# A Study on Perceptual Quality Assessment of Digital Images

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**Abstract**: The purpose of this study was to discuss the image quality realized from LCD-TVs by the visual assessment method. The image samples adopted in the experiment were common in daily life and divided into 7 categories. Discussed by a focus group formed by the experts of design and color, the colors of red, green, blue, yellow and achromatic were chosen as the image selective standard. Adopted the convenience sampling, 7 subjects who had frequent experiences of "image design and processes" were asked to conduct the experiment of visual assessment of image quality based on the picked 35 images, categorized by their physical attributes (e.g. image contrast or image saturation). According to the research result, people sensed higher perceptual image quality from the images with higher contrast; moreover, the subjects also perceived higher quality from the images with higher saturation. However, the influence of image contrast to image perceptual quality is bigger than that of image saturation to image perceptual quality. The correlation between the image physical attributes and the perceptual image quality had concluded a concrete result at this study, which provided a reference for image designers and organizations of video chipset design and research at LCD-TV fields.

***Key words: Image contrast, Image saturation, Digital image quality.***

## 1. Introduction

Currently, displaying digital images and graphic design products through large-size LCD-TVs has become a trend [2]. Therefore, one of the emphases concerned by the industries of digital image design and display technology is to maintain the quality of fine products. The traditional image quality assessments adopted by LCD-TV production industries or related research and development units are mainly divided into "image physical measurement" and "color appearance model" [6, 8]. Besides the displayed gamut assessment [1], the former issue primarily focuses on the transmission of signal process and image compression quality. "The image physical measurement" was to analyze the color different or match the processed and original images. Its evaluating standards emphasize at the fidelity of image reproduction, compress quality of image or the optimization of image noise. However, the image quality result from the previous algorithm is only for the deduction of quantitative model, which may not imply a direct inference or apply to the image standards recognized by human eyes. In 2002, Fairchild and Johnson *et al*. proposed the idea of "i-CAM, Image Color Appearance Model" [3, 4, 5], which adapted and revised from the concept of Color Appearance Model, the models of CIECAM97, CIECAM02 and the characteristic of human's visual perception [1, 5, 10, 11]. The purpose of i-CAM is to predict the perceived level of color change under the different observational conditions or light sources. In other words, i-CAM intends to infer the prediction model of every displayed pixel's lightness, hue and chroma with physical algorithm and to predict peoples' visual perception on color image at different environments.

Based on the previous development of image assessment research and the foundation of visual perception, the studies of image quality have been gradually emphasized by related research organizations and in applied fields. Moreover, the future study of perceptual image quality has also been mentioned. Nevertheless, empirical experiments are still needed to be done to determine if humans' perceptual image quality predicted by CIECAM is applicable to the practice of digital image design. Particularly, image designers usually adjust digital images by the suite software of image processing, which lacks systematic and casual relationship research towards the perceived quality of the adjusted images. Since the purpose of monitors is watching-oriented, the image quality of LCD shall discuss not only the measurement and evaluation of photonic physics, but human's visual mechanism and the correlation between visual assessment and physical attribute, which constructs the major emphasis of image perceptual quality assessment. Consequently, differing from traditional physical measurements of image quality, a different study approach, based on human factor engineering, was adopted in this research to discuss the subjective perceptual image quality. This study hoped to apply the image quality issue into the practical design field, and to provide the reference of perceptual quality standard for image designers and LCD video chip research and development organizations.

