Emotional Image Quality Evaluation Technology for Display Devices

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Abstract

In this paper, we explained the relation between evaluating display device and emotional image quality evaluation in human perceptual view. It is also suggested two emotional image quality evaluation method of display reflecting human visual function. One is the color space of CIECAM02 and the other is capturing moving image. It is necessary to standardize the evaluation methods of image quality based on emotional evaluation.

Key Words : Emotional Image Quality, Display, Evaluation, Human Perception, Visual Function, Color, Motion, CIECAM02

1. Introduction

As display industry has developed rapidly, we can often see the news that refers to emotional image quality for World's best quality. It means that the display, which can give emotional impression, will satisfy the consumer at the end. Though someone said "Emotional image quality" is not definite to represent the quality of display, the terminology is much widely used in display industry recently. However some people still think that it is completely different thing from the physical image quality data we used until now and it is simply good thing but too abstract to

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measure. According to the development of display device, someone think that the display image quality is already saturated. But Sony's television strategy "Pursuit of high image quality does not end" in Nikkei Microdevices October 2006 supports the development of emotional image quality [1]. The president of Sony's T. Kondo A3 Research laboratory said that now we are moving from Narrow Band Era to Broad Band Era. In Broad Band Era, not only recognition but also understanding is important. It can be explained by an apple. In Narrow Band Era, high image quality needs for delivering information like "it is an apple." On the other hand, in Broad Band Era, high image quality can answer the question "How's the apple's taste?" by showing the feelings of an apple. Sony keeps the research for the image quality improvement going and at the same time it means that image quality competition does not end yet.

For evaluation of emotional image quality, physical and psychological evaluations based on human eye's characteristics are necessary. Physical image quality characteristics which mean the luminance, contrast ratio and color gamut etc. were the criterion of display performance. But higher values of them do not always indicate superior image quality of display in accordance with the development of display industry and evaluation technology. For example, some displays which can be extremely bright in special circumstances or some displays which have the value over a million of contrast ratio are appearing. This paper is explaining the relation between evaluating display device based on vision sciences and emotional evaluation of image quality. Also objective and emotional image quality evaluation technique is going to be introduced.

2. Vision science and display image quality

It is not easy to understand visual system processed in human eyes. In addition, many parts of visual processing system have not yet cleared and many researchers of visual system have been making efforts for this. The visual system processed in eyes is achieved by Hubel who has researched for the visual system with Livingstone, a Novel prizewinner in 1981[2-3]. In Neuroscience (1987) and Science (1988) they published visual function of eyes as follows. Human eyes are informed of form, size, contrast, motion, direction, color, gradation, location, distance etc. from surrounding circumstances. Since we have immediate and efficient visual processing system in brain, we have no difficulty to analyze and understand in spite of a lot of information. The visual processing system has a parallel functional

channel which handles four kinds of information such as Form, Motion, Color, and Depth. It proved through a variety of clinical demonstrations and survey. And then the researches are continually published to prove the theory.
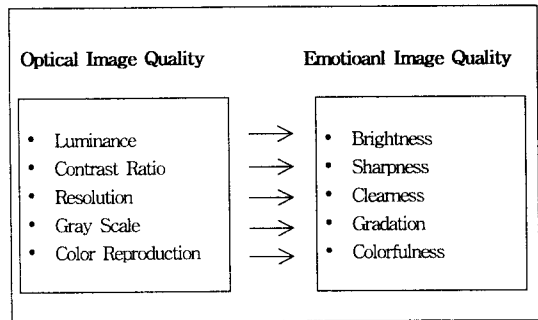

Fig. 1. Correlation of Optical Image Quality and Emotional Image Quality
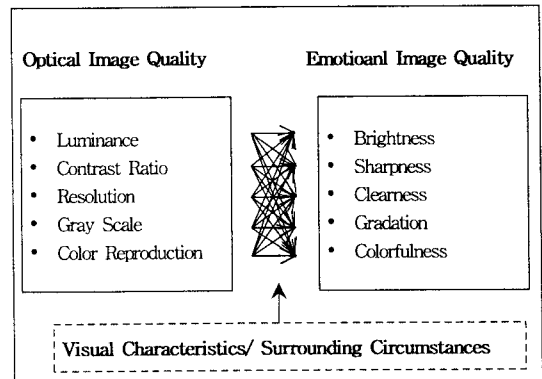
Fig. 2. Correlation of Image Quality Parameters and Emotional Image Performance

