Motion blur analysis by Gabor patch

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Abstract

Motion blur of LCD displays has been measured subjectively by using Gabor patch radiusese. Gabor radiuses at a normalized scroll speed, Scroll speed times Fc, to be unity, indicate motion blur strengths, which are named a perceived motion blur strength measured by a Gabor patch. The results are compared with eye perception, PBET and EBET.

1. Introduction

Motion blur of displays are important quality of display image. Extended blur edge width has been used for a blur parameter. Blur edge width at 10 and 90 % of luminance difference is extended to 0 and 100 % by a linear extrapolation. This width is called "Extended Blur Edge Width", EBEW. The EBEW is approximately proportional with the scroll speed. The proportionality constant is "Extended Blur Edge Time", EBET (ms). The blue edge width is affected largely on the luminance profile at the edge. The luminance profile is overlay of LCD pixel. To smooth out the profile, several smoothing filter functions are used. Low pass filter has a weak point that the width after filtering becomes larger. Notch pass filter with high frequency cut is a best selection.

Contrast sensitivity function will be a filter function to simulate human visual capability. We proposed "Perceived Blur Edge Width", PBEW, which is a distance between peak maximum and peak minimum of profile, which is produced after FFT filtering by a contrast sensitivity function, CSF. "Perceived Blur Edge Time", PBET is a result of PBEW divided by the scroll speed. The optically measured parameters such as EBEW, EBET, PBEW and PBET are physically well understandable. However, sight recognition is different from physical image. In addition, as the motion blur strength is smaller than 16 ms of EBET, transition curve will contain many factors other than a motion blur happened by as slow response of LCD. To study such small motion blur, we try new method.

A Gaussian-windowed, drifting sinusoidal luminance pattern (a Gabor patch) is used as a stimuli tool for vision science. In a reverse way of Gabor patch usage, a display performance such as a motion blur will be measured. We propose a new method to evaluate motion blur by using Gabor patch. Gabor patch is used for an analysis of visual display quality. Gaor patch is a brain model and therefore, the sensitivity is close with human vision. Therefore, we expect that this approach may be good method for visual quality analysis of display. We will compare EBET, PBET and Gabor patch method, and then select a best method, which presents motion blur to be close with eye perception.

2. Experimental

A Gaussian-windowed, drifting sinusoidal luminance pattern, namely a Gabor patch is a tool for analysis on human vision. In this paper, a Gabor patch is applied to measure motion blur of display. Gabor patch pattern is written by Equation (1). Figure 1 shows the pattern.

$$L(x,y)=$$
$$L_m\left\{1+C_F\cos[2\pi F_C x+\theta]\exp\left\{-\frac{1}{2}\left[\frac{\pi}{\sigma_x}\right]^2-\frac{1}{2}\left[\frac{\pi}{\sigma_y}\right]^2\right\}\right\} \quad 1)$$

A Gabor radius is a maximum size of pattern detection area, which is measured by using human eye. The experimental conditions are σ_x, σ_y, L_m, C_P, and F_C.

Gabor patch pattern is displayed by software named "Video Generator" developed by Nanosoftware Ltd. This can display various types of scroll patterns.

Several cautions on this vision experiment need to be taken. A visual noise such as a grid pattern added on a test pattern affects largely on the results. A viewing distance (500 mm for PC monitor and 3H: display height for TV), luminance level and display pattern size are constant. In case that examiner has good eyes, the viewing distance should be tuned to increase for decreasing eye sensitivity. This effect is not large.

Three kinds of LCD-Monitors (Benq FP93GX, FD747 and Mitsubishi RDT158V-N) and CRT monitor (Mitsubishi, RDF191S) for PC are used as shown in table 1. The LCD monitors have large motion blur. The CRT has small or almost zero motion blur. This study compares LCD and CRT displays, which have opposite characters.

3. Results

Scroll speed dependence of Gabor radius for three kinds of displays are measured such as shown in Fig. 2. Horizontal scale is a scroll speed after multiplied by values of Fc. Gabor radius decreases with increasing scroll speed in case of LCD monitor. However, the radius does not decrease with the scroll speed incase in case of CRT monitor at Fc<=0.2..

Gabor radius at zero scroll speed has slight luminance Lm dependence. The radius is 114, 116 and 118 at Lm=96, 128 and 192. Data is added by two experimenters, G.O. and D.O., who have slightly better acuity than K.O.. In such case, viewing distance will be longer, and the acuity decreases. The data will be corrected by changing a view distance.

