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A Gamut Compression Algorithm Based on the Image Spatial Characteristics

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Abstract. Since the traditional gamut compression algorithms will fail to consider the image spatial characteristics, a novel gamut compression method based on the image spatial characteristics is proposed in this paper. At first, the image is compressed by traditional compression algorithm, then the compensation values of lightness and chroma obtained by a high-pass filter are added to the compressed image. Finally, a gamut clipping processing is carried out. Experimental results indicate that the proposed method can not only guarantee the color features, but also preserve the image spatial characteristics quite well.

Introduction

Since different color reproduction mediums have different color gamut, image reproduction across device and media is bound to face a problem: colors of the original mediums or images with high chroma or high lightness can't be accurately reproduced because they are beyond the gamut of reproduction medium [1]. Therefore, it is necessary to do gamut mapping to make all image colors can be reproduced in the reproduction medium.

Gamut mapping methods can be divided into two categories: gamut clipping and gamut compression [2]. Color gamut clipping algorithm clips the colors which outside the reproduction medium gamut to the gamut boundary and keeps the colors within the reproduction medium gamut unchanged. Color gamut compression algorithm compresses all colors of the original gamut to the reproduction gamut in proportion, even colors inside the gamut will be compressed to the reference points closely. If minimum color difference is the goal, gamut clipping is no doubt better than gamut compression. However, Morovic and Luo suggested that the relationship between the image colors is more important than the accuracy of a single color in 1997[3]. Therefore, the concept of “what you see is what you get” aims at the whole image instead of some specific colors. That is to say, for the whole image, keeping the colors relationship is more important. Thus the gamut compression is usually chosen to do gamut mapping without special needs (such as digital proofing). CIE technical committee of gamut mapping TC8-03 presents SGCK gamut compression algorithm by combining the advantages of GCUSP and SLMCKS [4,5]. ICC specification also recommended SGCK gamut compression method for perceptual intent [6].

Current gamut compression mapping algorithms are based on color gamut of original device gamut and reproduction device gamut. It has two problems: first of all, generally speaking, image gamut is a subset of device gamut. If color gamut is compressed according to device, it will lead to the reduction of contrast and lightness and the distortion of chroma. In the second place, it fails to consider the image spatial characteristics, which will damage the spatial characteristics and result in losses of local details. Aiming at solving the above two problems, this paper proposes a gamut compression algorithm based on the image spatial characteristics.

A Gamut Compression Algorithm Based on the Image Spatial Characteristics

The basic principle of gamut mapping is to preserve the color hue unchanged, so the popular gamut compression algorithms are conducted on the hue angle plane of color points to be mapped. Since the neighboring pixels in the image are much likely to belong to different hue angles, the compression rates of lightness and chroma in different hue angle planes cannot be the same when conducting gamut compression. Therefore, those algorithms only considering overall colors will lead to the losses of local details, thus damaging the spatial characteristics of original image.

If the traditional algorithms are adopted to do gamut compression, the losses of lightness and chroma (ΔL and ΔC) can be calculated respectively. Then adjust them to the range 0~255 and save them as images, as is shown in Fig.1. (a) is the original image, (b) and (c) are the results of lightness loss and saturation loss. The parts of ΔL and ΔC with high frequency correspond to the areas in original image with large amount of compression in themselves and small amount in neighborhoods. Therefore, it is easy to understand the local loss of details. If the parts with high frequency are compensated appropriately to make the losses consistent with the losses of lightness and saturation of neighboring areas, the contrast invariance of overall colors can be guaranteed, and the spatial characteristics of the image are preserved quite well, avoiding losses in local details. The corresponding compensation values $\Delta L'$ and $\Delta C'$ can be obtained by applying a high-pass filter to ΔL and ΔC respectively and the filter is expressed in Eq.1. Through the filter, the degrees of over compression of each color, compared with neighboring pixels, are computed, which is the corresponding compensations.

$$\begin{cases} \Delta L_i' = \Delta L_i - \dfrac{1}{N^2} \sum\limits_{j \in s} \Delta L_j \\ \Delta C_i' = \Delta C_i - \dfrac{1}{N^2} \sum\limits_{j \in s} \Delta C_j \end{cases} \tag{1}$$

(a) Original image

(b) Results of lightness loss (c) Results of chroma loss

(d) Compensations of lightness (e) Compensations of chroma

Fig.1 Sketch of the gamut compression algorithm based on the image spatial characteristics

From the above analysis, this paper proposes a gamut compression algorithm based on spatial characteristics of the image. The main idea is: at first, the image is compressed by traditional algorithm and the losses of lightness and chroma ΔL and ΔC can be calculated by the difference between the compressed image and the original one. Then the compensation values of lightness and chroma $\Delta L'$ and $\Delta C'$ obtained by a high-pass filter are added to the compressed image. However, the compensated image may have some colors outside of the reproduction gamut, as a result, a gamut clipping processing is carried out. Finally, the colors of device of the image can be obtained according to the characteristics relationships of the reproduction device. The workflow is shown in Fig.2, where the gamut compression selects SGCK algorithm and the gamut clipping uses HPMINDE algorithm. The larger the neighborhood that high-pass filter adopts to compute compensations is, the better the effects is, however, the more calculations the algorithm needs. The size is 15*15 in the paper. Fig.1 (d) and (e) are the compensations of lightness and chroma $\Delta L'$ and $\Delta C'$ of (b) and (c).

