pp. 17–22, May 2015.

[6] http://www.nict.go.jp/, accessed May 25, 2016.

[7] Newsight Japan, http://newsightjapan.jp/, accessed May 25, 2016.

[8] ITU-R BT.500-13, https://www.itu.int/rec/R-REC-BT.500/en, accessed May 25, 2016.

[9] N. Kawabata and M. Miyao, "3D CG Image Quality Metrics by Regions with 8 Viewpoints Parallax Barrier Method," *IEICE Trans. on Fundamentals*, Vol. E98-A, No. 08, pp. 1696–1708, August 2015.

[10] Weka, http://www.cs.waikato.ac.nz/ml/weka/, accessed May 25, 2016.

[11] N. Kawabata and M. Miyao, "3D CG Image Quality Metrics Including Gray Scale Region with 8 Viewpoints Parallax Barrier Method," *The 2015 ITE Annual Conference*, pp. 32B-2-1–32B-2-2, August 2015 (in Japanese).