Conditions to get unscramble values:

1) Averaged values of 5 times measurements.
2) Fc=0.333, 0.25, 0.2, 0.166, 0.143, 0.125 and 0.1.
3) Scroll speed = 1/Fc.

Gabor radius at a scroll speed * Fc = 1 is a factor which indicates a blur strength. Table 2 indicates the factors after normalized by radiuses at scroll of zero. The normalized radius represents well the motion blur character of displays. Data from different examiners are slightly different. (The examiner dependence needs to be corrected. This is not large.)

Since eye is high sensitive device, signals are always over-lay on photon statistics. Average of couple of times measurements gives randomness reduced value. The values of Fc selected are 0.333, 0.25, 0.2, 0.166, 0.143, 0.125, and 0.1. The averaged Gabor radiuses are plotted in Fig. 4 and 5. Number of repetitions are 4. Uncertainties indicate standard deviations. Radiuses are minimum at Scroll speed * Fc=1. Gabor radiuses are independent on viewing distance.

Fig. 2, 3 and 4, 5 are similar plots except the data are accumulate and averaged. Values of Fc are selected to get Fc*scroll speed =1.

Normalized Gabor radiuses obtained from four kinds of displays are shown in Table 5. Gabor radius does not decrease in case of CRT-Mon except at Fc=0.333. CRT does not exhibit motion blur. On the other hand, Gabor radius reductions are larger in case of three kinds of LCD-Mon. In detail, Radius of FP93GX is slightly larger than other LCD.

4. Discussion

Normalized Gabor radiuses indicate subjective parameter of motion blur factors. Gabor patch method will be useful to measure motion blur at 16 ms and less of PBET or EBET. Since number of tested displays is small, we need to accumulate data of various displays.

Table 3 indicates PBET and EBET of same type monitors. Gabor radiuses are converted to motion blur indexes in table 4 as a trial. We tried to give motion blur indexes as in Table 4 by tuning multiply factors to get near reasonable index. This trial is not successful.

Motion blur of CRT has certain value of PBET and EBET. However, the radius of Gabor patch is not affected from scroll speed. The radius at large Fc=0.33 decreases slightly as shown in Fig. 6.

Motion blur width such as EBEW or PBEW is close with devise physics and help improving devise quality. Gabor patch analysis is one of trial for approaching visual quality of display. This research may approach to a vision of motion blur of LCD and give an idea of improving method.

We will accumulate data from variety type of displays.

5. References

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Size & kind	Type	Horiz	Vert	Aspect ratio	Horiz size
19' LCD Monitor	FP93 GX	1280	1024	1.25	377
19' LCD Monitor	FP747	1280	1024	1.25	377
15' LCD Monitor	RDT 158V-N	1024	768	1.33	304.1
19' CRT Monitor	RDF 191S	1280 1600*	1024 1200*	1.25	372

*) Maximum pixels

Table 1, Tested displays.

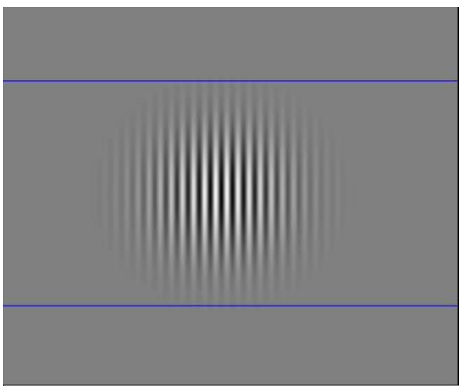

Fig. 1. Gabor patch. Lm=128, Fc=0.1,

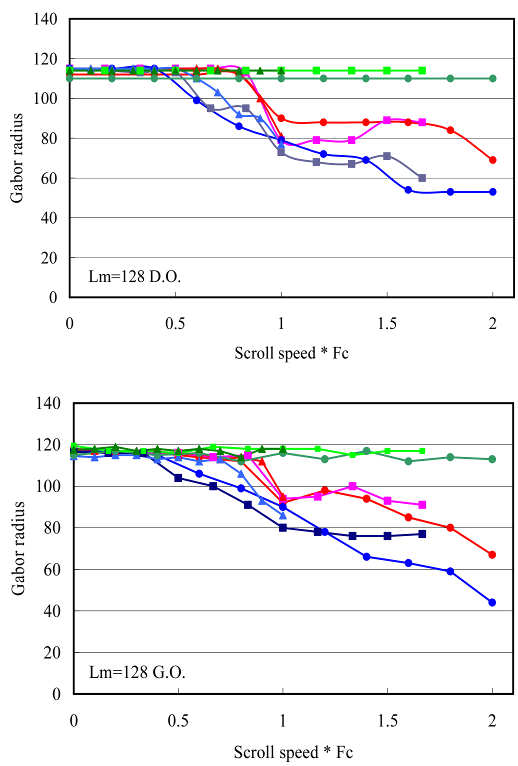

Fig. 3. Gabor radius observed by two different experimenters.

