

The Perception Limit of LCD TV's Motion-Blur Levels Based on Human Visual System at Moving Pictures

Kwang Hoon Shin*, Ji Young Ahn, Ki Duk Kim, and Hyun Ho Shin, and In Jae Chung
 LCD R&D center, LG.Philips LCD Co., Ltd.
 Hogae-dong, Dongan-gu, Anyang-shi, Gyongki-do, Korea
 Phone:+82-31-450-1822, E-mail: khshin@lgphilips-lcd.com

Abstract

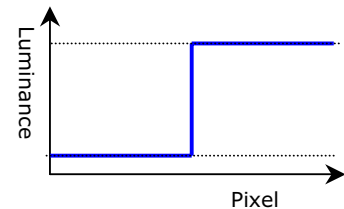
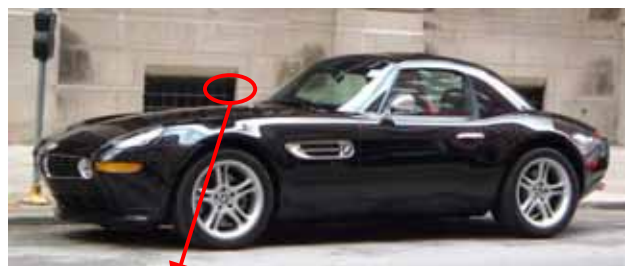
We conducted visual perception experiments to determine the perception limits of motion blur based on human visual system at LCD TV's moving pictures. The motion blur can be expressed Blurred Edge Width (BEW). The results showed that the BEW of moving pictures should be below 3.4pixels (visual angle 4.2') at 3H distance in a living room environment.

1. Introduction

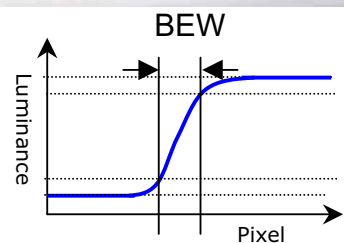
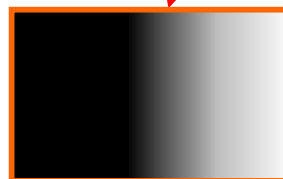
Since 2000, several displays such as LCD, PDP, OLED have been released which could replace transitional display (CRT) at the display market. Especially in case of LCD, because of the improvement of mass production technique, the number of LCD users significantly increased. As the LCD technology advances, LCD users continue to demand for improved quality of LCD. CRT has been the standard to which most CRT users compare and evaluate LCD. Therefore LCD makers have been developing LCD technologies that are compatible to CRT.

Motion blur is caused by slow LC response and hold type characteristics in LCD. Many LCD makers have been competitively making a lot of efforts to improve response time to minimize motion blur effect. As a result of these efforts by LCD makers, a significant improvement has been made in response time and motion blur [1-4], however such improvements are still insufficient to match the numerical value of CRT specification. In today's FPD market, many other display technologies are competing with LCD. Then we should consider carefully that improvement of LCD should not only focus on making CRT-like display. But also consider the ergonomics. Therefore the purpose of this paper is to suggest the perception limit of motion blur in moving picture and the target

of motion blur reduction technique. And motion blur can be expressed BEW as figure 1.

