Development of Image Control Tool for Reproducing Perception Based Images

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Abstract

Human perception becomes an important factor in high quality image reproduction. One of the ways to improve image quality is to use experimental data. The psychophysical observer experiments for collecting perceptual attributes are described and the general structure and implementation of image control tool for changing images is described. Also the experimental results are presented.

1. Introduction

To reproduce a realistic image is one of the final goals of photo-realistic rendering in computer graphics. The term 'photo-realistic' is widely used in computer graphics. And it is widely used in producing movie scenes such as image synthesis between real scene and computer generated actor or objects. The evaluation of the quality of computer graphics images is somewhat a subjective matter. Generally, image quality can not be measured by just calculating RMSE(Root Mean Squared Error) or PSNR(Peak Signal to Noise Ratio) methods. The final reproduced images are viewed by human observers, so considering factors of human perception is the most important issue in the field of realistic rendering. There is little or no attempt to study the human visual perception of feeling the quality of the movies. To reproduce the realistic appearance of the final movie, a correct device color management is performed first. In addition to that, human factor should be considered in order to provide more realistic image appearance. In this paper, the observer experimental method of image quality is described, and the general structure and implementation of image control tool is described. Also the experimental results for modeling the Korean tone reproduction are presented.

2. Perceived image quality

According to the Oxford English dictionary, the definition of image quality is described as 'the nature, kind of character of something; hence the degree or grade of excellence possessed by a thing'. In popular, the word 'quality' suggests a degree of luxury or expense or an item with a specification higher than average. Yendrikhovskij defined the three dimensional image quality model, FUN model[1]. FUN model consists of three coordinates which are fidelity, usefulness and naturalness like Fig. 1. Yendrikhovskij's definition is highly related with the functionalities. For example, images created for virtual reality should look realistic to human eyes, so naturalness is important. On the other hand, images created for the medical purpose, they should be correctly rendered to make a correct decision by doctors, so usefulness is more important than naturalness and fidelity.

Image quality can be measured or evaluated by either using measuring devices or color difference calculation-objective method. In computer graphics, quality evaluation can be expressed as the computational

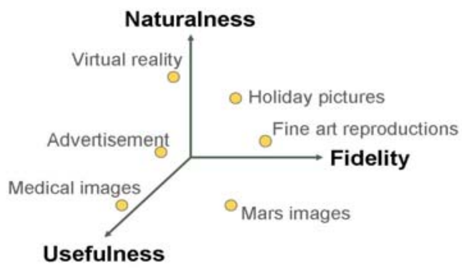


Fig. 1 FUN image quality model

complexity of the algorithm. So reducing the computational time is a major issues. In analog or digital TV system, image quality is generally referred as the distortion of the original image when it is transported to the public, and root-mean-square error(RMSE) and peak-signal-to-noise ratio(PSNR) are widely used to evaluate the image quality. In color science, image quality can be calculated pixel-by-pixel computation of color differences between the original and reproduced images based on the information of color changes of each corresponding pixels. CIELab$\Delta E_{ab,}$ CIE94, CMC(1:1), and CIEDE2000 are widely used methods of calculation of image differences. Another method of image quality evaluation is the subjective method in which image quality is assessed by the observers with several parameters affecting the quality. Psychophysical experimental method is a widely accepted method in the fields of computer graphics, TV systems, and color science.

McNamara, in her PhD thesis, suggested the experimental set up comprised of real environment and a computer representation of that environment to quantify the visual realism of computer synthesized images[3]. Fig. 2 shows the test environmental set up. It has a five sided box of 557 mm high, 408 mm wide and 507mm deep, with an opening on one side. All interior surfaces of the box were painted with white matt house paint A small front-silvered, optical mirror was incorporated into the set up to facilitate alternation between the two settings, viewing of the original scene or viewing of the rendered scene on the computer monitor. When the optical mirror was in position, participants viewed the original scene. In the absence of the optical mirror the computer representation of the original scene was viewed.

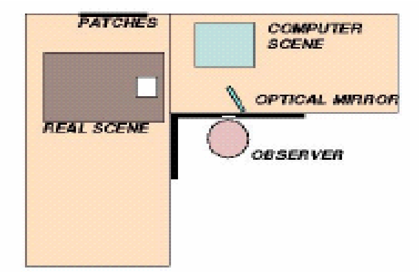


Fig. 2 McNamara's experimental setup

3. Image control tool

Image control tool was implemented to collect the observer's preference about images. The framework of the tool is described in Fig. 3.