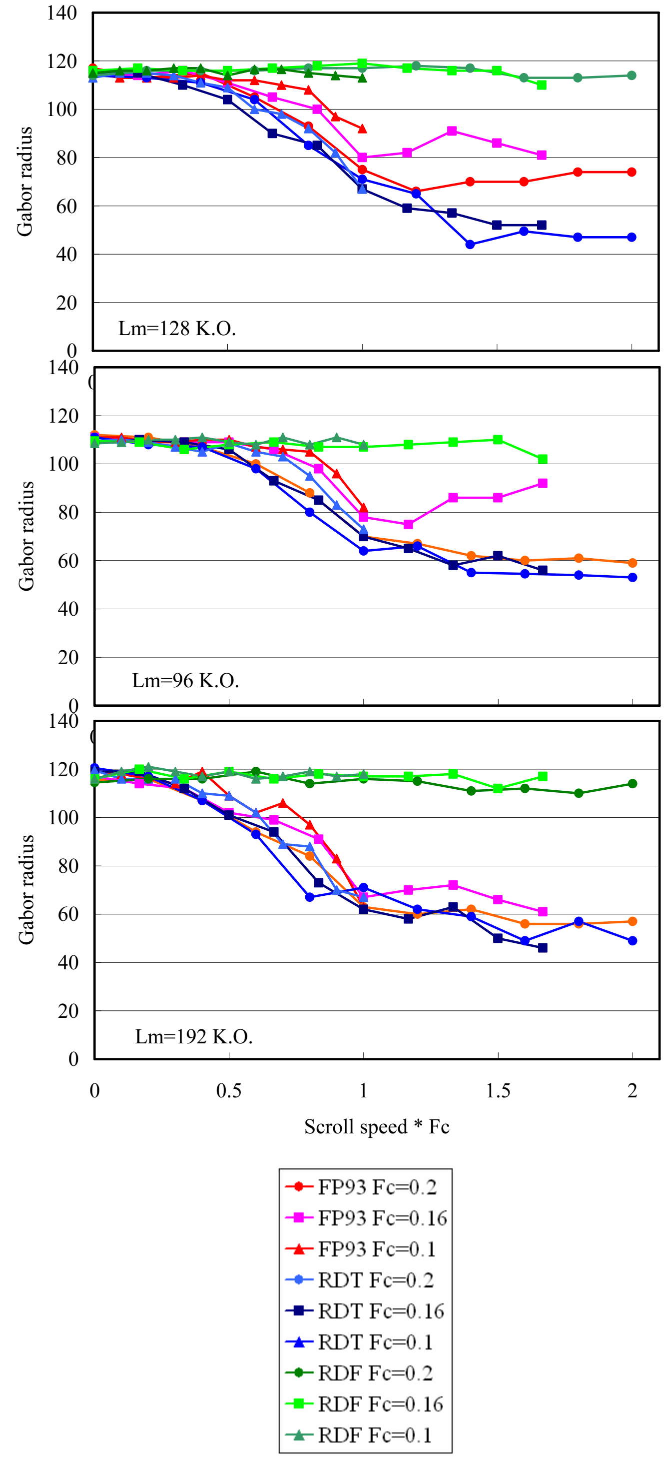

Fig. 2. Gabor radiuses of LCD-mons (FP93 and RDT) and CRT-mon (RDF). The conditions are Fc=0.2, 0.1666, and 0.1. Lm=128, 96 and 192.