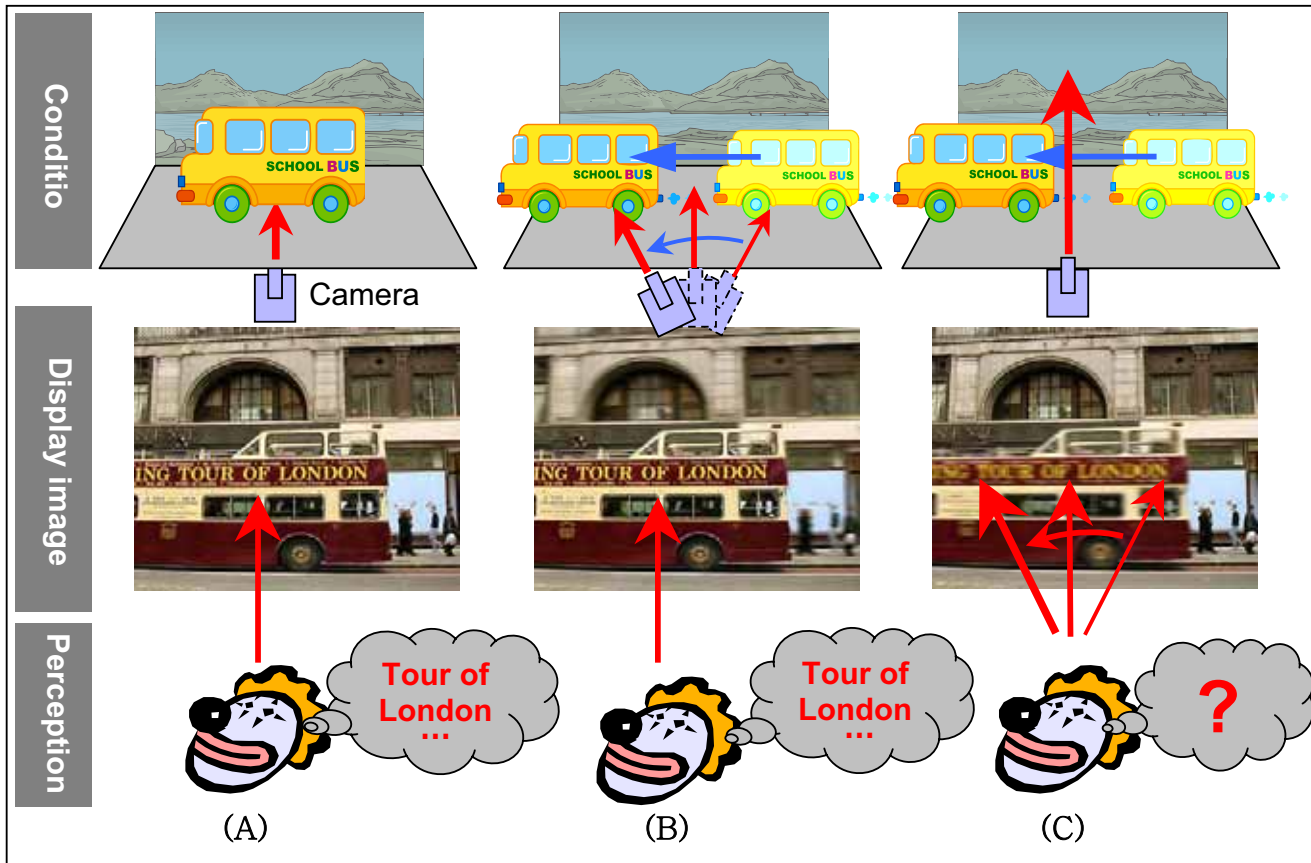


(a) Still image



(b) Moving image with motion blur

[Figure 1] BEW of motion blurs



[Figure 2] Visual Perception according to moving pictures

Generally, three entities, camera, subject, and background constitute moving picture which are further divided into three cases depending on how these three entities interact with each other. In first case, there are no movements of camera, subject, and background. In second case, camera follows moving subject. In third case, other objects move between subject and background. Among three cases, the third case is one that causes worst motion blur of moving picture. As in figure 2 (C), even if subject is photographed by camera, but one should see blurred image of the bus when human eyes look at the moving bus. We would often find the similar condition in scroll image. From the viewpoint of moving picture, because the main purpose of scroll text is to convey information on the screen at a certain moving speed, it stands out from the background. And from the viewpoint of viewer, because one should concentrate on scroll text in order to get the information, the eye tracks the moving text which is natural for human. Consequently, one feels serious

motion blur in scroll text in moving picture. In other words, one should feel more motion blur in moving picture with scroll text than normal moving picture. Therefore if we set the limit of perception of scroll text picture, this would also set the limit of perception in other moving pictures.