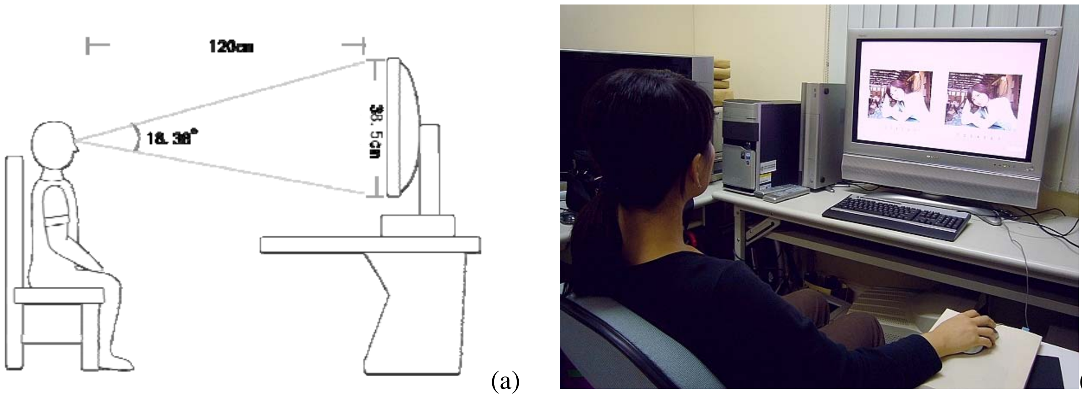
## 2. Method

### 2.1 Experimental Design

Quasi-experiment design was adopted in this study. Moreover, resulting from the combination of comparison and visual scaling method, incomplete with-in subject design was adopted to conduct the experimental procedure of image perceptual quality assessment. In other words, subjects judged and evaluated the image quality and gave assessments of interval scale from two randomly displayed images through LCD-TV (figure 5). According to the data analysis method, this experiment design could simultaneously collect all image evaluation scores from subjects. Furthermore, mean, standard deviation, ANOVA and other statistic methods were adopted to analyze the raw scores.

### 2.2 Experimental Environment

With the resolution of 1280(width) by 768(height) pixels, a 30-inches LCD-TV was adopted as the sample-displaying monitor. Moreover, GretagMacbeth Eye-One was adopted to conduct the characterization correction and establish the ICC profile. According to Kurita and Saito (2002), the accuracy of image assessment would gradually drop owing to the increase of external light [8]. Therefore, the formal experiment was conducted at a darkroom where the light of monitor is the only illumination to increase the accuracy (figure 1). The researcher also assisted the subjects to conduct the experiment trial and explained the rules of experiment and operation.



(a) (b)

Figure 1 Experimental Environment：(a)side view of environment；(b)authentic experimental environment

### 2.3 Classification and Selection of Images

Owing to the coverage of the chosen images including every image type, this study followed the digital image classification method suggested by Wu (2005) as the selection standard [13]. Her research result indicated that the digital images mostly taken by public were ordered as the following seven categories: A. Portrait, B. Architecture, C. Landscape, D. Food, E. Animal, F. Still Life and G. Plant. Besides, the major colors distributed from the image were set as the selection criterion in accordance with the topics of image contrast and saturation in this study. The images were picked according to the color in red, green, blue, yellow and white/black, the low-information color. Three experts from design and color field were organized for three times as a focus group and followed the previous rules to choose 35 images (referred to figure 2).