Figure1 shows that relation between optical image quality and emotional image quality has been respectively expressed by 1:1 matching. This relation has been fairly used in the field of studying measurement and evaluation for measuring emotional image quality. It is, however, not enough to reflect visual function. For instance the luminance matched by brightness as an item of optical quality in Figure 1 is actually connected with clearness, gradation and sharpness in the

perceptual view. In addition, contrast ratio, though it stands for clearness, is connected with emotional image qualities like brightness, clearness, gradation, naturalness and sharpness. Even though it is not perfect and need more researches, Figure 2, based on primary image quality elements in non-moving pictures, represents relation between the image quality items for display performance and emotional image quality items. Thus we should consider the complex relationship not 1:1 matching so as to evaluate display image quality psychologically and emotionally. We must have evaluation skills reflecting human visual characteristics and surrounding circumstances. Cue of the evaluation skills is to quantize emotional display quality based on perceptual image quality technique. In other words human eyes' characteristics should be considered for the emotional display image quality evaluation.

3. How are we evaluating image quality now?

Isn't there any emotional image quality evaluation method until now? I think the answer is yes. Many display company is evaluating displays by using human eyes: image contest. And recently the portion of the visual image quality evaluation is getting larger than the portion of physical image quality evaluation carried out electrically and optically. For instance some companies have bred up to the qualified experts of image quality evaluation for evaluating display objectively by the experts. In addition, video image standards corresponding with each test item are being made and utilized for the visual image quality evaluation to objectify results of emotional evaluation of display. However, these companies have recently developed the image quality analysis based on image signal processing techniques and the

quantized perceptional quality measuring system based on CCD camera technique because the visual image quality evaluation needs lots of resources. Especially a research on the relation between physical measurement results and perceptional image quality evaluation results is very important to objectify quantize perceptual image quality. It can be explained by the luminance, one of the main physical measurement items. In Figure 3 the x axis is the luminance: physical measurement result and the y axis is the
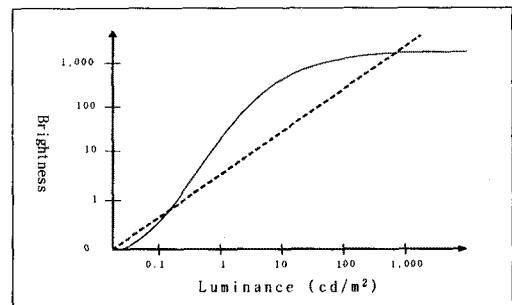
Fig. 3. Relation of Luminance and Brightness

Type of TV		
TV Maker		
Size of Display		
Rapid Developed Items	Viewing Angle	
	Response	
	Luminance	
	Contrast Ratio	
More Opimize Items	Color Reproduction	
	Color Gamut	
	Gray Scale	
	Uniformity	
	Image Sticking	
	Ringing	
	Sharpness	
	Smoothing	
	Image Tail	
	Noise	
	Color Shift	
Total		
Ranking		

Fig. 4.1. Evaluation Items of Japan image quality technology institute

brightness: perceptual lightness property. The relation between luminance and brightness is not linear as the dotted line in Figure 3. In low luminance, as luminance increasing, perceived brightness is dramatically increasing. On the other hand, as luminance reaching definite luminance or over, brightness is saturated as shown in Figure 3. Given more luminance, it gives the human eyes pain. This relationship is also affected by surrounding circumstances. The human eyes have the function of adaptation. In bright surroundings, more luminance needs than in dark surroundings.

Point	5	4	3	2	1
Luminance	Full White over 120[cd/㎡], Peak White over 600[cd/㎡]	F/W 90~120[cd/㎡], P/W 500~600[cd/㎡]	F/W 70~90[cd/㎡], P/W 400~500[cd/㎡]	F/W 50~70[cd/㎡], P/W 300~400[cd/㎡]	F/W under 50[cd/㎡], P/W under 300[cd/㎡]
Contrast Ratio	> 400:1	300:1~400:1	200:1~300:1	100:1~200:1	< 100:1
Color Reproduction	Over CRT	←		→	Very Poor
Color Gamut Area	Over CRT	Same as CRT	NIST 60~70[%]	NIST 50~60[%]	<NTSC 50[%]
Gray Scale Performance	Over CRT	←		→	Very Poor

Fig. 4.2. Scoring Check List of Japan image quality technology institute (a part)[%]

