Influence of Rotation Processing on Digital Image's Colors

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Abstract

In order to understand the influence of rotation processing on digital image's colors, six different color images, 72 dpi and 144 dpi for each one, were chosen and rotated clockwise plus anticlockwise a same angle from 0.1^0,to 10^0 respectively, totally 18 angles. The image RGB data were regarded as the sRGB values, and then was transformed into S_CIELAB color space which considered the spatial sensitivity of the human eye to spatial pattern. So, the color differences between the rotated images and their original ones were investigated from these two aspects. The results showed that there were no definite relationships between the two type color data errors and rotation angles for the two compared images, or the relations changed with the image's pattern and resolution. However it was significant that the average S_CIELAB color differences ΔE_{S_LAB} were strongly in line related with the average RGB errors ΔRGB, and the line relationship was independent on image spatial pattern and its resolution factor.

1. Introduction

Rotation processing on digital color image is needed in many applications. For instance, in the color press on-line quality detection, each presswork needs to become digital image and compared with the standard one. During the process, the registration for the two digital images is first to be done to make them comparable one pixel by one pixel. And the key matter of registration is the rotation processing on the image. Because the color values of many pixels will change after rotating, the image color values and its visual colors must be influenced.

The rotation processing on a color image is the process of rotating the image any one angle clockwise or anticlockwise with one pixel as the center. And the process is achieved by the method of analytic geometry[1]. No matter how algorithm is used, the caves would inevitably come into being in the rotated image. And the caves would be filled in with proper values by some arithmetic, usually the nearest neighbor interpolation, the bilinear interpolation and the bicubic interpolation, with the values of their ambient pixels[2]. It is well known that the last one could get the best overall image effect.

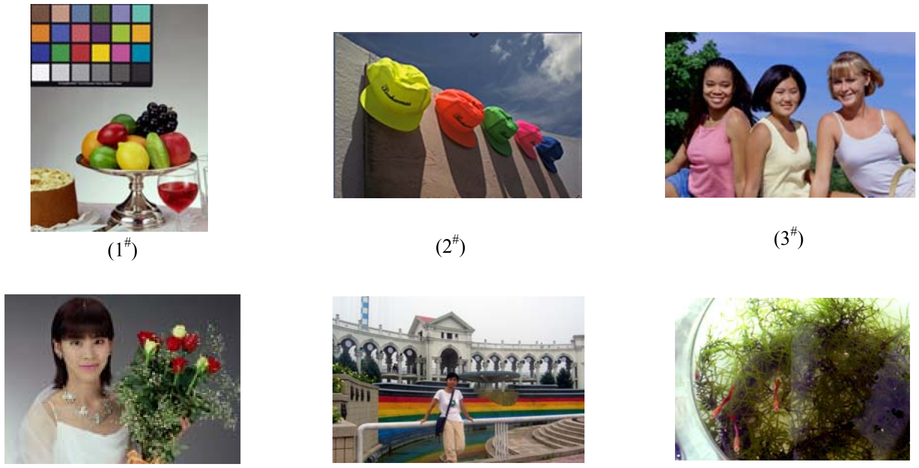
Color images usually contain spatial pattern. Zhang and Wandell[3] proposed a spatial extension to CIELAB to account for how spatial pattern influences color appearance and color discrimination, named S_CIELAB color difference metric. The metric consists of three pre-processing stages, First the input image, which is normally represented in a device-dependent color space, such as RGB, is converted into a device-independent representations consisting of one luminance and two chrominace color components. Second, each component image is passed through a spatial filter that is selected according to the spatial sensitivity of the human eye for that color component. Third, the filtered images are transformed into the CIE-XYZ format such that standard CIELAB color difference formula can be applied. Some applications have shown its validity for predicting the visual effect of changes in the reproduced image[4-6].

In industry quality detection applications, CCD capture devices are usually used to make an image into a digital one, forming the RGB color data. In the study, the image's errors of RGB, regard it as the sRGB, and S_CIELAB were computed and analyzed, so as to give a reasonable consideration in rotation processing applications.

2. The experimental images and their color difference representations

Six RGB color digital images, noted with $1^{\#}$-$6^{\#}$, with 72dpi and 144dpi spatial resolutions respectively for each one, were chosen in our computational experiments. They are shown in figure 1. We assumed that these images would be shown on screens. So these two spatial resolutions could be suitable for this intent.

The color difference between the original image and its reproduction one could be described in two type of color value: one is the device-dependent representation, and the other is the device-independent one. For many industry CCD devices, the RGB response values are designed to be the sRGB[7]. Although the real situations differ from the ideal more or less, the sRGB is still the standard for these devices. So the RGB data of an image captured by a CCD camera could be regarded as the sRGB values, and the average RGB error was chosen to represent the device-dependent color change of an image. According to the relationship between the CIEXYZ and sRGB, the CIEXYZ and CIELAB color data could be calculated, and S_CIELAB color data could further be obtained. Then the average S_CIELAB color difference was used for predicting the device-independent color change, also predicting the perceived image color change.



