3D Visualization of out-of-gamut in Graphic Communication

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Abstract

In order to achieve high-fidelity representation of colors, it needs to do some purposeful interference when colors are conversed, so the color gamut mapping which is the main technology to ensure visual matching would be used during this process. And the accurate visualization of out-of-gamut between images and devices plays an important role in color gamut mapping, so a method of the 3D visualization of out-of-gamut in graphic communication based on segment maxima algorithm was proposed in this paper. And this method mainly had two steps, the first step was that the device color gamut boundary points could be obtained when used the color conversed information in digital output device profile, so as to generate accurate device color gamut. The next step was that out-of-gamut points could be obtained through making comparison between device gamut and digital image gamut, as result that the area of out-of-gamut could be presented in digital images and image gamut according to the out-of-gamut cloud dots. The advantages of this method were that it can encourage us to predict whether the image gamut is beyond the output device gamut in advance, and then it can help us to select appropriate color gamut mapping algorithm according to the result of out-of-gamut judgment, so as to realize the accurate reproduction of colors.
Keywords: Out-of-gamut ; visualization; device gamut.

Introduction

In recent years, more and more traditional printing companies involved in digital printing and found a new developed method to improve this technology. The development of digital printing industry also lead to the rapid development of digital printing technology and have the continuous application [1].

The digital printing developed in 1990s, which is a kind of printing technology that transmits information in digital way. In order to promise the color information to achieve high fidelity reproduction in different equipment [2], The ICC international color consortium established equipment description, includes making the device description file format and the standard of test data and the observation conditions when established the description file.

Based on the study of color management system, this paper focuses on finding a method to obtain the region of out-of-gamut of an image during digital printing process, which could help us to achieve the goal that the representation of out-of-gamut[3].

In this paper, a method of the 3D visualization of out-of-gamut in graphic communication based on segment maxima algorithm was proposed, its function was to compare the difference of gamut between the source and target image, which could help us to choose the better color gamut mapping method to achieve the representation of out-of-gamut of digital images and reflect to digital images.

Research on the Judgmental method of Out-of-Gamut in Digital Images

Image gamut visualization is very important in color gamut mapping, it gives an intuitive view of the image gamut.[4]It is also the first step in the process of performing gamut mapping. There are three function in the current color management system, which are the equipment calibration, equipment characterization, and equipment conversion. The basic principles of color management is to select the device-independent color space, such as CIELAB uniform color space, In order to make a characterization

description for the entire system and set a relationship between the device color space and the uniform color space[5-9], the ICC color management system plays an important role in this process. The ICC color management is shown in the **Fig.1**

What's more, the device profile plays an important role in process of the color management, it could record the color information and the displayed characteristics of devices, which could offer data of color space conversion for the CMM. The CMM could promise the color consistency between different devices.
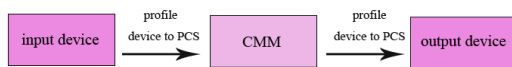

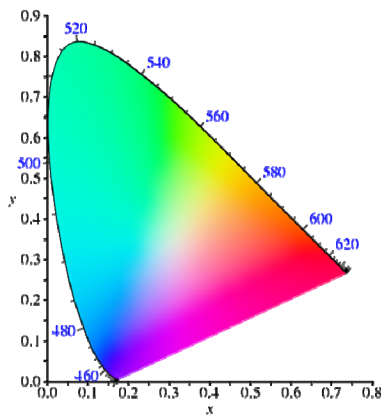*Fig .1* ICC Color Management (source Fabienne Dugay)

Fig.2 CIE-xy chromaticity diagram (source wikipidia)

The gamut boundary description of digital images

The color gamut is a color geometry that is represented by the entity in the CIELAB. The definition of color gamut was that a media could get color shaped as sphere under the certain observed conditions.[10] The color gamut was defined as a color entity which contains all colors of an image in the color space by the ISO02208-1, 2004,

In order to accurately describe the definition of color gamut, the CIE-xy Chromaticity diagram was built to describe color gamut by the CIE, as shown in the **Fig.2.** In the Chromaticity diagram, the color gamut range of various devices are displayed by the triangle area which use the RGB three-point to connect. And the larger the area were, the larger color gamut range of devices were.[11]