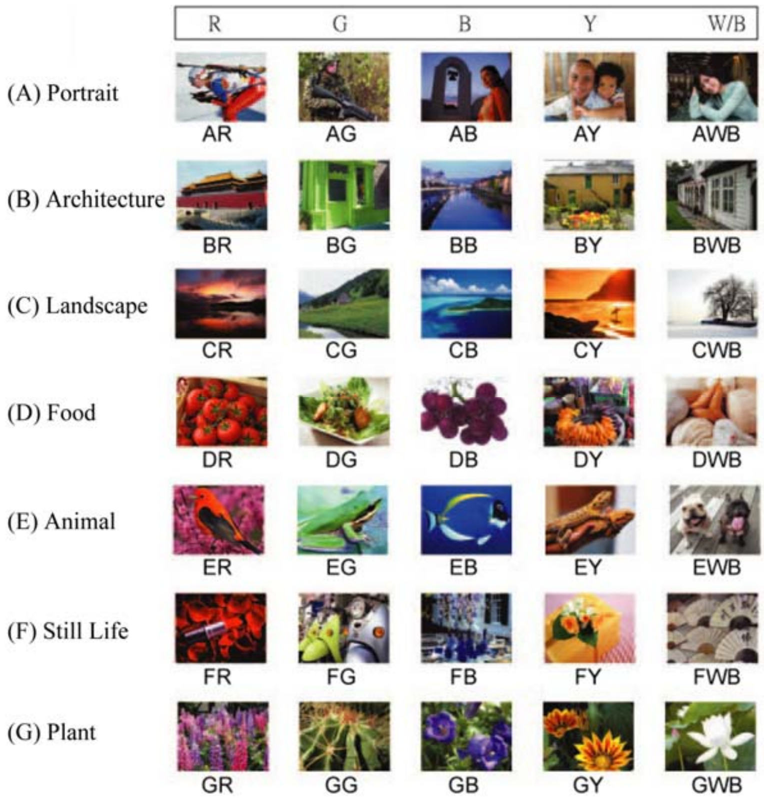



Figure 2 Experimental Images (vertical line for color attributes, horizon line for image types)

## 2.4 Production of Image Stimulus Material

Every subject needed to evaluate images from these seven categories. Based on the image topic, each category contained 4 major colors (red, green, yellow and blue) and an image with low-information color. Moreover, two different image processing methods were adopted to conduct the difference analysis of subject's evaluating results. At the method of image contrast, 35 images were divided into 7 categories, 5 images for each, and being adjusted into 20 parameters by the software of Adobe Photoshop CS according to the forward and reverse degree of image contrast. Each two parameters were regarded as one level since the difference between every two parameters was very limited. In other words, the number of the adjusted images ranging forwardly and reversely 10 levels (figure 3), including the original image, is 21. Every single trial randomly demonstrated two images with different contrast level in the same classification at the contrast assessment. Furthermore, to achieve reliability of visual evaluation, a randomly non-processed image was displayed at the left and right side in the screen respectively in the experiment. The experiment of image saturation adopted the same method (figure 4).


Figure 3 Adjustment of image contrast

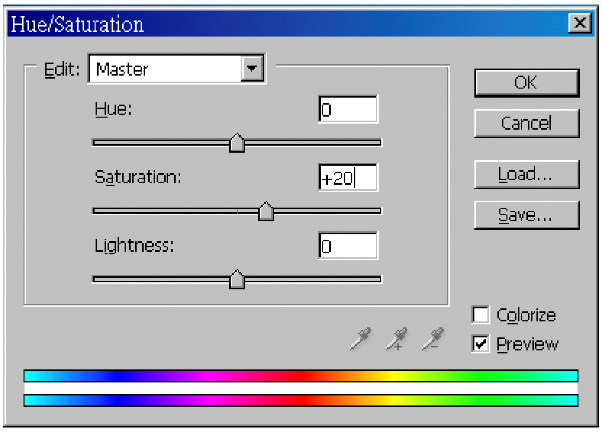
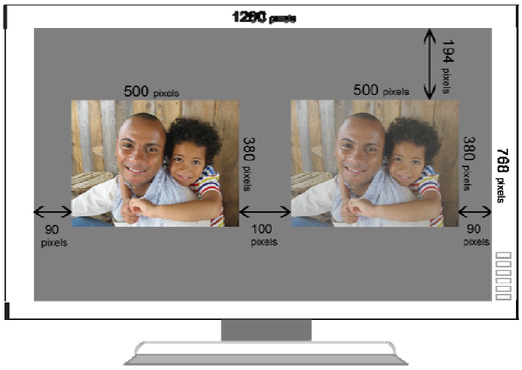



Figure 4 Adjustment of image saturation

## 2.5 Demonstration of Image Stimulus Material

The design of experiment window was made by Visual Basic 6. The view frustum of screen was 64 by 38.5 (cm.). The watching distance from the screen to the subjects was 120 centimeters. The width and height of visual angel was 30.56 and 18.38 degree. The screen resolution was set to 1280 by 768 (pixels) to meet the demand of screen's physical resolution. As shown as figure 5, the size of single image was 500 by 380 (pixels). The width and height of visual angel was 15.7 and 9.55 degree. The distance of two images was 100 pixels (visual angle 2.4 degree). Two images were randomly displayed at each experiment where the background was middle grey (RGB were set to 128). Constructed from random noises, a noise frame showed at the screen after subjects' completion of image quality assessment to avoid the after-image effect generated from the previous stimulus image.



