Colorfulness Enhancement Using Image Classifier Based on Chroma-histogram

Moon-cheol KIM[1], Kyoung-won LIM[2]
(1. *Color Media Institute, Korea Polytechnic University, Siheung* 429-793, *Korea*;
2. *Digital TV Lab. LG Electronics. Inc., Seoul University, Seoul* 151-742, *Korea*)

Abstract – The paper proposes a colorfulness enhancement of pictorial images using image classifier based on chroma histogram. This approach firstly estimates strength of colorfulness of images and their types. With such determined information, the algorithm automatically adjusts image colorfulness for a better natural image look. With the help of an additional detection of skin colors and a pixel chroma adaptive local processing, the algorithm produces more natural image look. The algorithm performance had been tested with an image quality judgment experiment of 20 persons. The experimental result indicates a better image preference.

Key words – *colorfulness enhancement*; *image classification*; *chroma histogram*

Manuscript Number: 1674-8042(2010)02-0112-04

dio: 10.3969/j.issn.1674-8042.2010.02.03

1 Introduction

In a computer-based image processing system and in consumer electronics such as DTV-System, the colorfulness of still and moving pictures is altered by various reasons. Possible reasons are a systematic capturing error by an image Pick-Up system, a device dependent color correction system and an influence of a transfer channel. Especially in DTV system, the fluctuation of image colorfulness occurs in dependence of time and broadcasting channels. As a result, it sometimes produces unnatural image look. Hence, it may be needed to adjust the colorfulness of images timely in optimal stand[1]. To do this, a conventional method adjusts the amplifying gain of chrominance signals. However, such type of simple enlargement of the colorfulness may not be sufficient for various types of images and memory colors, which typically registered in human brain like skin, green grass, and blue sky colors respectively[2-4].

As well-known, image quality is a very complex psychophysical function, which usually depends on physical attributes of image quality, a type of scenes, and a cognitive influence of observers[3-6]. Therefore, overall increasing of an image quality is a very big challenging task and a time consuming process. So, in this paper, we limit and try to enhance only a colorfulness of image as one of physical factors for the image quality.

2 Image enhancement algorithm

In order to enhance image quality, we classified the image types and computed an amount of colorfulness using a Probability Density Function (PDF) of chroma signals of individual images.

From the determined chroma PDF, a type of images can be classified into a natural, a monotone, and a test pattern type images. With this information, a scene type adaptive gain is globally applied to the entire image pixels to enhance the colorfulness. This art of scene adaptive processing ensures more natural image look of enhanced images and could be maximized image preference to observers.

Return to the scene type detection algorithm, a typical natural image usually has a continuous distribution in a chroma PDF. However, most pattern-like images usually have a discrete distribution of histogram. So, we determined the decision property P in Eq. (1) which is an average sum of absolute differences of the neighbored probability density distributions of the chroma histogram $H(i)$.

$$P = \frac{1}{N}\sum_{i=1}^{N-1} | H(i) - H(i+1) |, \qquad (1)$$

where N is the total number of bins.

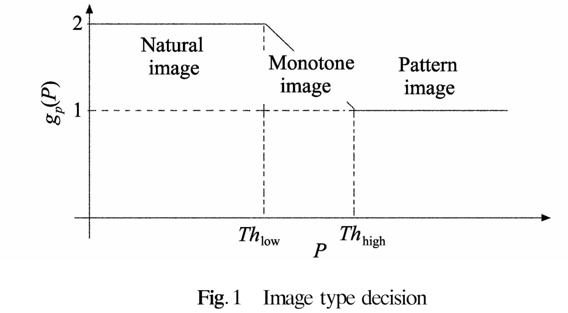

Fig. 1 Image type decision

Using the determined P, the pattern gain $g_p(P)$ can

※ **Received**: 2010-03-08
Project supported: This work was supported by System IC 2010 Project (No. 10030518), the MKE(Ministry of Knowledge Economy, Korea)
Corresponding author: Moon-cheol KIM(mckim@kpu.ac.kr)

be calculated by the predefined function in Fig. 1. As shown in Fig.1, the gain will be decreased from $P=2$ to $P=1$, where two threshold values represents as decision bounds for natural and pattern image types. Thereby, the threshold values may be obtained experimentally, typical values in our experiments $Th_{low} = 0.5$ and $Th_{high} = 0.9$. The g_p gain is superior to any other gains in the following chapters and it can adaptively suppress the chroma enhancement in function of scene types.