However, the color gamut boundary is a surface which are decided by the color gamut extreme points, and it is a similar description of the color gamut boundary. There are two methods of the color gamut boundary description, one is the medium-specific method, another is the generic method. The medium-specific method is suitable for describing the gamut boundaries of a medium, such as a printer, and this method has many characterization models, like Kubelka-Munk equation, Niujie Fort equation and Inui algorithm using partial differential equations.[12]But this method is not suitable for describing the gamut boundary of images. While the generic method has more extensive application, including the convex hull algorithm, improved Convex Hull Algorithm and segment maxima algorithm.[13]

3D Visualization Method of out-of-gamut in digital images based on segment maxima algorithm

In this paper, the judgmental method of out-of-gamut in digital image was considered, which could accurately get area of out-of-gamut in digital image. The thought of this method was that color gamut points of digital images were used as the source color gamut and the color gamut points of the output devices are used as the target color gamut. With this method, firstly, the color gamut boundary of target color gamut was set through using the segment maxima algorithm. And then the color gamut of image were segmented by using color points and these points were made comparison with the target color gamut boundary points, which could help us to find the out-of-gamut of digital images. Finally, the out-of-gamut points could be reflected and displayed in the Lab color space. The process is shown in the **Fig.3.**
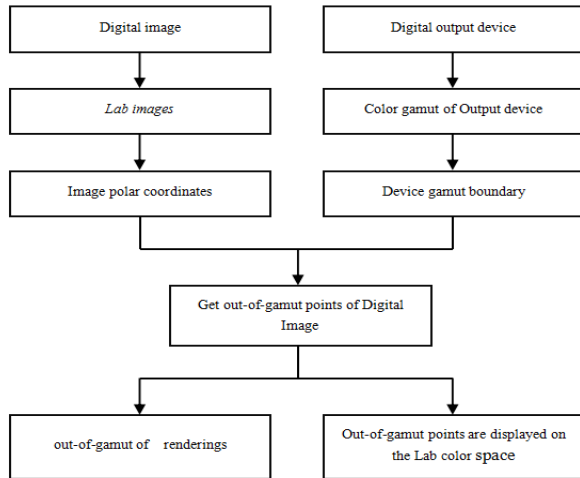
Fig.3 the framework of the judgmental method of out-of-gamut in digital images

The experiment method

Firstly, the color gamut boundary of output device were gotten by using the ICC profile and the segment maxima algorithm. This process could be achieved by getting the ICC profile of output device and making uniform sampling for the color space, and then these samples would be converted into the Lab color space which was segmented in order to control the accuracy of the out-of-gamut judgment, and the relative equations could be used to convert the Lab values. Secondly, the color gamut polar coordinates of digital image would be acquired. Thirdly, the out-of -gamut points would be found. Fourthly, the image and the area of out-of-gamut would be rebuilt and visualized. Finally, the color gamut of image would be reconstructed and the area of out-of-gamut would be displayed.

Experiment and Conclusion

In this experiment, the canon Ipf8300 inkjet printer was selected to research the 3D visualization of out-of-gamut. The control of RGB value could be accepted by the cannon Ipf8300 inkjet printer, so the RGB color space could be made uniform sampling, and then the RGB value would be converted into the Lab value which could be displayed in Lab color space, we can see the graph of color gamut dots in the **Fig.4**
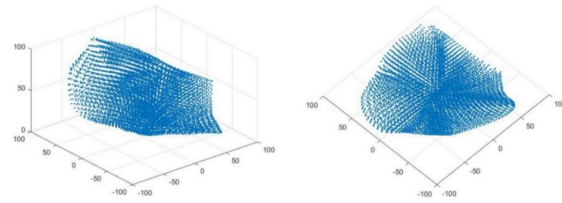

Fig.4 the color gamut graph

The next, the Lab color gamut was partitioned by using the segment maxima algorithm. Through making the comparison of gamut points in the same partition, the color gamut boundary extreme points could be found and they were written in the same matrix with Lab value of the color gamut boundary. The part of the matrix value are shown in the **Table.1**

m	N	L	a	b	R
1	17	5	-4	0	45
1	18	9	-11	-2	43
1	19	14	-23	-1	42
1	20	17	-33	-3	47
1	21	22	-39	-4	48
1	22	27	-51	-1	56
1	23	36	-68	-1	69
1	24	44	-82	-1	82
1	25	51	-80	-1	80
1	26	69	-73	-5	76
1	27	79	-67	-6	73
1	28	84	-47	-12	59
1	29	87	-35	-4	51
1	30	91	-24	0	47
1	31	95	-11	-2	46
1	32	85	0	0	35