Quantizing the emotional image quality has been attempted in Japan's image quality research group since the early 2000s. Nakamura in Japan image quality technology institute suggested comprehensive and objective evaluation method to quantize image quality of TV as choosing five primary image quality items, Brightness, Contrast ratio, Response, Color, Viewing angle, and deriving 15 specific evaluation items as shown Figure 4.1 and making scoring standard. Each item can score up to five as shown Figure 4.2[4]. Around that time, Asakura, a video critic of

Japan's image quality society, announced the evaluation method which classify the emotional evaluation items by display device and score the grade of image quality. However, these evaluation methods have some insufficiencies to utilize. The method of Nakamura is good at scoring image quality but the items need the weight, and besides, the scoring standard did not consider the human visual characteristics. The method of Asakura is just evaluating the grade of emotional impression. Choosing the video image for evaluation is also difficulty in that objective video image is uncertain and it can not be used twice to a person due to learning effect.

Visual Functions	Emotioanl Image Quality Indices
• Form → • Motion → • Color → • Depth →	• Clear Image • Real Motion Picture Image • Natural Color Reproduction • Three Dimension Perception

Fig. 5. Correlation of Visual Functions and Emotional Image Quality Indices

4. The emotional image quality evaluation method based on visual characteristics

If we objectively quantize the display quality in human perceptual view, we can use the term: the emotional image quality evaluation. To solve this problem, the relation between four 1st order visual functions of human eyes, formerly explained, and emotional quality standards has to be understood. Figure 5 shows the relation. Display's fundamental objective is to satisfy four emotional image quality indices in Figure 5. First, Clear Image is connected with resolution, luminance, contrast ratio, and viewing angle. It is also related to Form which functions as perceiving shapes. Second, Motion,

for making real motion picture image, is corresponding to response time, driving frequency of display, motion blur, flicker and dynamic false contour etc. Third, Color is related to color gamut of display, gamma, and gray level etc. Fourth, three dimension perception is corresponding to depth, dependency on viewing angle, and 3D embodying method etc. The three dimension perception is not clear because 3D display industry has not grown up yet. To sum up, we can evaluate most of image qualities based on the four 1st order visual functions (Form, Motion, Color, and Depth) and emotional quality indices corresponded with them.

It is more interesting that the developing history of device is related to display as shown in Figure 6. A camera invented in 1826 can reproduces the Form, one of the visual functions. After that, researches for reproducing not only form but also

moving had continually proceeded, they invented motion pictures: movie, corresponding to the Motion, one of the visual functions, in the late 1800s. In 1951 Color TV relating to the Color function was invented after all. From this point of view, the displays perceiving three dimensional space will be soon commercialized. However, displays can not express clear image not likely photos and real motion not likely movies. Also displays have the limitation to reproduce natural color. Therefore display quality performance has to be more improved.