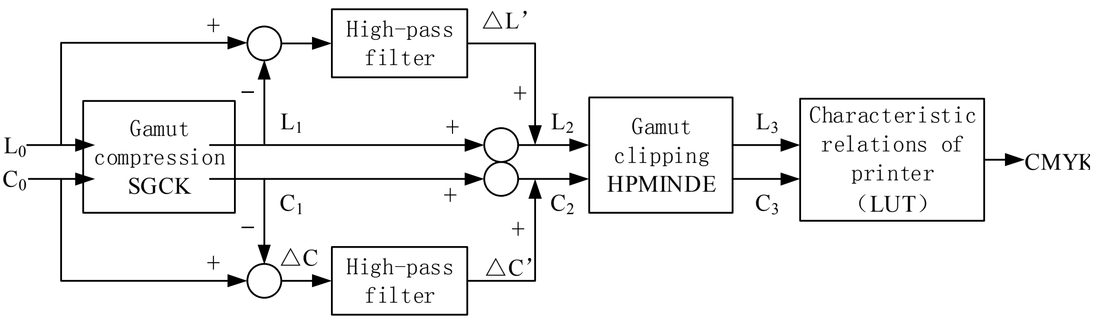

Fig.2 Workflow of the gamut compression algorithm based on the image spatial characteristics

Experiments and Analysis

Color difference and structural similarity are usually utilized to evaluate the gamut mapping algorithms [6][7]. Color difference assesses the color distortion degree and structural similarity mainly evaluates the local spatial characteristics of images before and after gamut mapping. To validate the applicability of the proposed algorithm, the typical and representative images are chosen as the test images. This paper adopts 6 images which ISO and CIE TC8-03 recommend to test gamut mapping algorithms. It includes 3 natural images (ski.tif, picnic_4v.tif, party_4v.tif) and 3 computer graphics (countrychart.tif, polution.tif, peanuts.tif). The image color space is RGB and the ICC profile of device is sRGB Color Space Profile.icc.

Tab.1 shows the assessment results of images processed by SGCK algorithm and the proposed algorithm. The performance of gamut mapping with the proposed algorithm has been improved compared to that with SGCK, where the degree of improvement of natural images is larger than that of computer graphics. The reason is that natural images have relatively abundant details while computer graphics have fewer, which gives rise to more compensations of lightness and chroma for natural images than computer graphics.

Tab.1 Evaluation results

Image type	Image	Color difference		Structural similarity of lightness		Structural similarity of chroma	
		SGCK	Proposed algorithm	SGCK	Proposed algorithm	SGCK	Proposed algorithm
natural images	ski.tif	7.031	6.5514	0.9015	0.902	0.851	0.8653
	picnic_4v.tif	5.7315	5.376	0.8444	0.8455	0.8245	0.8341
	party_4v.tif	3.9573	3.5943	0.9353	0.9353	0.8822	0.8921
computer graphics	countrychart.tif	8.8266	8.7773	0.9097	0.9154	0.8925	0.8974
	polution.tif	6.154	6.0596	0.8873	0.8891	0.8761	0.8835
	peanuts.tif	4.7760	4.7322	0.9484	0.9495	0.9638	0.9638

Tab.2 is the processing time of gamut mapping with SGCK and proposed algorithm. Our algorithm took a relatively longer time because that two convolution computations (compensations of lightness and chroma) and one gamut clipping for the whole image were operated besides gamut compression.

Tab.2 Operation time (second)

	ski.tif	picnic_4v.tif	party_4v.tif	countrychart.tif	polution.tif	peanuts.tif
SGCK	2.37	1.38	1.38	0.93	11.1	11.05
Proposed algorithm	4.09	2.35	2.35	1.6	19.39	19.37

Conclusions

This Paper compensates the lightness and chroma for the image. By integrating the spatial characteristics of images with traditional gamut compression algorithm, the purpose of keeping the overall colors and meanwhile preserving the spatial characteristics as much as possible can be achieved. Experimental results indicate that gamut mapping results using the proposed algorithm are superior to those with traditional SGCK gamut compression algorithm.

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