Table.1 the color gamut boundary points (partial)

3D visualization of the out-of-gamut in digital images

In order to verify the accuracy of MATLAB algorithm and run the relative codes, the following three digital images were chosen as the experiment subjects, as shown in the **Fig.5.**
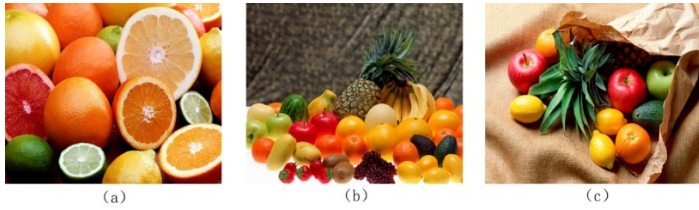
(a)　　　　　　　(b)　　　　　　　(c)

Fig.5 *the original digital images*

The three-dimensional color gamut dots cloud would be obtained by codes of digital image color gamut, Using the out-of-gamut visualization technique to obtain out-of-gamut points, the area of out-of-gamut will be marked red. Finally they are displayed in three-dimensional color gamut dots cloud. The out-of-gamut points are shown in the **Fig.6**.
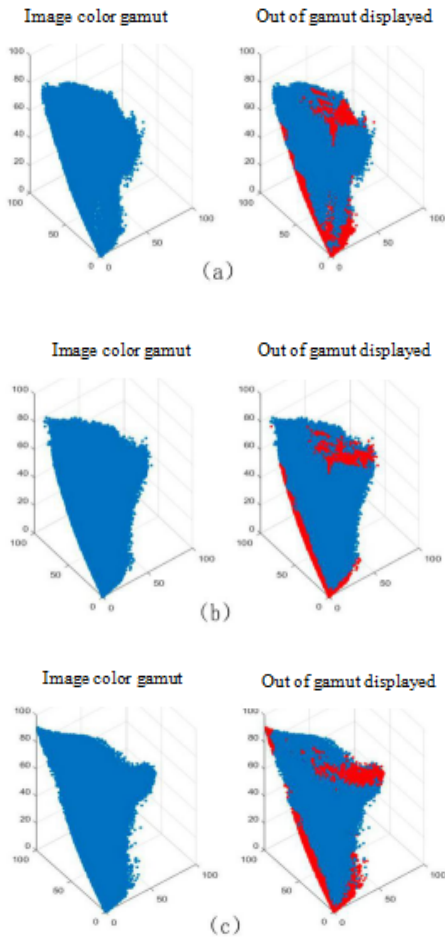

Fig.6 *Out-of-gamut dots cloud.*

Next, when images were reconstructed and parts of out-of-gamut were visualized, the corresponding RGB value could be found according to the polar coordinates of out-of-gamut dots, and then the RGB value of out-of-gamut would be changed into [127,127,127], as result the out of gamut section would be displayed as the neutral gray. And the rebuilt images are shown in the **Fig.7**.

（a）

(b)

(c)

Fig.7 *the reconstructed images*

Through this algorithm, we can find that the 3D visualization of out-of-gamut in graphic communication will truly reflect the situation of out-of-gamut of an image, and the stability of this procedure which was used in this paper are relatively more

excellent through making comparison with many images after 3D visualization of out-of-gamut. What's more, after optimizing this procedure, the algorithm which was used in this paper could be applied for all kinds of images.

Summary

In this paper, through analyzing the advantages and disadvantages of various color gamut boundary description methods, it could help us to find that the judgmental method of out-of-gamut based on the segment maxima algorithm were relatively stable and excellent. And making the comparison with original images, we would find the output effect was much better than our imagination. Finally, the conclusion of experiment was also proved that this method could be used in all kinds of images.

Acknowledgments

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Biography

Meiqi Lin obtained her graduate degree in Printing Engineering in Qilu University of Technology. She will finish the postgraduate degree within the group of Prof. Lin (Qilu University of Technology) with the focus on the preparation of the color science.