Recent Development of High Quality LCDTV

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Abstract

The production technologies of the flat panel display in the large-size liquid crystal TVs have been developed remarkably. The importance of evaluation method of the display has been also increased. Using the new indexes for evaluations of the motion picture quality and the viewing angle characteristic of the liquid crystal TVs, we review the developments of the recent liquid crystal television technology .

大型液晶TVにおいて，平面ディスプレイの生産技術が飛躍的に発展しています。同時にディスプレイの評価方法の重要性も益々高まっています。本論文では，液晶TVの応答特性と視野角特性について，新しい評価法を提案し，その評価結果に基づき，最近の液晶TV技術の進展状況をレヴューします。

Introduction

In 2001, the ASV technology [1], [2] has established the new century of the liquid crystal televisions (LC-TVs). In 2004, the operation of the LC-TVs factory in the 6th generation has been started and a market of large-size screens over 40 inches occupied so far only with PDP will be expanded by the LC-TVs steadily. On the other hand, the infrastructures of the telecommunication and the digital broadcasting have been growing remarkably. The developments of the large-size and high quality LC-TVs have been accelerated by the rapid spread of digital AV contents and equipments such as DVD and hard disk recorder.

It is needless to say that the best motion picture qualities of display, not only in ordinary temperature but also in low temperature, are demanded for the LC-TVs. The less influences of viewing angles on the characteristics of the display, for example the color shift, contrast and the gamma, are required to the large-size LC-TVs. The motion picture quality and the viewing angle characteristics of the LC-TVs are remarkably improved, but do not yet exceed that of CRT-TV.

It is not easy to promote further development of the LC-TVs without the correct objective evaluations and the subjective evaluations of display. The discussion of the standardization of the evaluation of the image quality will become an important problem in the next LC-TVs development. We propose the new index measuring the qualities of LC-TVs and review the present situations of the LCD technology using these indexes.

1. Evaluation of motion picture

A video motion blur is caused by a hold type display with liquid crystal of slow response time. It has been well studied the relations between the eyes tracking and the video motion blur in the field of the PDP, the projector as well as the LC-TVs. The various technologies including the over drive, the OCB within 1 frame response time [3], the impulse type drive, the high refresh rate [4] are proposed to get the good quality image of LC-TVs.

Considering the causes of the video motion blur, the way

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of evaluating the image quality is classified into two subjects, the first: the evaluation of response time based on eye tracking integral, the second: the contour accompanied with the impulse type drive. We propose to introduce the new index for the evaluation of the motion picture blur. Using the index, it becomes possible to evaluate the motion blur in the hold type drive and the contour in the impulsive type drive, in a unified way. In the previous works, MPRT (Motion Picture Response Time) and N-BET (Normalized Blurred Edge Time) [5] were proposed as the way of expressing the response time of the motion picture, but the discussion on the impulse type drive was not sufficiently accomplished. We have recently proposed the "VIEW" and "VICC" for evaluations of response time [6].

1.1 Visual intensity and VIEW and VICC

We analyze the response time and the contour of the impulse type drive by the new way of the evaluation, on the basis of the eye tracking integral. We assume that visual intensity of motion picture moving in x direction is expressed by G(x),

$$G(x) = \frac{1}{2T} \int_0^{2T} d\tau f \left\{ x + \frac{L}{2T} \tau, \tau \right\},$$

where f(x, t) is the response function of liquid crystal, 2T equals to the frame time and L is the scrolling length per unit frame time. The ideal visual intensity G_I is written by the step function as,

$$G_I = \sigma \quad (x \leq 0), \quad G_I = 0 \quad (x > 0).$$

The visual intensity represents shape of blur function based on eye tracking integral. We introduce VIEW (Visual Intensity of Edge Width) and VICC (Visual Intensity of Contour by Compaction) the new index evaluating the motion blur [6].

The blur width w of the motion picture at x is calculated by the $w=|\sigma/dG(x)/dx|$. The sensitivity of motion blur will be proportional to the difference between visual intensity $G(x)$ and G_I. It is understand that VIEW represents the average of the motion blur width, multiplying the motion blur width and the difference between visual intensity $G(x)$ and G_I. The index VICC represents the average of the contour width due to the impulse type drive.

