플라즈마 디스플레이 패널의 플리커 발생에 대한 예측

김광욱 * , 홍기상**
포항공과대학교 영상정보처리 연구실

Prediction of Flicker for PDP Devices

Guangxu Jin*, Ki-Sang Hong**
Image Information Processing Lab., POSTECH
*king@postech.ac.kr, ** hongks@postech.ac.kr

Abstract: Flicker is the *" variation in brightness or hue perceived upon stimulation by intermittent or temporally non uniform light."* [2].This phenomenon is known as the cause of eye strain and headaches. Many researchers are dedicated to reducing this phenomenon. However, it is difficult to define flicker by more than one subjective judgment. So, an objective measurement of flicker is necessary and convenient for research on displays. In this paper, a computational prediction model is proposed, which is used to predict luminance flicker (not chromatic flicker) by giving a quantitative output that describes the probability of occurrence of flicker. Through this work, we expected to provide a practical tool for flicker-free design in PDP.

Keywords: PDP, Flicker, Human Vision

Ⅰ. INTRODUCTION

Plasma Display Panel (PDP) is now considered as one of the most suitable devices for large area applications due to their large display size with very thin depth, high resolution, and high picture quality. Although the picture quality of PDP is improving, there are still some limitations, such as MPD (Motion Picture Distortion), peak-luminance, load effect, and flicker, which seriously degrade the image quality of PDP. In this paper, we focus on the flicker phenomenon.

Many researchers are dedicated to reducing this phenomenon. However, it is difficult to define flicker by more than one subjective judgment. So, an objective measurement of flicker is necessary and convenient for research on displays. In this paper, a computational prediction model is proposed, which is used to predict luminance flicker (not chromatic flicker) by giving a quantitative output that describes the probability of the occurrence of flicker.

Ⅱ. PREDICTOR OF FLICKER

Usually, it is wondered whether the flicker takes place. Intuitively, practical observation on PDP is the most straightforward method. However, it takes much time to conduct experiments and it is difficult to define the flicker by more than a subjective judgment. Under the same conditions, some people might detect flicker, while some people may not. So, it is necessary and convenient to predict flicker by a predictor which simulates the characteristic of human visual perception.

In this section, a computational predictor is to be proposed and described in detail. This predictor embodies three parts, which are corresponding to various characteristics of human visual perception introduced.

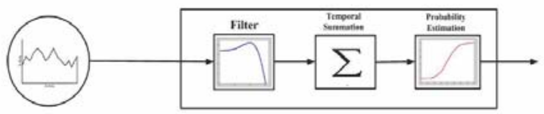


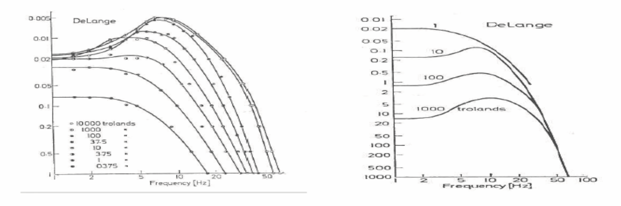
Fig.1. Block Diagram of Predictor

The block diagram of this predictor is shown in Fig. 1. There are three components in it, which are eye-like linear filter, temporal summation and probability estimation. From the next section, we will respectively present the various functions and implementations of these components in detail.

A. Contrast Sensitivity Function

1) Critical Flicker Frequency: The effort to understand the sensitivity of the eye to rapid fluctuations has generated a large amount of research, a great deal of it concerned with the Critical Flicker Frequency (CFF). CFF is the transition point of an intermittent light source where the flickering light ceases and appears as a continuous light.

De Lang (1952, 1958) was the first to measure temporal CSF (Contrast Sensitivity Function) systematically. Fig. 2(a) shows the example of de Lange' s measurements, for various levels of illumination. At high illumination levels, sensitivity was maximal at about 8Hz, and fell steadily with higher or lower temporal frequencies. Note that the frequency yielding a contrast threshold of one (maximum modulation) is an estimate of the CFF under those conditions. At lower levels of illumination, the curves shift downwards (implying lower absolute sensitivity) and to the left (implying lower temporal resolution, or CFF).



