The Influence of Constant Luminance on Digital Video

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Abstract

High-definition TV system or Digital Cinema system require more precise colour reproduction than what we've used since the invention of TV system in which images are encoded, transmitted, decoded, and finally displayed on the TV system or theatre screen. This paper describes the conventional method of TV signal CODEC and the constant luminance method. The differences in between images using conventional methods and constant luminance methods are also reported.

Introduction

The conventional television system uses non constant luminance scheme. There might be some leakage in the calculation of the colour difference components. In an ideal constant luminance system, all true CIE luminance information would be conveyed in the non linear luminance component Y.[1] It is worth implementing and testing the colour differences between the conventional method and the constant luminance method by using observer evaluation method.

There are four aims in this study, i.e. (1) to explain the theory of constant luminance signal coding, (2) to set up the experimental environments for evaluating the result of constant luminance signal coding, (3) to analyse the result of the evaluation experiment, and (4) to give an idea of future study with some conclusions.

Generally, the constant luminance signal coding provided better image quality in the region of magenta and green. In addition test images with high spatial frequency gave more significant visual effect in terms of constant luminance.

2. Constant Luminance

Colour video system consists mainly of gamma correction and luminance matrix. In a conventional encoding and decoding system, gamma correction is performed before and after processing the luminance matrix. *Figure 1* and *Figure 2* show the conventional video signal encoding and decoding methods.

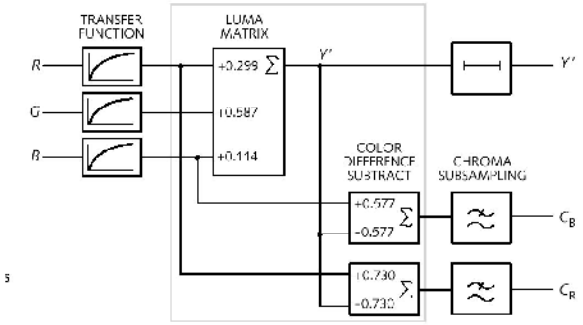

Figure 1 Conventional video encoding

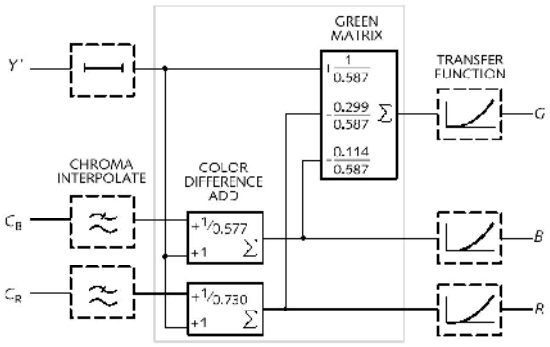

Figure 2 Conventional video decoding

Due to the non linearity in calculating Y from the gamma corrected R,G,B, some brightness information necessarily leaks into the colour difference components.[1] Although there are other defects in using conventional signal coding system,[1] this coding system is widely used by ease of implementation. For the purpose of reproducing correct image colour in a HDTV or high quality DTV, conventional video coding system no longer valid. And a constant luminance signal coding should be used in order not to loose any luminance leakage or colour information

when transforming video signal. Figure 3 and Figure 4 show the constant luminance signal coding methods.

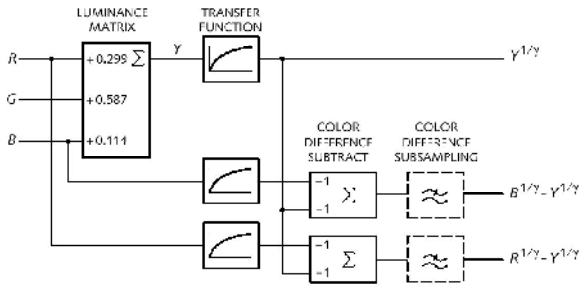

Figure 3 Constant luminance video encoding

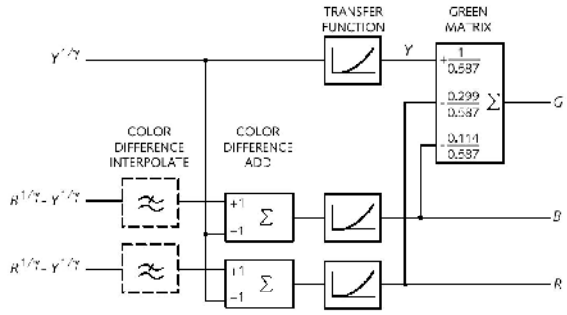

Figure 4 Constant luminance video decoding

3. Experimental Environments

BARCO CRT monitor was used in this experiment. Before starting main experiment, channel additivity and spatial uniformity test were carried out. *Table 1* shows the result of channel additivity test and *Table 2* does result of spatial uniformity test.

Also, *Figure 5* shows the results of the temporal stability test of BARCO CRT for the luminance and the chrominance. The series of preliminary tests for the monitor show that BARCO monitor used in the main experiments has appropriate reproduction performance.