Using these indexes, it becomes possible to evaluate the motion blur due to slow response of liquid crystal and contour due to impulse type drive in a unified manner. If the indexes are divided by the motion speed L/2T, the response time of motion picture are obtained. We call the “Xtime” (extended response time) that is quotient of VIEW+VICC by motion speed and “Ytime” (yield response time) quotient of VICC divided by motion speed. The name of Ytime is due to the shape of the graph of stress and warp around yield point, the graph shape resembles to the visual intensity with contour.

Fig. 1 shows Xtime and Ytime with the various impulse parameters α (= 0, 0.1, 0.2 , 0.3 , 0.4, 0.5) which show the rate of the impulse type drive and with several response times R (= 4msec, 8msec, 12msec, 16msec, 20msec).

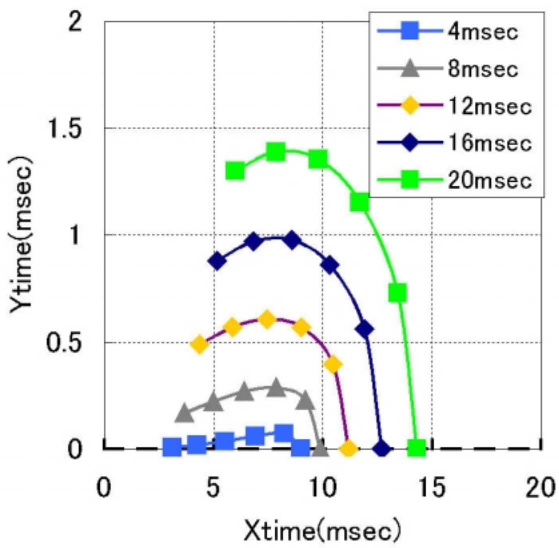

Fig. 1 Relations between Xtime and Ytime.

Relation between Xtime and N-BET is shown in **Fig. 2**. The difference in the behavior of both figures is the dependency on the liquid crystal response time in impulse type drive. That is, Xtime is nearly proportional to the liquid crystal response time, but N-BET changes rapidly between 12msec and 8msec. The reason is that Xtime is the average integration of the motion blur, on the other hand N-BET is the blur edge width between the threshold values on visual intensity.

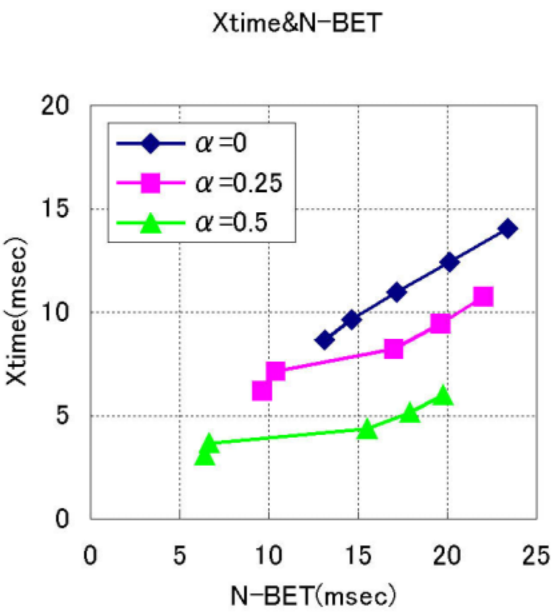

Fig. 2　Relation between Xtime and N-BET.

1.2 Simulation of visual intensity

Fig. 3 shows the simulation results of the visual intensity for the hold type and the impulse type drive. Studying these results, it will find that the motion blur is improved with response time of liquid crystal and motion blur in the impulse type drive is decreased dramatically. The contour in the impulse drive becomes the conspicuous artifact of the motion picture, when the Ytime is greater than 0.5. As for the case of the high refresh rate, response time is improved much more. It will be possible to understand that the combinations of Xtime and Ytime become the effective evaluation indexes complementing the subjective evaluation.