($1^{\#}$) ($2^{\#}$) ($3^{\#}$)

($4^{\#}$) ($5^{\#}$) ($6^{\#}$)

***Figure 1** The experimental digital color images*

(a) (b) (c) (d)

***Figure 2** The rotation process of an image*

3. Experiments and analysis

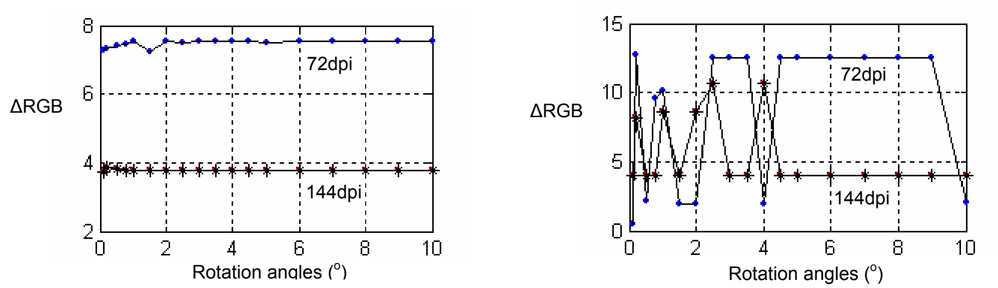
3.1 Influence of rotation processing on RGB color values

In our experiments, RGB images that were captured by a CCD camera were used to make their rotated images in order to avoid the added error, may coming from the non-ideal device stability by two times capturing. And MATLAB 7.0 soft was used to complete the rotation processing on an image, and the bicubic interpolation algorithm was accepted. The process was shown in figure 2. The image of figure 2(a) was the original RGB image. And the other images from figure 2(b) to figure 2(d) were the rotated and crop processed images.

Since the rotated image became slantwise because of a rotation angle, and it would enlarged in size to contain the slantwise pixels of original image, such as the image of figure 2(b), and so that could not be compared with its original image one pixel by one pixel. Hence, rotating the rotated image once again rightabout with the same angle was accepted to get a new non-slantwise image, shown in figure 2(c). After cropping the added pixels of image 2(c), shown with black color, it became the image of figure 2(d) and could be compared with its original image. There into, a metric, making the average RGB error of the last image and its original one the minimum, was programmed and accomplished to get the last image shown in figure 2(d).

The experimental rotation angles were 0.1^0、0.2^0、0.5^0、0.8^0、1^0、1.5^0、2^0、2.5^0、3^0、3.5^0、4^0、4.5^0、5^0、6^0、7^0、8^0、9^0 and 10^0 respectively, totally 18 angles. Because of two times rotation, the actual rotation angles were not that above, and were not affirmed to be the two times of that. Here they were just regarded as the notations of different rotation angles from smaller ones to larger ones.

Hereafter, the rotated and crop processed image, such as that shown in figure 2(d), was compared with its original one pixel by one pixel. The average R, G, B and RGB errors over all pixels were computed, and it was found that all these errors had the same relations with the rotation angles. So the average RGB error, noted ΔRGB, was used to represent the influence of rotation angle on the device color values. The results showed that there was no definite relationship between the ΔRGB and rotation angles for all the experimental images, relating the image pattern and resolution. The cases of image $1^{\#}$ and $6^{\#}$ were illustrated in figure 3(a) and 3(b).



(a) Image $1^{\#}$ *(b) Image $6^{\#}$*

Figure 3 *The RGB errors changed with the rotation angles*

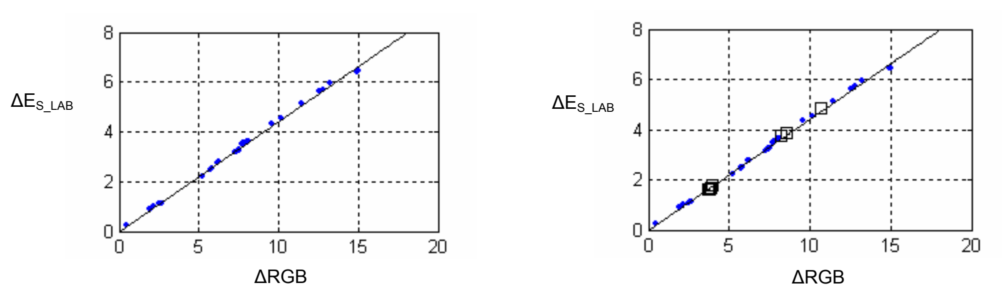
From the plots it was seen that the fluctuant extent of ΔRGB of image $1^{\#}$ was relatively slight, going stable after 2^0 angle. Comparatively the fluctuant extent of the case of image $6^{\#}$ was much stronger, still fluctuating at near 10^0 angle. Besides most ΔRGBs of image $6^{\#}$ were much bigger than that of image $1^{\#}$ in case of the 72dpi resolution, but the most ΔRGBs of the two images were similar at 144dpi resolution. Finally the ΔRGB would decrease with an increase in resolution for each image.