Four images were used: "Ski", "IT8", "Colour bar", and "Z20". *Figure 6* through *Figure 9* show those test images. The Ski and IT8 images are standard images and generally used for the evaluation. Colour bar and Z20 images are specially reproduced for the evaluation of constant luminance signal coding.[3] The experiments were carried out in a darkened room. The experiments consist of two stages, one was to evaluate the overall image pleasantness and the other was to evaluate the accuracies for the overall image quality and for each colour regions of the test images.

Figure 6 Ski

Table 1. Chromaticities of the primary and white colours

	X	Y(cd/m2)	Z
White	56.16	59.02	65.38
Red + Green + Blue	56.22	59.17	65.43
Difference(%)	0.11%	0.25%	0.08%

$$* \text{ Difference}(\%) = \frac{(R+G+B)-White}{(R+G+B)} \times 100(\%)$$

Table 2. Calculated results for the spatial uniformity test

No.	ΔL^*	ΔE^*_{ab}	No.	ΔL^*	ΔE^*_{ab}	No.	ΔL^*	ΔE^*_{ab}	No.	ΔL^*	ΔE^*_{ab}	No.	ΔL^*	ΔE^*_{ab}
1*	-3.77	4.93	6	-2.36	3.37	11	-0.64	2.93	16	-1.64	3.83	21	-5.29	6.10
2	-4.15	4.85	7	-1.21	1.62	12	-0.35	2.01	17	-0.49	1.51	22	-3.85	4.37
3	-1.93	3.20	8	0.63	1.27	13	0.00	0.00	18	-0.42	0.82	23	-2.14	2.55
4	-2.00	2.12	9	-1.28	1.72	14	-1.21	1.66	19	-2.14	2.43	24	-3.70	3.94
5	-1.06	3.64	10	-1.21	1.62	15	-1.06	1.52	20	-1.35	1.35	25	-3.25	3.53

*Total 25 points were measured, No. 1 is the top left position and 5 points were numbered from left to right in the front row and then 5 lines were given vertically, and ΔL^*, ΔE^*_{ab} in CIE 1976 L*a*b* coordinate system was calculated with a reference data No. 13 tristimulus values at the center of the CRT display.

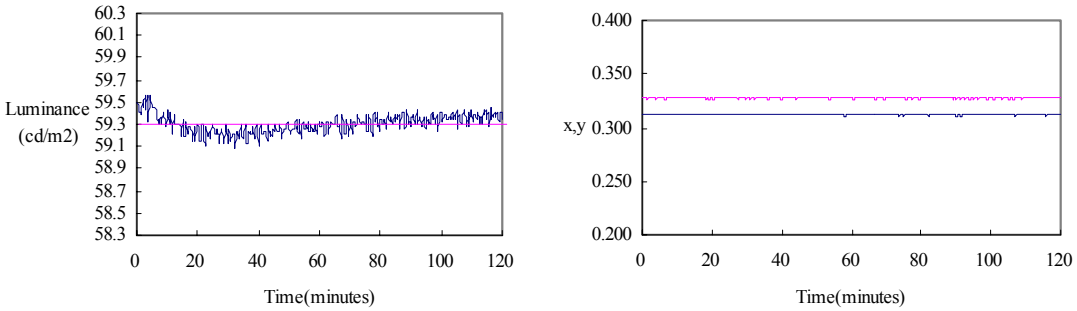

Figure 5. Results of temporal stability test for the luminance and the chrominance.

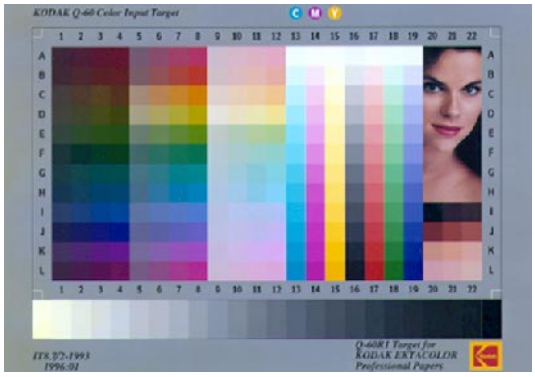

Figure 7. IT8

Figure 8 Colour bar

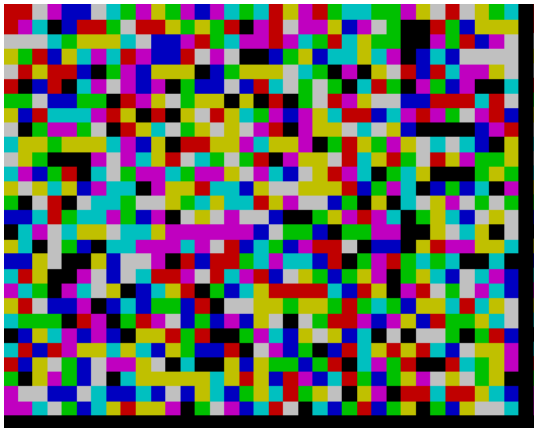

Figure 9 Z20

Eight observers with normal vision took part in this experiment, and pair comparison method[2] was used to evaluate the experiments. At first stage, the original image was displayed on the BARCO CRT, then two transformed images, one by conventional signal coding method and the other by constant luminance signal coding were displayed side by side. Observers could go back to the original image any time to determine which one was more pleasant within the given time interval, 10 seconds(pleasantness test). At the second stage, the original image was displayed on a on the same monitor as the first stage for 10 seconds, then neutral background was displayed for 5 seconds to avoid afterimage effect.[2] Finally, two transformed images, one by conventional signal coding method and the other by constant luminance signal coding were displayed side by side. Observers can go back to the original image any time to determine which one is more accurate within the given time interval, 10 seconds(correctness test).