	Fc	FP93GX	RDT158V-N	RDF191S
Lm=128 K.O.	0.2	0.64	0.62	1.03
	0.167	0.70	0.58	1.03
	0.1	0.80	0.59	0.98
Lm=96 K.O.	0.2	0.63	0.58	0.99
	0.167	0.70	0.64	0.98
	0.1	0.74	0.67	1.00
Lm=192 K.O.	0.2	0.55	0.59	1.01
	0.167	0.57	0.52	1.01
	0.1	0.53	0.56	1.02
Lm=128 D.O.	0.2	0.80	0.69	1.00
	0.167	0.69	0.64	1.00
	0.1	0.70	0.67	1.00
Lm=128 G.O.	0.2	0.78	0.77	1.01
	0.167	0.69	0.69	0.99
	0.1	0.75	0.75	1.00

Scroll speed * Fc=1

Table 2. Normalized Gabor radius at Scroll speed * Fc=1.

	PBET	EBET
RDT158V-N	24.0	30.8
Benq-91(OD on)	20.7	19.8

Table 3, PBET and EBET (ms)
1) Viewing distance: 500 mm
2) Scroll speed: 12 deg/s
3) Frame frequency=60 Hz(or equivalent)
4) Frame frequency=75 Hz(Benq), and
BETs is converted to 60 Hz equivalent.

	FP93GX	RDT158V-N	RDF191S
Lm=128 K.O.	23.8	25.0	−1.7
	20.2	27.7	−1.7
	13.3	27.0	1.2
Lm=96 K.O.	24.9	28.1	0.9
	19.7	24.0	1.5
	17.3	22.1	0.3
Lm=192 K.O.	30.2	27.3	−0.9
	28.4	31.8	−0.6
	31.2	29.2	−1.1

=(Normalized Gabor radius − 1) * 16.6 * 4 ms

Table 4. Trial index of motion blur strength.

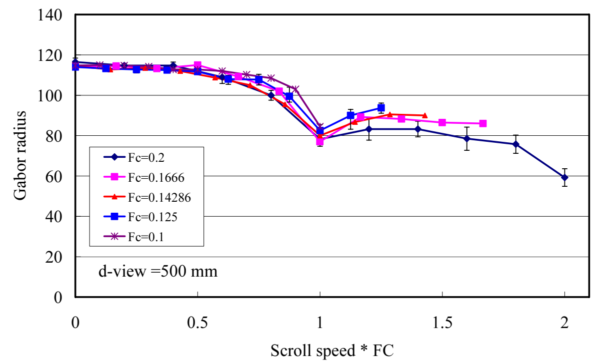

Fig. 4. Averaged (N=4) Gabor radiuses. View distance=500 mm. Panel: FP93GX.

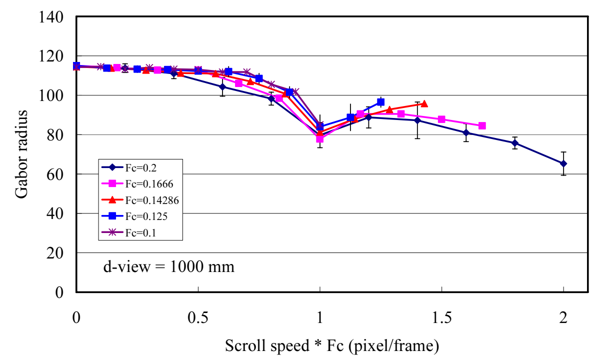

Fig. 5. Averaged (N=4) Gabor radiuses. View distance=1000 mm. Panel: FP93GX.

Fc=	0.33	0.25	0.20	0.17	0.14	0.13	0.10
RDF191F	0.89	0.96	0.96	1.00	1.02	0.99	0.99
FP93GX	0.67	0.67	0.66	0.66	0.69	0.67	0.69
FP747	0.64	0.62	0.60	0.70	0.66	0.66	0.70
RDT158V-N	0.61	0.57	0.62	0.64	0.63	0.65	0.69

Examinor: K.O.
Viewing distance: 500 mm, Lm= 128, N=4

Table 5. Normalized and averaged Gabor radiuses.

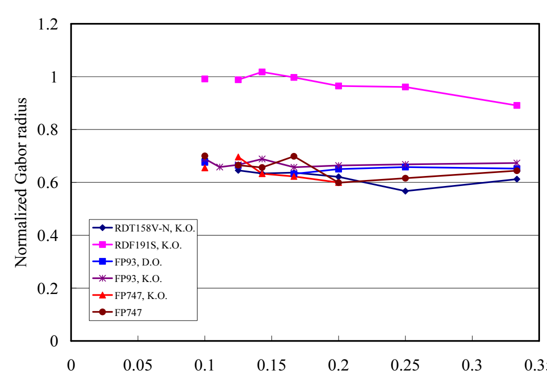

Fig. 6. Normalized Gabor radiuses of various displays.