If the spatial patterns were compared between them it was found that there were too much float grass in image $6^{\#}$, but more big uniform color regions in image $1^{\#}$. Considering the mechanism of filling in a cave, if there is a big value difference between one pixel and its ambient pixels, the calculated cave value would differ clearly from its real value, resulting in a big ΔRGB such as the case of image $6^{\#}$. Hence it should be concluded that the ΔRGB, resulting from rotation processing, would be bigger when there were more textured contents in an image, and more varying with changes in rotation angles, in a definite spatial resolution case. And for one image, the ΔRGB would be bigger when the image spatial resolution was smaller, and the vice versa. From this point that the experimental six images could be divided into two groups: one contained less textured color regions, consisting of image $1^{\#}$-$3^{\#}$; the other one on the other hand contained more textured color regions, consisting of $4^{\#}$-$6^{\#}$. The computed results indicated that the situations of images $2^{\#}$ and $3^{\#}$ were real similar to image $1^{\#}$, and images $3^{\#}$ and $4^{\#}$ to image $6^{\#}$.

3.2 Influence of rotation processing on S_CIELAB color values

In experiments, RGB values of an image were converted into CIEXYZ according to the sRGB formulae, and then converted into opposite color space and passed through a spatial filter according to the S_CIELAB color regulations with an 18 inches viewing distance. Finally the average S_CIELAB color difference between the rotated image and its original one, noted ΔE_{S_LAB}, was obtained.

The experiments also gave the similar results that there were no definite relation between the ΔE_{S_LAB} and rotation angles, changing with image texture character and resolution. However it was found that the ΔE_{S_LAB} data were well line-related with the ΔRGB data for all the six 72dpi images, shown in figure 4(a). And the relation formula was $\Delta E_{S\_LAB} = 0.44\times\Delta RGB-0.017$. And the more complicated patterns were there in a image, the bigger ΔRGB and ΔE_{S_LAB}, and the vise versa.



(a) 72dpi images *(b) 72dpi and 144dpi images*

Figure 4 *Relationship between the ΔE_{S_LAB} and ΔRGB*

In order to investigate the influence of image resolution on the relation between the ΔE_{S_LAB} values and the ΔRGB values. The same calculations were carried out for three 144dpi images, $1^{\#}$, $4^{\#}$ and $6^{\#}$, and the results were plotted on Figure 3(b) with the square points. It was shown that these square points also follow the same line as the case of 72dpi images.

The plots of Figure 4(a) and 3(b) indicated that S_CIELAB color difference ΔE_{S_LAB} was line-related with the RGB error, independent in image spatial texture and resolution factor. This characterization is very useful for predicting the perceived image color change resulting from rotation processing by simply calculating the error of RGB values.

Besides the experiments described above, the pixels of big ΔRGB and ΔE_{S_LAB} values, more than 90 percent maximum error, were located with white color in the image to analyzing the properties of color changes. Figure 5(a) showed the big ΔRGB pixel locations and figure 5(b) showed that of the big ΔE_{S_LAB}.

(a) RGB color errors (b) S_CIELAB color differences

Figure 5 *Locations of the big error pixels*

It was clear that the locations of the big ΔRGB pixels were random, but the locations of the big ΔE_{S_LAB} pixels were always at the edges of image patterns. The same results were obtained for the other five images. This is because that there are always some exceptional pixels their values are much different from that of ambient, and their values will change strongly after rotating, resulting in the big RGB errors. In actually, nevertheless, these isolated big RGB error pixels could not be perceived by the human eye because of its property of spatial sensitivity. Also in terms of the spatial sensitivity of the human eye, just the region consisting of a number of big RGB error pixels, so that being the big S_CIELAB error region, may color changed perceived, such as the edges of patterns. Figure 5(b) is just agree with the point of view, and at the same time implies that the S_CIELAB color metric may correctly compute the effect of color crimination of the human eye.

4. Conclusions

The computational experiments have been carried out to know the influences of rotation processing on digital color image's color changes. The results reflected that there were no definite relationship between the changes in image RGB values and the S_CIELAB values and rotation angles. Significantly there was a definite linear relationship between the average S_CIELAB color differences and the average RGB errors, regardless of what image spatial patterns and its resolution. This can be used for measuring the perceived color change of a digital color image introducing from a rotation processing by simply calculating its average RGB error.

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