4. Analysis

CIELAB colour differences between the original images and processed images by conventional signal coding method and those by constant luminance method were calculated and *Table 3* and *Table 4* show the results. This analysis is aimed to reveal the quantitative colour differences between original and two different transformation methods.

Table 3 and *Table 4* show that overall colour difference is smaller in case of constant luminance method than that of conventional method. As expected chroma and hue colour differences are smaller than luminance difference in general.

It can be seen from each corresponding Δ values in between Table3 and Table4 that the differences are quite small and those amounts of differences are rarely distinguished in normal image and viewing condition. However, the differences are mainly concentrated on the edges in constant luminance method and we can recognize the differences. Also images contain more edges tend to have bigger difference than others.

Overall z score results were also calculated not only for the accuracy but also for the pleasantness based on Thurstone's law of comparative judgement[4]. *Figure 10* and *Figure 11* show the z (accuracy) score results for the images and for the colour regions respectively. In *Fig. 10,* the z (accuracy) score of the colour bar image is relatively smaller than that of other images, this means observers can hardly distinguish the colour differences when target image is consist of solid colours. *Figure 11* also shows that

individual colour regions in the images processed by constant luminance method outperforms those by conventional method.

Figure 12 shows the z (pleasantness) score result based on Thurstone's law of comparative judgement. Like the test results of accuracy test, constant luminance method outperforms the conventional method over all test images. In *Figure 12*, Z20 image has the biggest difference in z score and other three images have the similar z scores. It can be analysed that images which have high frequency and high chroma are more sensitive than others.

Table 3 CIELAB colour differences between original image and conventional method

	ΔL*	ΔC*	ΔH*	$\Delta E^*_{CMC(1:1)}$	ΔE^*_{ab}
COLOR BAR	0.41	0.02	0.02	0.32	0.41
IT8	0.50	1.13	1.02	1.20	1.81
SKI	1.50	2.50	1.75	2.47	3.87
Z20	3.81	5.95	4.55	7.16	9.86
sum	6.22	9.60	7.34	11.14	15.96

Table 4 CIELAB colour differences between original image and constant luminance method

	ΔL*	ΔC*	ΔH*	$\Delta E^*_{CMC(1:1)}$	ΔE^*_{ab}
COLOR BAR	0.37	0.02	0.01	0.30	0.37
IT8	0.47	1.04	0.93	1.10	1.67
SKI	1.28	2.17	1.44	2.13	3.30
Z20	2.87	4.67	3.60	5.65	7.67
sum	4.98	7.89	5.98	9.18	13.00

Figure 10. Z (accuracy) scores for each images

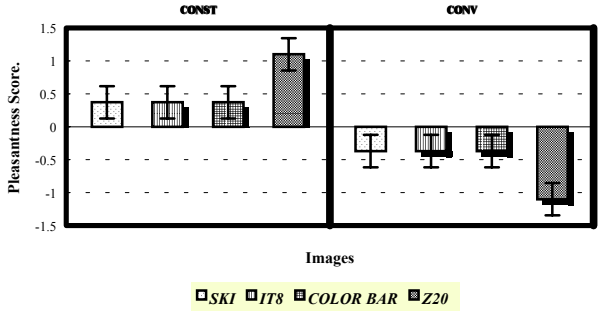

Figure 12 Z (pleasantness) scores for each images

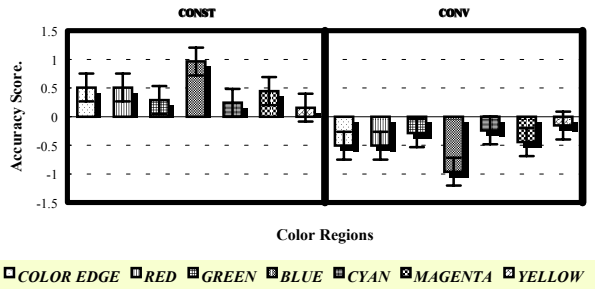

Figure 11. Z (accuracy) scores for each colour regions

5. Conclusions and Future Studies

Constant luminance signal coding method was implemented and tested in this study. Two images and two specially reproduced images were used in this study. Based on Thurstone's law of comparative judgement, psychophysical experiments were carried out. Generally, constant luminance signal coding method outperformed the conventional method in both cases of image accuracy and image quality. More experiments about constant luminance method will be carried in the future study and various test images including moving stream will be included in the study.

References

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