Using the determined P , the pattern gain $g_p(P)$ can be calculated by the predefined function in Fig. 1. As shown in Fig.1, the gain will be decreased from $P=2$ to $P=1$, where two threshold values represents as decision bounds for natural and pattern image types. Thereby, the threshold values may be obtained experimentally, typical values in our experiments $Th_{low} = 0.5$ and $Th_{high} = 0.9$. The g_p gain is superior to any other gains in the following chapters and it can adaptively suppress the chroma enhancement in function of scene types.

In addition, an average colorfulness of a scene can be determined from the chroma PDF. This representative mean chroma let us know how much colorful of the input image is. According to the previous research result on the image quality[2, 3, 5-6], we applied the enhancing gain in function of the determined mean chroma C_M like in Fig.2, so that a level of colorfulness of an individual image may be tuned in a more preferred stand. The heuristic value of Tm and Th can be chosen in the range of 0.25～0.3 and 0.5～0.6, so that images with low chroma may be enhanced into images with a sufficient colorfulness.

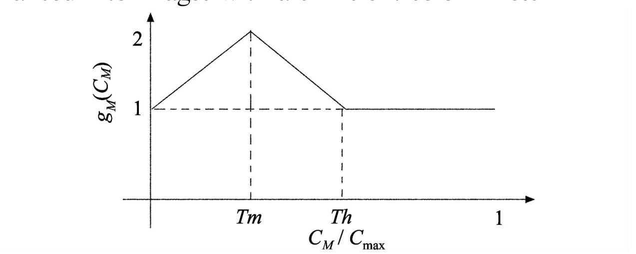

Fig. 2 Mean chroma CM adaptive enhancing gain *gM*

After the global processing, a local enhancement can be applied further. The aim of the local processing is thereby a pixel-based colorfulness enhancement and a selective control of an unnatural effect of skin colors.

To do this, a chroma level of each pixel must be determined first of all. And then, according to the Fig.3, an enlargement gain $g_L(C)$ can be computed for the chroma C . This local gain $g_L(C)$ should be applied to the chrominance signal of each pixel. As shown in Fig.3, the gain is constructed in function of the determined chroma C . The gain increases from unity (bypass) to a free selectable maximum gain (g_{max}) until a certain level of chroma Tc (roughly 3040% of maximum chroma C_{max}), which has been determined experimentally, and over this level decreases to unity reversely. This shape of the gain function was considered by the previous research result in which the image quality can be increased with the increasing chroma until about 60% of the maximum chroma[2,5]. In addition, highly saturated colors by this process do not exceed the range of color gamut so that an expensive gamut mapping algorithm does not required, respectively[7-8].

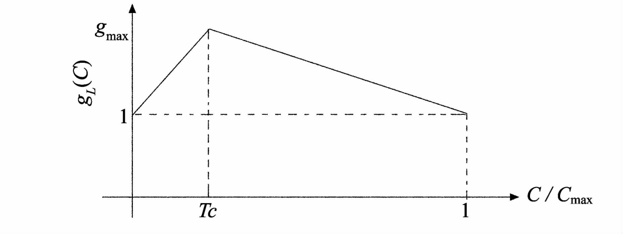

Fig. 3 Pixel enhancing gain for pixel chroma *C*

The algorithm together with the global and the local enhancement usually can elevate the colorfulness of image. However, an over-enhanced chroma value in human skin colors-disturbs a natural image look. Therefore, a suppression chroma gain of image pixels around the skin color range had been added in the system. Thereby, the range of the ideal skin color had been determined by the dichromatic skin model in the 3-dimensional color space under D65-illuminant (Tab.1)[9-11].