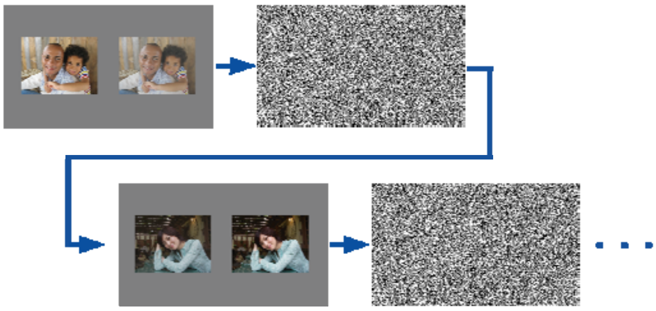



Figure 5 Experiment window

Figure 6 Trial sequence at experiment

## 2.6 Subjects

Seven subjects who had frequent experiences of "image processing" were asked to adopt the convenience sampling to conduct the experiment of visual assessment.

## 2.7 Image Perceptual Quality

The meaning of "image perceptual quality" in this study referred to the subjective image quality evaluation resulted from the perceived displayed images from the monitor.

## 3. Data Collection and Analysis

The influence to image quality was discussed from two physical attributes (image contrast and saturation). Moreover, a visual assessment experiment was adopted to evaluate image quality. The evaluating data from the result were analyzed as follows:

The result of image quality assessment indicated an obvious difference at experiment of image contrast ($F_{(20, 6160)}$=106.893, $p$<.001). Moreover, the post hoc test of Turkey HSD was implemented to understand the relationship between the parameter change at each level and image quality. The parameters at the level of "+2" to "+20" did not present an obvious difference ($p$=.114). Nevertheless, comparing to the "reversely" parameter adjustment, the mean of evaluation result of "forwardly" image quality was higher than that of "reversely" one (figure 7). Similarly, an obvious difference of image quality results ($F_{(20, 6160)}$=94.982, $p$<.001) showed at the image saturation experiment. The post hoc test of Turkey HSD was also implemented to realize the relationship between the parameter change at each level and image quality. The parameters at the level of "+6" to "+20" did not demonstrate an obvious difference ($p$=.334). Comparing to the "reversely" adjustment, the mean of evaluation result of “forwardly” image quality was higher than that of “reversely” one (figure 8), which implied a similar result to the visual assessment of image contrast.

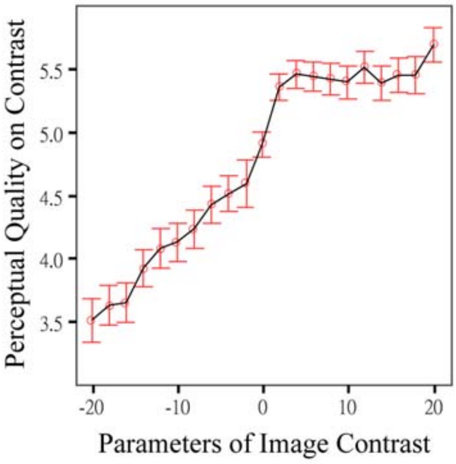



Figure 7 Distribution of perceptual quality evaluation at image contrast.

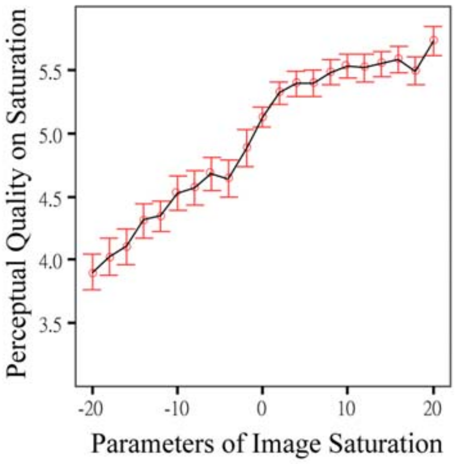



Figure 8 Distribution of perceptual quality evaluation at image saturation.