2. Experiment

2.1 General experimental setting

In order to quantify the motion blur that humans perceive on LCD, we carried out subjective evaluation experiment. Several subjects using the following evaluation scale evaluated the quality of the test picture relative to that of the reference picture.[5,6]

Five-grade impairment scale for deterioration of quality of the test picture is:

5: imperceptible, 4: perceptible, but not annoying, 3: slightly annoying, 2: annoying, 1: very annoying.

Grade 4.5 is sometimes called “threshold of perception (for deterioration)” and grade 3.5 is sometimes called “limit of acceptance” in the result.

In this method, a test image and a reference image taken from the same material are used as the reference and the test, and both are displayed on the same simulated display. Therefore, the method eliminates the influence of many characteristics other than the quality of moving images.

Our subjective evaluation is operated in a test room, which is modeled on a living room to emulate the LCD-TV consumer environment. And we carried out the visual perception experiment with commercial HD LCD TV and/or HD CRT TV at 3H distance, where H is Height of display. The reference display and the test display have the same image quality setting of brightness, color temperature, etc. We directly displayed the selected test image to LCD TV and got real blurred images for visual perception experiment. And to analyze experiment results, we measured MPRT (Moving Picture Response Time) of test display by MPRT-1000[7]. So we get the BEW value of blurred image as subject speed. And in our subjective evaluation experiment, eight men and seven women, all in their 20s to 40s, were used for test subjects. Those fifteen subjects included engineers working in LCD field and nonengineers.

2.2 Scroll text perception experiment

Depending on purposes of each broadcast station and program, scroll texts in moving picture have different shapes. To get the perception limit of motion blur in this experiment, letters with several stroke characters were chosen and black and white color were used to express high contrast. In order to execute the experiment of perception about motion blur, we made several images that have a different BEW. The blurred images that would use perception experiment was made by scrolling of a selected HD image at the LCD TV which was measured N-BEW(Normalized BEW) by MPRT-1000.

$$BEW(\text{pixel}) = \text{Scroll Speed}(\text{pixel/frame}) \times N\text{-BEW}(\text{frame})$$

Visual perception experiment was executed by repeating ten test images three times at 3H distance with reference still image by PC control.

2.3 Moving picture perception experiment

Moving picture perception experiments were executed by fourteen image which consisted of drama, documentary film from the public HD broadcasting, and LCD TV (test image) and CRT TV (reference image) were controlled by set top box. And we got the N-BEW of test images by MPRT measurement of LCD TV.

3. Results

3.1 The perception limit of scroll text

At the result of scroll text visual perception experiments (Table 1.), we found through a statistical analysis that a threshold of perception was 2.2pixels, and the limit of acceptance was 3.4pixels on average. This means when BEW of scroll text was 2.2pixels, one recognized motion blurs but not annoying. And in case that BEW was 3.4pixels on average, one felt discomfort about moving picture. Consequently, the limit of visual perception for motion blur is 3.4pixels at 3H. This normalized to visual angle, 4.2’. And at the moving picture, the 10pixel/Frame speed of scroll text is ranked top 1% under overall speed of scroll text. In this condition, BEW is translated into BET (Blurred Edge Time, at 60Hz), 5.7ms. This means that if moving speed is 10pixel/frame and the BET of display is over 5.7ms, one should feel discomfort for moving picture.

$$BET = BEW / \text{Frame rate}$$

[Table 1] The perception limit of scroll text

Scroll text experiment	Threshold of Perception	Limit of Acceptance	Remarks
BEW	2.2 pixels	3.4 pixels	Blur Edge Width
Visual angle	2.4’	4.2’	3H distance
N-BEW	0.22Frame	0.34 Frame	Scroll speed ; 10pixel/Frame(60Hz)
BET	3.6 ms	5.7 ms	MPRT

3.2 The perception limit of moving picture

In case of moving picture, we found through the same statistical analysis that a threshold of perception was 2.5pixels, and the limit of acceptance was 4.5pixels on average. This means when BEW of moving picture was 2.5pixels, one recognized motion blurs. And in case that BEW was 4.5pixels on average, one felt discomfort about moving picture. In this condition, BEW is translated into BET, 7.5ms(Table2). This means that if moving speed is 10pixel/Frame(at 60Hz) and the BEW of display is over 7.5ms, one should feel discomfort for moving picture. Especially we found out the different response of moving image impairment for the same speed test images. It was caused by the difference of test image that had shape, contrast for background, etc.