Tab. 1 Ideal human skin color range in ITU-R.BT.709 YCBCR color space

	Y	Cb	Cr	C	H
Ideal skin tone range	0.38～ 0.7	−0.12～ −0.05	0.05～ 0.1	0.078～ 0.153	123°～ 152°
Mean(m)	0.51	−0.074	0.098	0.124	126°
Variance(σ)	±0.08	±0.02	±0.01	±0.018	±8°

In the algorithm, if the color range of a given pixel is far from the defined $1-\sigma$ skin range in the three dimensional YCbCr color space, the enhancement of chroma can be applied in normal way. In contrast, if a color of pixel locates in the defined skin color range, a suppressing chroma gain is calculated in function of the distance from the mean coordinates ((Y_m, C_{bm}, C_{rm}) or (Y_m, C_m, H_m)) of ideal skin color. And, it might be applied to suppress the chroma enhancement of the skin colors so that the naturalness of the human skins could be preserved.

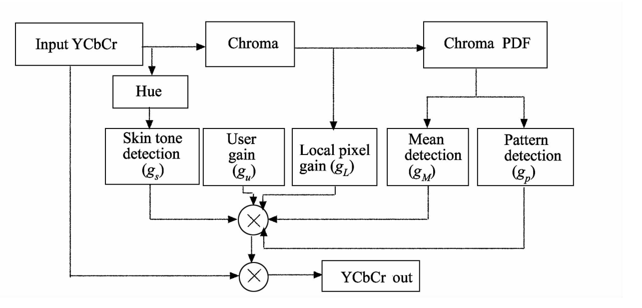

Fig. 4 Algorithm block diagram

The block diagram of the total color enhancement system shows in Fig. 4. The system had been implemented for YCbCr standard color space for DTV[12]. For input

YCbCr signal, the pixel chroma should be computed first of all. In the following, the local gain can be calculated for this chroma on one hand, on the other hand the chroma PDF can be build up for whole image pixels. Using the constructed PDF, we can compute the average chroma for image frames, the decision value P for an image type, and also image type dependent gains (g_P, g_M) successively. For the skin color detection, the input rectangular coordinate signals (C_b, C_r) can be transformed to the polar coordinate signals (C, H) via chroma and hue computation block in Fig. 4, in order to make a simple detection of the skin color region. With these values, the suppressing skin color gain can be calculated. All computed gains and one additional user gain can be merged as a final enhancing gain for each pixel $g(i)$.

$$g(i) = g_u \cdot g_p \cdot g_M \cdot g_L(i) \cdot g_s(i). \qquad (2)$$

Finally, the total gain $g(i)$ can be applied to the input chrominance signal (C_b, C_r) to enhance the colorfulness of images.

3 Results

Typical results of the algorithm are found in Fig. 5, 6, 7. If an input image has a poor colorfulness like Fig.5(a), the algorithm enhances the colorfulness of the image like Fig. 5(b). However, if an input image has enough colorfulness like Fig.5(c), the algorithm does not elevate image colorfulness like Fig.5(d).

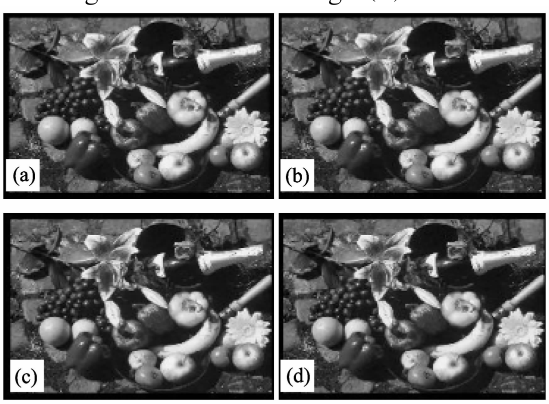

Fig. 5 Typical colorfulness enhancement based on a mean chroma of input images: (a) input image with poor colorfulness, (b) enhanced output for (a) image, (c) input with good colorfulness, (d) bypassed output for (c) image