According to the result from the 35 images at the image contrast evaluation experiment, totally 32 images indicated that the quality of image with high contrast is better than that of image with low contrast. Similarly, 33 images also suggested the quality of image with high saturation is better than that of image with low saturation at the image saturation experiment. The related analysis result demonstrated an extremely high positive correlation (*r*=.993) between the means of image contrast and image saturation. In other words, a higher quality evaluation of image contrast came with the same one of image saturation (figure 9). Besides, the correlation analysis of perceptual quality of image contrast and saturation among each image classification (referred to figure 10) also implied a positive correlation between image contrast and saturation among different image types.

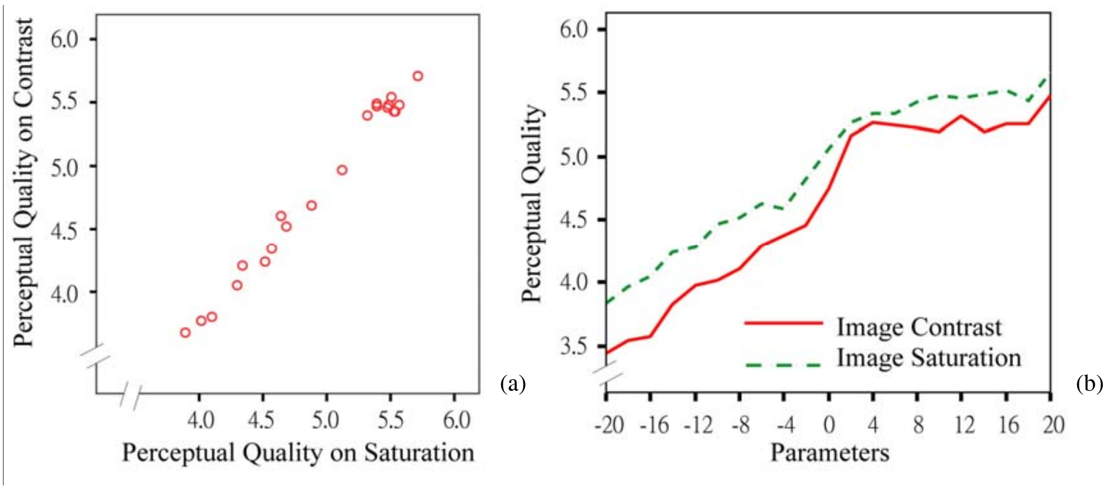



Figure 9 Correlation analysis of the perceptual qualities of image contrast and saturation ($p$<.0001):
(a) Correlation analysis of image contrast and saturation
(b) Assessment result of image quality at different parameters

The visual assessment experiment of image contrast and saturation was conducted at this study. Based on the findings, images with different contrast and saturation at different categories demonstrated dissimilar results.

Generally, different physical factors brought different reacted image qualities. However, the visual assessment experiment of image contrast and saturation suggested the quality of higher image contrast and saturation was better than that of lower image contrast and saturation. Simultaneously, the visual quality assessment of image contrast and image saturation proved an extremely high positive correlation.