Image quality evaluation methods reflecting human visual characteristics are appearing nowadays. In this paper two emotional evaluation methods corresponding to three visual functions except the three dimension perception are introduced. One is three dimensional color space reflected Form as the first visual function and
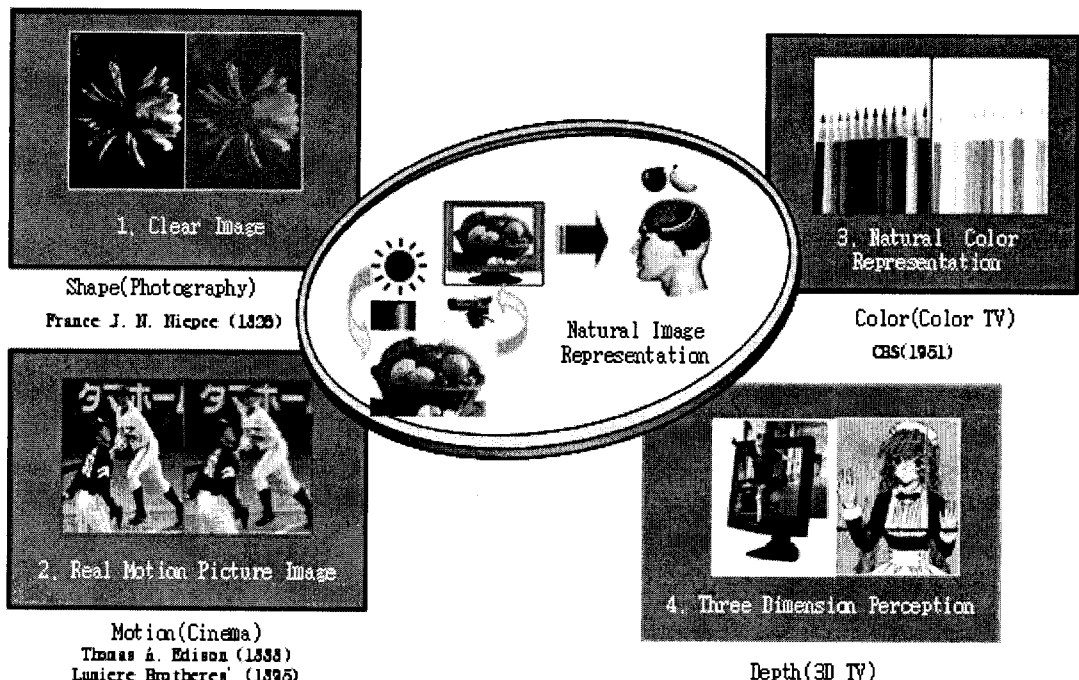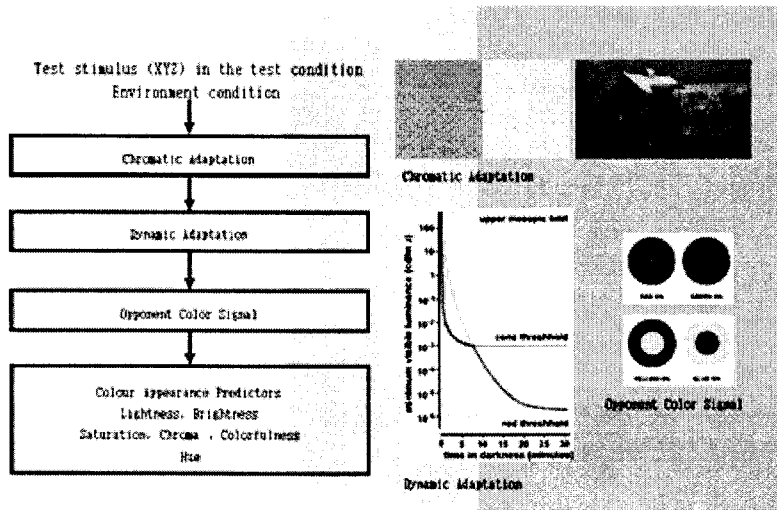

Fig. 6. The Histry of Device Development for Image

Mark D. Fairchild, IS&T/SID 12th Color Imaging Conference
http://www.handprint.com/HP/WCL/color4.html

Fig. 7. The Principle of CIECAM02 Color Space

Color as the third visual function. The three dimensional color space indicates the Color Appearance Model (CIECAM02) announced as an international standard of color by CIE (Commission Internationale de l'Eclairage) in 2002. CIECAM02 is the most improved standard color space as shown in Figure 7[5]. It is reflecting surrounding conditions and human eye's adaptation and provides mathematical formulate to transform physical measurements of the stimulus and viewing environment into correlates of perceptual attributes of color. This three dimensional color data in each gray can also quantitatively provide useful information relating to emotional image quality. After the method of display using CIECAM02 announced for the first time in CIE 2007 Conference in Beijing, on July 2007, it is acknowledged as a good emotional evaluation method [6-7]. Figure 8.1 is an example of the CIECAM02 output including visual functions by inputting electrical and optical measurement data at each gray of display. This volume of color space can not only objectify color

reproduction capability but also analyze the gray and gamma characteristics. In other words, using the method, form, the first visual function, which can related to clear image and such evaluation items as luminance, contrast ratio, black and white etc. can be quantized as well as color, the third visual function, how close to natural color can displays be . Image quality as viewing angle or ambient light can also be analyzed by it. The color data of image can also be expressed like right side of Figure 8.1 and analysis of the picture can be done by using this. Figure 8.2 is another example of utilizing CIECAM02. Perceptual contrast evaluation method which uses the ratio and range of black level and white level of brightness on z axis announced in IMID 2007 and 2008. Thus it is a chance to prove the display having contrast ratio of over one million [8]. Like these examples, emotional evaluation method using CIECAM02 has many advantages to estimate non-moving picture characteristics and it has been paid much attention to.