[Table 2] The perception limit of moving picture

Moving Picture	Threshold of Perception	Limit of Acceptance	Remarks
BEW	2.5 pixels	4.5 pixels	Blur Edge Width
Visual angle	2.5'	5.6'	3H distance
N-BEW	0.25 Frame	0.45 Frame	Scroll speed ; 10pixel/frame(60Hz)
BET	4.2 ms	7.5 ms	MPRT

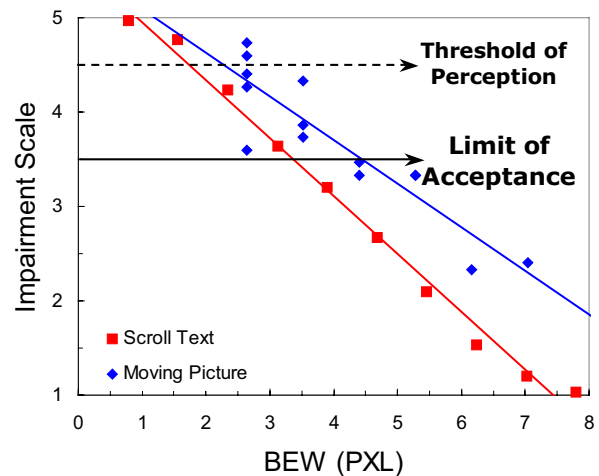
3.3 The perception limit of motion blur

As we said above, the perception limit of scroll text and moving picture was different. The reason of this difference was caused by human visual system that recognized scroll text and moving picture. The purpose of scroll text was delivery of a lot of information in short time. So broadcaster made the scroll text that was distinguished from the background. Therefore the TV audience concentrated their attention more to scroll text than moving picture.

But in case of general moving picture, broadcaster will express the meaning of image, so they emphasize subject from the point of view of image aesthetics. And they made subject more clearly than background image and made the TV audience attend to additional sounds and narrations as well. So although the TV

audience saw motion blur, they do not more easily recognize blurring of moving picture than scroll text.

Therefore the perception limit of scroll text is smaller than that of moving picture. So we concluded the perception of motion blur is that of scroll text and the perception limit of motion blur is 3.4pixels.



[Figure 3] Perception limit of motion blur

4. Conclusion

In this study, we proposed the proper motion blur level of a LCD TV that was derived from a discomfort level in a living room environment. And we concluded the perception limit of motion blur is that of scroll text and it is 3.4 pixels. These results can help engineers and end-users make right decision about motion blur of LCD TV.

5. Reference

- [1] Kawabe, K.et al. "New TFT-LCD Driving Method For Improved Moving Picture Quality", SID '01 Digest 35.4 pp998-1001
- [2] Kimura, N., et al. "New Technologies for Large-Sized High-Quality LCD TV", SID '05 Digest 60.2 pp1734-1737
- [3] Lee,S.W.,et al. "Improved Technology for Motion ArtifactElimination in LCD Monitors: Advanced DCC", SID '05 Digest 46.4 pp1496-1499

- [4] Hirakata, J. I., et al. "Super-TFT-LCD for Moving Picture Images with the Blink Backlight System" SID '01 35.2 pp990-993
- [5] Kurita, T. "Moving Picture Quality Improvement for Hold-type AM-LCDs", SID '01 Digest 35.1 pp986-989
- [6] Kurita, T "Invited Paper: Desirable Performance and Progress of PDP and LCD Television displays on Image Quality" SID '03 Digest, 17.1, pp776-779
- [7] Youichi et al, "Summary of Moving Picture Response Time (MPRT) and Futures", SID '04 Digest, 43.3, pp1262-126