For pattern and monotone type images, the pattern detection algorithm will be active so that the pattern images, which are originally designed for test, can be then bypassed. For monotone type images, the algorithm adaptively reduces the enhancing gain for the natural image look. Because of the human visual system, an observer perceives more colorfulness of monotonic images than normal complex images like Fig. 5. Fig. 6 shows this monotone type image simulation. The input image Fig.6(a) with the monotonic sky tone was enhanced without the adaptive gain g_P, it resulted in an over-enhanced colorfulness for the human observer like Fig. 6(b). This effect especially comes out on a large screen size display. Fig.6(c) indicates the result with reduced colorfulness by the adaptive gain g_P for natural image look.

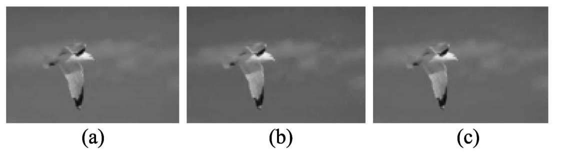

Fig. 6 Monotone type image enhancement: (a) input image, (b) output without gain g_p, (c) output with gain g_p

Fig. 7 (a) input, (b) conventional enhancement output (unnatural skin colors), (c) detected skin colors, (d) output image with skin color suppression

Fig.7 shows the result of the selective skin color control. The input image (Fig.7(a)) will be enhanced without the adaptive skin color processing, so achieved the output image with the unnatural skin color like Fig.7(b). Fig.7(c) shows the image with skin color region detection. The detected skin color pixels are marked in grey. Thereby some buildings in the background are also detected as a part of the skin color. With a reduced color gain in the detected skin color region, shows the output result in Fig.7(d) with more natural image look. At the same time, the other colors have been enhanced in normal way.

4 Image qulaity evaluation

The developed algorithm had been tested for 20 observers (5 females and 15 males) in the age range of 23~35 using the Double Stimulus Continuous Quality-scale (DSCQS) method of ITU-R. BT-500 with the 5-step scale values (much better (5), better (4), equal (3), bad (2), and worse (1))[13]. The 10 test images are selected from the published KODAK images and their colorfulness are reduced to the 50% and 25% saturation by the conventional Adobe Photoshop. So, total 30 input images were made (Fig.8). These original images and the output images by the proposed algorithm were pair-wise showed to the test person according to the DSCQS method of ITU-R. BT500 recommendation.

The test result shows in Fig.9 as the statistical box-whisker plot and their statistical reports in Tab.2. The image quality enhancement by the proposed algorithm is clearly increasing with the decreasing saturation of the test images. Total image quality enhancemeot! has been reported in the average 3.77 and the variance about 0.56.