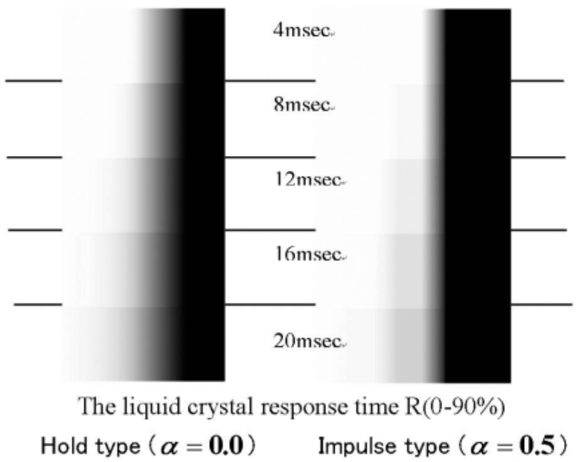

Fig. 3　Simulation image of the visual intensity.

In **Fig. 1** and **Fig. 3**, it shows that the contour of the impulse type drive could be decreased by the improvement of the liquid crystal response time.

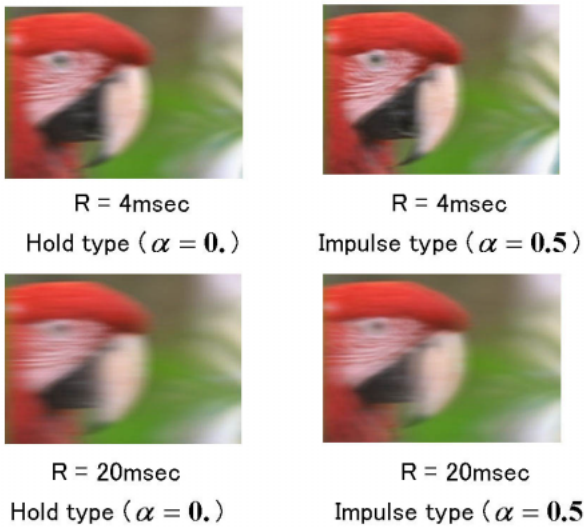

Fig. 4　Simulation images of the scrolling picture.

We have done the subjective evaluation of the motion picture and the scrolling simulations as shown in **Fig. 4** for the LC-TVs of the hold type drive and the impulse type drive. We obtain the similar results in the subjective evaluations and picture simulations comparable to the “Xtime” and “Ytime”.

1.3 Temperature adaptive over drive

The temperature dependence of the response time of the LCD has a large influence on the blur of the motion picture. **Fig. 5** shows the reaching percentage of the target level in the transition from the start level with non-over drive at 5 degrees of centigrade. As the reaching percentages in low temperature are low, there are the degradations of the motion pictures.

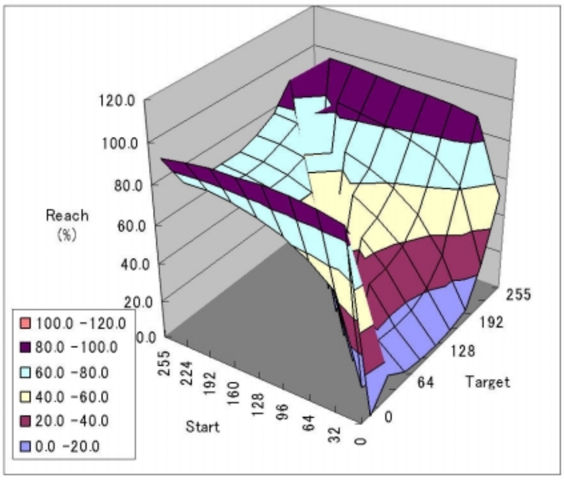

Fig. 5　Reaching percentage for non-over drive.

At low temperature, because of the slow response liquid crystal, it is necessary to use the extreme exaggerated parameter that is different from that of the room temperature. The over drive system with the temperature sensor can select the parameter according to the temperature. **Fig. 6** shows the reaching percentage for the over drive.

The reaching percentages are drastically improved by the over drive. However, the impulse type drive in the low temperature is still a difficult problem because of contour. It is expecting that the developments of the liquid crystal material and the driving method will solve these difficulties in a near future.