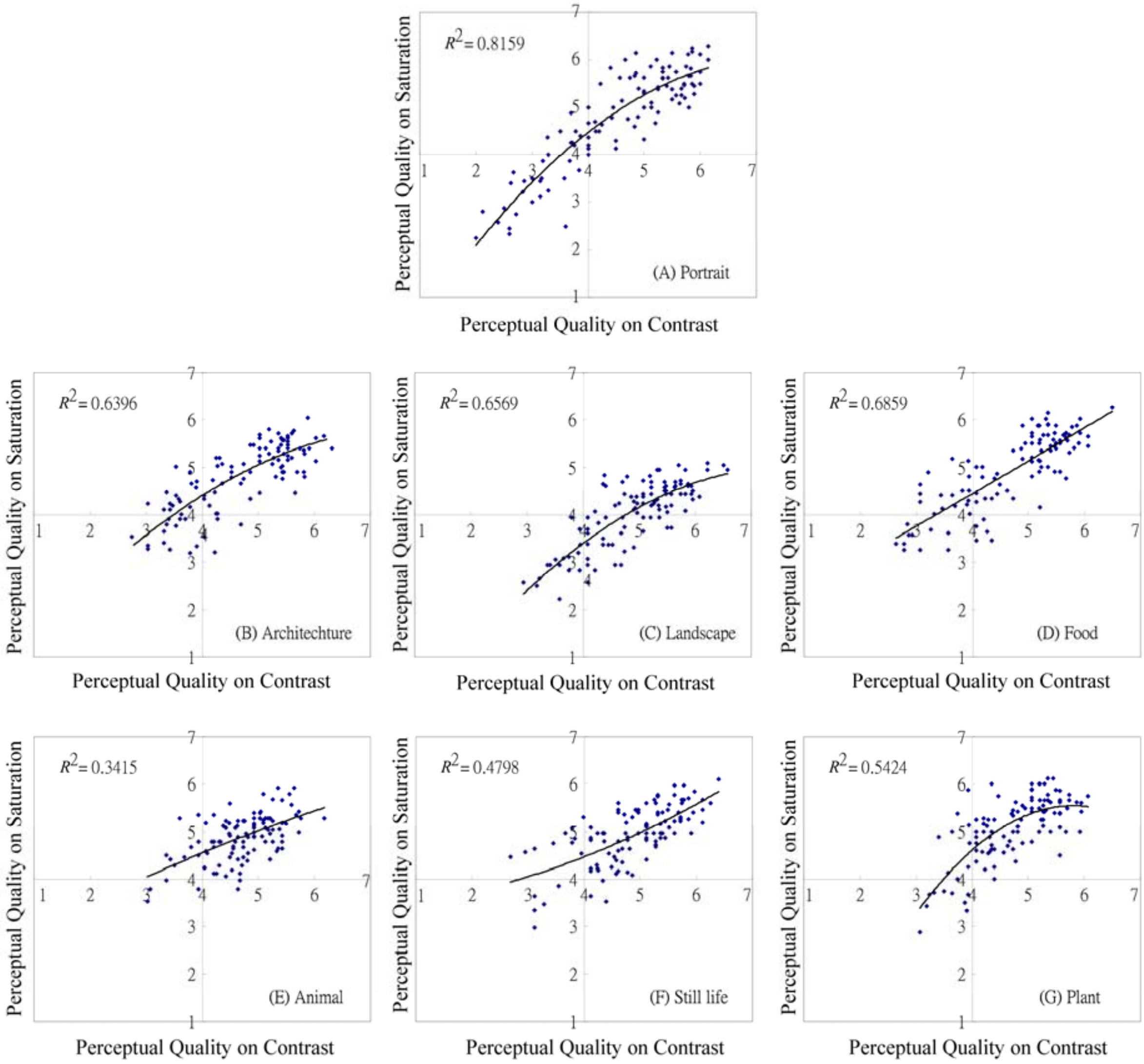



Figure10 Correlation analysis of the perceptual qualities of image contrast and saturation at each classification ($p$<.0001)

## 4. Results and Discussion

A clear conclusion of psychical factors of image quality has not yet been made. The relationship between images' physical attributes and human's perceived image quality is still in the phase of exploratory researches. Serious visual assessment experiments and data analysis methods are needed to acquire the stable reaction data and the concentrated trends from people's complicated visual system and recognition processing. The focus of this study was to discuss the relationship between image's physical attributes and human's perceived image quality. Additionally, a concrete result had been found.

In general, the study result indicated that the image with higher contrast or saturation came with a higher image perceptual quality. In other words, the adjusted images with higher contrast or saturation led a positive correlation with human's perceived image quality. However, an opposite result of image quality assessment would generate if the image saturation at the content of original image was too high or too low. Fewer image samples were adopted in the previous visual evaluations of image quality, which conducted uncertain external validities for experiment results. Therefore, the daily images categorized into 7 categories were adopted and the colors of red, green, blue, yellow and tinge were chosen as the image sampling distribution to enhance the external validity of experiment and practical application. Furthermore, differing from the adjustment method of CIE*a*b** adopted by Fedorovskaya *et al*. (1996) [6], this study adopted the built-in function of parameter adjustment in Photoshop to adjust the image chroma and saturation, which provided a reference for digital image designers and image processing engineers to adjust image contrast and saturation and gave a practical support for digital image design and creation.

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