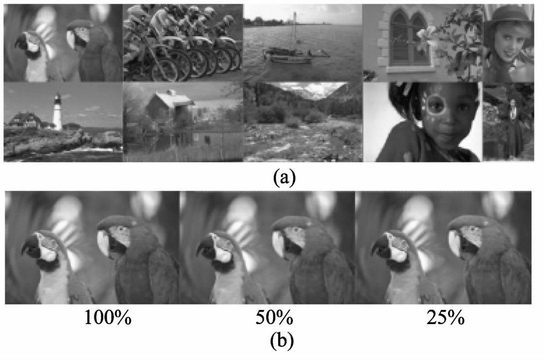

Fig. 8 (a) KODAK test images, (b) images with reduced saturation to 50% and 25%

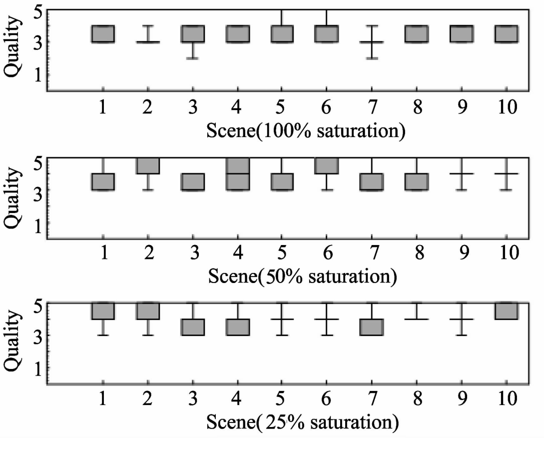

Fig. 9 Image quality observer test

Tab. 2 Statistical report of image quality

Test image set (saturation)	100%	50%	25%	Total
Mean(m)	3.4	3.88	4.04	3.77
Variance(σ)	0.41	0.59	0.48	0.56

5 Conclusion

In the paper, the statistical distribution of chroma based colorfulness enhancement of an image has been introduced, in which two major terms of the mean chroma and the pattern decision value P of an image are evaluated from the chroma histogram. They are taking into account as the decision parameters for the enhancing color gain. Besides, the local gain function has been applied for the chroma enhancement of each pixel. With these, a typical colorfulness enhancement of images may be achieved by the proposed algorithm.

However, with this concept may not sufficient for variety scenes in real world. One of disturbances is the skin tone problem. The simple skin tone detection algorithm was applied to detect skin colors and it allows suppressing the chroma enlargement of the skin colors. But, the introduced simple detection algorithm is not able to distinguish the human skin from other objects with the same skin colors. But it is rarely significant for human eyes, because the algorithm keeps the original color (bypass). The other enhancing task is the process for the pattern and monotone type image. The algorithm preserves the pattern type image and performs an adaptive enhancement for the monotone type images.

References

[1] R. Eschbach, B. W. Kolpltzik, 1995. Image-Dependent Color Saturation Correction in a Natural Scene Pictorial Image. U.S. Patent. 5,450,217.

[2] T. J. W. M. Janssen, 1999. Computational Image Quality, Center for User-System Interaction. Technical University of Eindhoven, Netherland.

[3] N. Sergej, Yendrikhovskij, 1999. Color Reproduction and the Naturalness Constraint, Center for User-System Interaction. Technical University of Eindhoven, Netherland.

[4] M. D. Fairchild, 1997. Color Appearance Models. Addison-Wesley.

[5] P. G. Engeldrum, 2000. Psychometric Scaling: A Toolkit for Imaging Systems Development. Imcotek Press, Winchester, MA.

[6] S. Fernandez, M. D. Fairchild, 2002. Observer preferences and cultural differences in color reproduction of scenic images. IS&T/SID 10th Color Imaging Conference, Scottsdale, p. 66-72.

[7] P. G. Herzog, H. Buering, 2000. Optimizing Gamut Mapping: Lightness and Hue Adjustments. *Journal of Imaging Science and Techn*., 44(4): 480-485.

[8] J. Morovichi, CIE Technical Report (CIE 156:2003) for Gamut Mapping.

[9] M. Stoering, H. J. Anderson, E. Granum, 2001. Physic based modeling of human skin colour under mixed illuminants. *Robotics, and Autonomous Systems*, 35(3-4): 131-142.

[10] M. Stoering, H. J. Anderson, E. Granum, 1999. Skin Color Detection under Changing Lighting Conditions. 7th International Symposium on Intelligent Robotic Systems, Coimra, Portugl, p. 187-195.

[11] Moon-cheol Kim, Jae-hwan Oh, 2002. Human Favorite Skin Color Enhancement. IEEK. p. 5-8.

[12] International Telecommunication Union. Recommendation ITU-R BT. 709-4, Signal Parameter Values for the 1125/60/2:1 System and the 1250/50/2:1 System.

[13] ITU-R BT. 500-11, Methodology for the subjective assessment of the quality of television pictures.