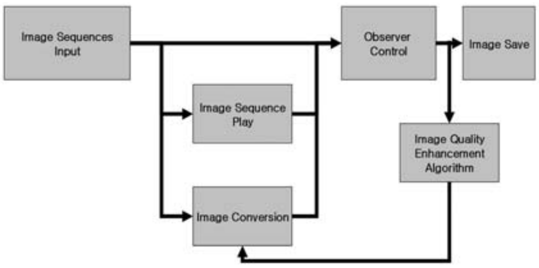


Fig. 3 Framework of image control tool

The tool consists of five blocks. Computer generated images or synthesized images including the real photographed scene and the computer rendered objects are input to the image sequence input block. The input image sequences can be played with several play options such as play, stop, pause, replay, etc. through the image sequence play block. Or the input sequences can be converted by the image quality enhancement algorithms which are pre-determined in the image conversion block. The pre-determined algorithms are CIECAM97s color appearance model, CIECAM02 color appearance model, iCAM image appearance model and observer preference algorithm. CIECAM97s and CIECAM02 are the CIE standard color appearance models which can predict the various color appearance factors such as hue angle, hue composition, lightness, brightness, saturation, chroma, and colorfulness viewed by the human eye when the illumination is changed from one to another. The factors are calculated with respect to the attributes of human visual system. And the images converted by these models have more realistic color appearance by human eye. While CIECAM97s and CIECAM02 have the prediction capabilities of color changes in models[4],[5], iCAM image appearance model adds the prediction capability of the image quality in an objective way by calculating spatial correlation of the image pixels[6]. Observer preference algorithm is created by modeling either the psychophysical experiment or observer controlled images results. Fig. 5 shows the observer control function of the image control tool. Image control tool has control bars those are selected by the consideration of human visual perception. Therefore observers can change the most properties for image appearance with this image control function. The properties are lightness, chroma, hue, contrast, brightness, blur, sharpness, and noise. In case of lightness, and chroma, observers can change the parameters with three separate ranges such as high, middle and low range so that the tool gives observers more controllability. Also in case of hue, there are six color regions which are red, green, blue, cyan, yellow and magenta.

4. Psychophysical experiments

15 observers with normal vision were participated in the psychophysical experiments. The optimal number of observer can vary according to the availability. In general, the precision increases as the square root of the number of observers. However doubling the number of observers does not double the precision. In imaging area, it can be ranged from four to fifty observers. Engeldrum recommended the number of observers from ten to thirty[7]. The experiments were conducted in order to modify the sample image so that it looks like Korean tone which is an ideal concept existing in every observer's mind. 11 were men and 4 were women with ages from 20 to 28. All of the observers were new to this type of experiments, and the required knowledge for conducting the experiment were learned before the actual experiments. All the observers took twice of the experiment in order to exclude any untruthful observers. The experiment was conducted in a darkened room. The test image we used was originally created for the cinema projection, we used a THOSHIBA projector and a screen as the observer viewing condition. IBM compatible PC and a BARCO monitor were used to control the image control tool. The scheme of the experimental room is in Fig. 4.

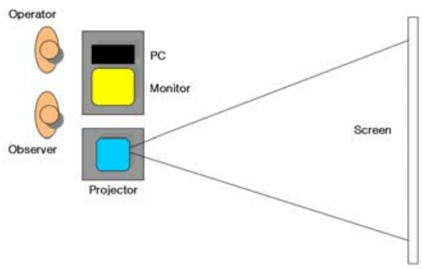
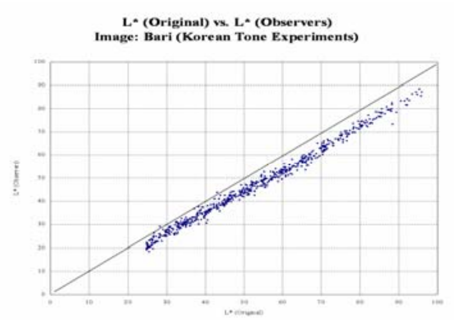


Fig. 4 Scheme of a darkened room

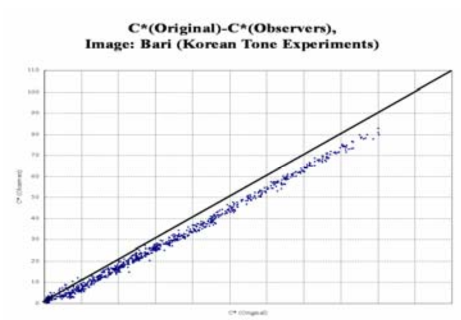
Fig. 5 View of color control function

5. Results and analysis

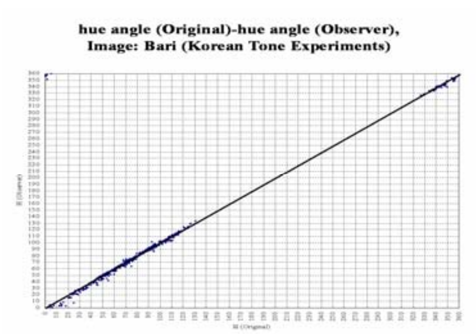
The 30 observer changed images were collected and the analysis of the 30 images were performed with respect to the combinations of factors of lightness, hue, and chroma. The results of data analysis are in Fig. 6.