(a) Contrast Sensitivity (b) Sensitivity

Fig.2. de Lange's Experiment Results

Now, we know the flicker sensitivity is not only dependent on the temporal frequency but also dependent on the mean luminance. So, the variation function of contrast flicker sensitivity against temporal frequency and mean luminance is wanted. In order to describe the changes of sensitivity to different light levels, some dynamic light adaptation models were developed. But, in this work, a Static Light Adaptation method will be employed. That means this prediction model can not dynamically self-adjust to the various light.levels.

2) Computational Contrast Sensitivity Function: In this section, a detailed computational CSF will be introduced. In the pre-sections, the sensitivity function was given the form of $H(f)$ (f refers to the temporal frequency) in several retinal illuminations, not in continuous retinal illumination. Now, the form of $H(f, I_{mean})$ (I_{maan} refers to the mean retinal illumination) is wanted.

In this prediction system, the detailed CFS data came from the fitting model made by Rovamo[3]. These data can be obtained from the Equation 1, 2, 3, 4, 5

$$N_e = 0.148 \times f^{-0.568} \quad (1)$$

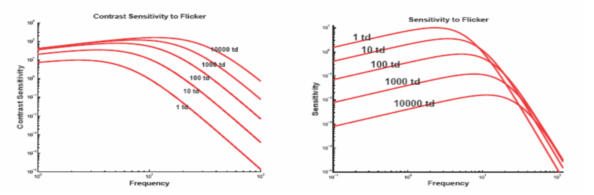
$$f_c = 6.33 \times I_{mean}^{0.172} \quad (2)$$

$$R_i = (1 + \frac{31.5}{I_{mean}})^{-0.473} \quad (3)$$

$$R = R_i \times (1 + (\frac{f}{f_c})^2)^{-3} \quad (4)$$

$$H(f, I_{mean}) = (N_e)^{0.5} \times (1.4 \times (4.44 \times 10^{-5} \times R^{-2} \times f^{-2})^{\frac{1}{2}})^{-1} \quad (5)$$

These data were plotted in Fig.3. As shown in Fig 3, the good fit of the model to the data was achieved without any luminance-dependent adjustments. This fitting model can supply the information of $H(f, I_{mean})$ which we need.



(a)Contrast Sensitivity (b) Sensitivity

Fig.3. Rovamo's Model

B. Probability Summation over Time

"The sensory response to light persists in time." [4] This fact obliges us to consider the collective effect caused by the temporally distributed visual stimulation. A classical solution to this problem has been to suppose that the eye integrates the light signal over some intervals of time. Probability Summation over Time is a more general solution to this temporal cumulative effect.

1) Temporal Summation: The presence of internal noise ensures that within each instant there is some probability that the threshold will be exceeded, and so the overall probability that the signal is detected must take into account all of these momentary probabilities. P_i is the probability that the threshold is exceeded during the instant beginning at time ti.

$$P_i = 1 - \exp(-|r_i|^{\beta}) \quad (6)$$

Where β is the steep parameter presented in the paper [5] by Watson. r_i is the output of the eye-like filter(See Section II-C).

Then supposing that the signal is detected if and only if the threshold is exceeded in at least one instant, the probability of detection P will be

$$P = 1 - \prod_i (1 - P_i) \quad (7)$$

Substitute the Equation 6 into the Equation 7, we got

$$P = 1 - \exp(-\sum_i |r_i|^{\beta}) \quad (8)$$

So before probability estimation, we first get the absolute temporal summation R by the following equation:

$$R = \sum_i |r(i)|^{\beta} \quad (9)$$

2) Probability Estimation: Substitute the summation R into the Equation 8, we get the probability estimation as follows:

$$P = 1 - \exp(-R) \quad (10)$$

In addition, we introduced a constant C to Equation 10 to adjust the criteria and reduce the system error caused by the eye-like transfer function or other potential factors we cannot forecast. Then, Equation 10 transfers into:

$$P = 1 - \exp(-C \times R) \quad (11)$$

3) How to Determine Constant "C": This prediction system is an approximate system. Any part could introduce system errors. For example, when eye-like transfer function was established, we didn't consider the factor of the target size, and this may affect the result of the prediction. In order to eliminate potential error, before using this

predictor, it is strongly recommended to re-estimate the constant " C" by a series of typical experiments.

C. Algorithm of Predictor Model

The detailed algorithm is shown in Fig. 4. So, as shown in Fig. 4, in the step of pre-processing, the mean retinal illumination (I_{maan}) will be calculated firstly and be conveyed to the eye-like filter part to generate a transfer function $H(f)$ which is implicitly dependent on mean retinal illumination.