The other evaluation method reflecting human

visual characteristics is for moving pictures. Until now evaluation of moving pictures only depends on devices on/off response time. But the on/off response time is not suitable in that it is not directly connected motion characteristics which viewers perceive. Recently, to evaluate moving pictures characteristics, moving CCD camera systems has been designed.
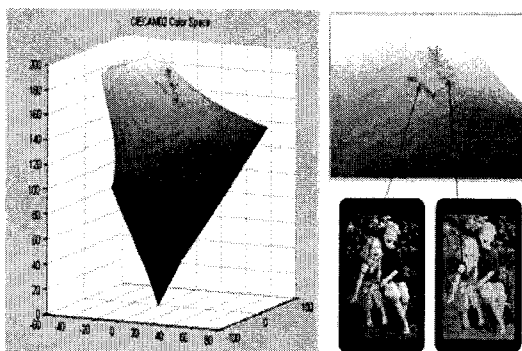

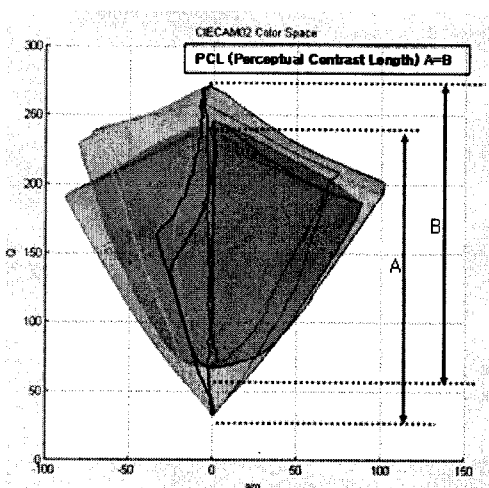Fig. 8.1. Emotional Image Quality using CIECAM02(Example 1)

Fig. 8.2. Perceptual Contrat Evaluation Method using CIECAM02(Example 2)

The systems can analyze blurring edge of the image captured by the camera and can measure the perceptual resolution of moving pictures using

resolution pattern [9-10]. This is one of the proper measurement methods to evaluate motion blur which is the most fundamental feature of Moving: the second visual function, seeing that it is emotional evaluation method based on human perception characteristics. Moving picture evaluation method considering form, color and the velocity as well as eyes' pursuit will develop in the near future.

5. Conclusion

It is necessary to develop and standardize the evaluation methods of image quality in the view of emotional evaluation to avoid meaningless spec (specification) competition. A display which has the most impressive quality is expected by drawing up guidelines for developers and optimizing performance of emotional image quality. Besides these the most optimized image quality, we should not miss things like comfortable image quality not to cause eye's fatigue. We need to pay attention to the result of falling eyesight in time of watching TV that is published by Prof. Takahashi in Osaka University of Education, Japan [11]. If some factors affect human eye's fatigue, these are sufficiently considered in designing image quality. Increased requests of the environment and human friendly product, researches about them have also become essential.

Finally, the item of Depth:the fourth visual function not mentioned in this paper will be developed and standardized in according to 3D display commercialization.

References

[1] T. Kondo, Pursuit of high image quality does not end, Nikkei Microdevices, October, 30~31(2006) / Japanese.
[2] D. Hubel & M. Livingston, Segregation of form, color and stereopsis in primate area 18, J. Neuroscience, 7, 3378~3415(1987).

[3] Livingston & Hubel, Segregation of form, color, movement and depth, Science, 240, 740~9(1988).

[4] J. Nakamura, Advent of rear projection approached LCD and PDP TV, Nikkei Microdevices, Sep 9, pp. 69~74(2004) / Japanese.

[5] Mark D. Fairchild, Color Appearance Models, 2nd Edition, John Wiley & Sons, New York(2005).

[6] S. Lee, J. Chong, J. Bae, J. Kim, J. Oh, S. Lee, H. Kim and H. Chung, A study on method of evaluating image quality with CIECAM02, Proceeding of 26th Session of the CIE, Beijing, D8-2~5(2007).

[7] J. Chong, S. Lee, H. Park, S. Kim, J. Bae and H. Kim, A Noble Evaluate the Emotional Image Quality with CIECAM02, IMID '08 Digest 3-3(2008).

[8] J. Chong, S. Lee, S. Lee, Y. Choi, J. Bae, H. Kim and H. Chung, A Study on the Evaluation Method of Perceptual Contrast with CIECAM02, IMID '07 Digest 1661~3(2007).

[9] Jaeshin Kim, J. Chong, S. Kim, G. Kim, J. Bae, Seungbae LEE, and J. Oh, A Noble Measurement Method for Moving Picture Quality of Display. IMID 2008 Digest 1039~42(2008).

[10] I. Kawahara, Excellent Moving Picture Resolution, IMID '07 Digest 1685~7(2007).

[11] M. Takahashi, LCD vs PDP Picture Quality Status and the Task of FPD TVs, KDC(2006).

Biography

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