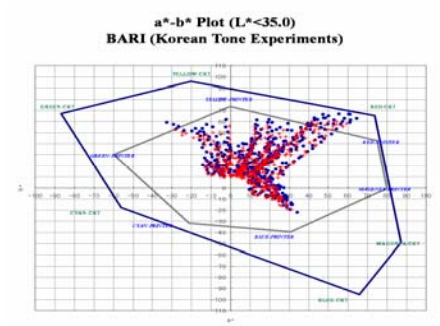
(a)



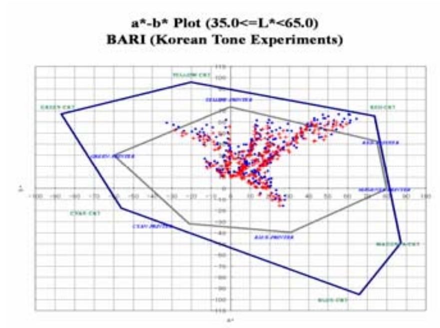
(b)



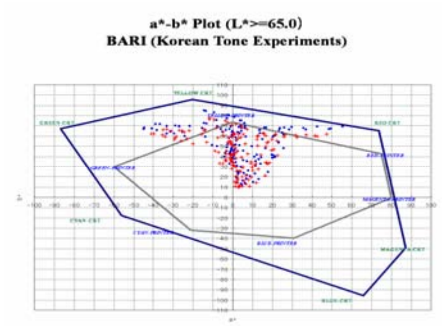
(c)



(d)



(e)



(f)

Fig. 6 Experimental results analysis

The results of changes in lightness, chroma, and hue of the observer experiments are plotted in Fig. 6 (a) – (c). In this plots, most observers tend to lower the lightness of the test image than the original image displayed on the projection screen. Also they changed the chroma to lower the saturation than that of the original image. However, hue tends to be preserved by the most observers. Fig. 6 (d) – (f) plot the results of changes of hue and chroma in the lightness lower than 35, in between 35 and 65, and higher than 65 respectively. In the plots (d) – (f), the dots are the original pixel data of the test image and crosses are the observer changed data. In plots (d) – (f), most pixels of the original image goes toward the center of the coordinates, and this means that along the whole lightness scale, observers tend to move the chroma to lower the saturation with preserving hue.
We can make a hypothesis from the results that Koreans have common idea that Korean traditional images might be lower the lightness and lower the chroma than the images they see. With these experimental results, the image conversion algorithm was developed based on the

following conversion step.

$$[X, Y, Z] = M \times \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (1)$$

where, *M* is the sRGB conversion matrix

$$[L^*, a^*, b\ ] = f(X, Y, Z) \qquad (2)$$

where, *f* is the CIE standard conversion equation from XYZ device independent color space to Lab uniform color space.

$$[L^{*\prime}, a^{*\prime}, b^{*\prime}] = g(L^*, a^*, b^*) \qquad (3)$$

where, *g* is the new conversion function based on the observer experimental data.

$$[X', Y', Z'] = f^{-1}(L^{*\prime}, a^{*\prime}, b^{*\prime}) \qquad (4)$$

where, f^{-1} is the inverse function of *f*.

$$[R', G', B'] = M^{-1} \times \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} \qquad (5)$$

where, M^{-1} is the inverse matrix of *M*.

The original and the observer changed images are converted to XYZ tristimulus values based on the sRGB conversion matrix (1). Then the tristimulus values are converted to visually uniform color space $L^*a^*b^*$ based on the CIE standard conversion equation (2). The observer preferences are analyzed in this $L^*a^*b^*$ uniform color space. Image conversion algorithm is applied in this Lab color space (3). Changed Lab values are back transformed to X'Y'Z using the inverse function of f (4), and finally we can get R', G', B' values using the inverse matrix of *M* (5). The reproduced image using the conversion function is presented in Fig. 7 (b). As expected, the reproduced image looks darker and a little paler than the original image in Fig. 7 (a).

(a) Original image

(b) Tone converted image

Fig. 7 Results of perception based image conversion

5. Conclusion

In this paper, image control tool was developed which is based on the psychophysical observer experiments. The tool has functions need to change the characteristics of image in both chromatic and achromatic properties. The pilot experiment was conducted in order to find the Korean style tone reproduction characteristic. According to the psychophysical observer experiments, Korean style tone tends to lower the lightness and saturation than those of the original images, and hue doesn't change.
This experiment can be a starting point of the future study to predict the image quality of computer synthesized images or to enhance the photo-realistic rendering algorithm.

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