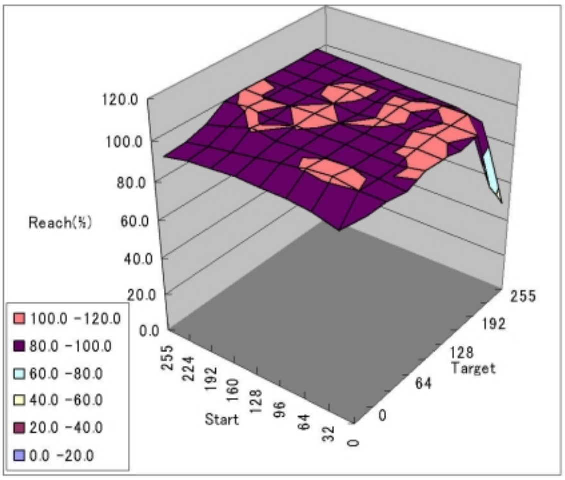

Fig. 6 Reaching percentage for over drive.

2. Viewing angle characteristic

The characteristic of the LC-TVs, the viewing angle characteristic is a problem as important as the response time. The smaller variation of the gray scale in viewing angle is requested for the large-size LC-TVs.

In the previous works, the contrast ratios have been used as the index for viewing angle evaluations. The LC-TVs have been commercialized with the sufficiently large contrast ratios over 800:1 in the dark room. The contrast ratios of LC-TVs are superior to those of PDP, CRT and other flat panel displays in the bright room. In order to improve the viewing angle characteristic LC-TVs using ASV modes, the multi-domain alignment of liquid crystal, black TFT and the retardation films which have been used to compensate the viewing characteristics.

There still remain the investigations of the index to identify with the subjective evaluations of LC-TVs and the physical quantities expressing the quality of the viewing angle. The types of the degradation related to the viewing angle are classified into two kinds, the overexposure of gray scale and the low contrast and color shift in a diagonal viewing direction. The former is due to the birefringence of the vertical alignment liquid crystal and latter due to the light leakage in the black of the S-IPS mode.

It is needed to discuss and to find the evaluation quantities coping with the overexposure in gray scale and light leakage in black of the LC-TVs in a unified manner. We expressed the viewing angle characteristics of the LC-TVs as the variation from the ideal value and compared with the results of the subjective evaluation.

2.1 Ratio of Visual viewing variation

In order to evaluate the viewing characteristics in a unified manner, we propose the new index on the basis of the visual sensitivity. When the small quantity changes ΔI into the strength I of some stimulation, it is known as the Weber - Fechner law for the sensitivity, that the ratio $\Delta I/I$ is nearly constant. And the sensitivity S is simply expressed by the integral of strength as, $S=\log(I/I_0)$. Measuring the sensitivity of the brightness in the given viewing directions, we find that the dynamic range of brightness in ASV is superior to those of other flat panels.

The viewing variation of the half tone in diagonal direction is attributed to the difference of the sensitivity in the front and diagonal direction. For the given variation of gray scale Δg we can calculate the visual variation in a diagonal as $\Delta Y/Y_{diagonal}$ and in the front as $\Delta Y/Y_{front}$.

The ratio of variation of the visual intensity in diagonal direction and front is named RV^3 (ratio of visual viewing variation) and is defined by the below equations.

$$RV^3 = \frac{\left(\frac{dY}{Ydg}\right)_{diagonal}}{\left(\frac{dY}{Ydg}\right)_{front}} = \frac{d\log(Y)_{diagonal}}{d\log(Y)_{front}}$$

The RV^3 value represents the viewing angle characteristic of the display equipment faithfully, because it is proportional to the derivative of visual density for human sensitivity in diagonal direction and the front. In the ideal case, the variation of visual density equal in any viewing direction and any brightness, the values of RV^3 equal to 1.

Because the value of MVA becomes around 0.6-0.75, the gray scale characteristics of MVA is not sufficient. The S-IPS mode shows the lower RV^3 value due to the light leakage around low brightness. The ASV mode under development shows the improved characteristics of the overexposure in the half tone and has good viewing characteristics in all direction. After subjective evaluation of the LC-TVs, PDP and CRT, the RV^3 evaluation and subjective evaluations have a good agreement.

Conclusion

We proposed the new evaluation method coped with the improved technology of the display with fast response time and wide viewing angle. The importance of the new way of evaluation in place of the subject evaluation will be increased to promote the development of new technology.

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