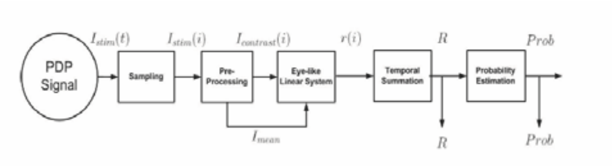


Fig.4. Block Diagram of Algorithm

Simultaneously, in the step of pre-processing, the fluctuating part was extracted from the sampling signal $I_{stim}(i)$ by the following Equation:

$$I_{contrast}(i) = \frac{I_{stim}(i) - I_{mean}}{I_{maan}} \qquad (11)$$

Then, the fluctuating signal will be conveyed to the eyelike linear system that was presented in Section II-A.

$$r_i = \sum_j I_{contrsast}(i)h(i-j) \qquad (12)$$

Next, according to Equation 12, the output of the eye-like filter is obtained. Applying the temporal summation to this output, we get the output R. Using this value R, the probability estimation could be carried out. Thus, the last output of probability was produced.

D. Signal from PDP

Another problem has to be solved, which is how to describe the signal from PDP quantitatively. Here, we adopted an approximate strategy to describe this complicated waveform. To catch the key feature of this waveform, we employed three approximate methods to simplify the waveform as follows:

① Energy emitted only in the sustain period, no energy emitted from the non-sustain periods.

② In the same sustain period, the emitted energy is steady.

③ Temporal average energy is proportional to number of sustain pulse.

In addition, 5000 nanosecond is selected as the value of the sampling interval for the sake of convenience, since the time of a sustain pulse is 5000 nanosecond.

Based on the above approximate condition, we obtained the quantitative description of signal from PDP illustrated in Fig. 5

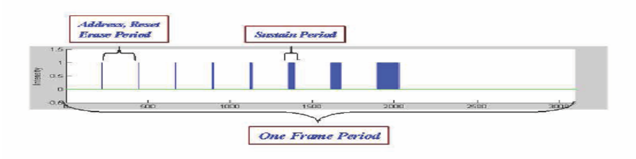


Fig.5. Quantitative Description of Signal from PDP

In this case, there are 8 subfields in one PDP frame. It is seen that light is given off only in sustain period and in the same one sustain period the signal is steady.

Ⅲ. EXPERIMENTS

Several experiments on flicker in PDP have been carried out. By comparing the results of the experiments with the prediction, the performance of this predictor was estimated. The basic experiment conditions are selected as the following

- Device: **-PDP, 42 Inch, 852×480 Resolution
- Viewing Distance: 3 Meters
- Environment Light: Dark Room
- Subfield Number: 12
- Observer: JGX, HTO, KTS (Abbreviation of Observers' Names)

A. Experiment One

1) Experimental Conditions: In this experiment, the same mean luminance and various sustain pulse configurations are utilized. It is known that various sustain pulse configuration can generate a signal which has different flicker levels. We predicted these flicker levels and compared them with the results of the experiments.

The detailed experiment conditions are illustrated as follows:

- Amount of Sustain Pulse: 256
- Mean Luminance: 231 Candela/ m^2
- Mean Retinal Illumination: 746.05 Trolands

Various sustain pulse configurations are displayed in the Fig. 6. In this figure, we gave the number of sustain pulses of every subfield and its mapping method. There are in total 21 configurations listed here, which have the same gray level or number of sustain pulses.

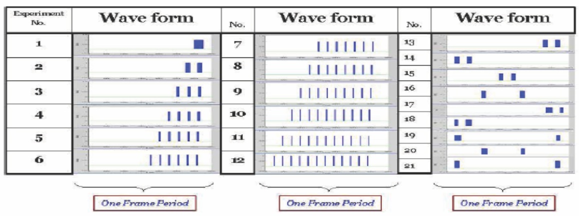
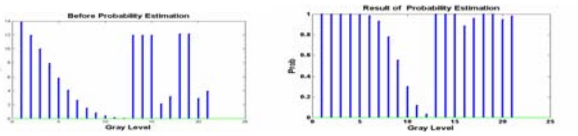


Fig.6. Quantitative Description of Signal from PDP

2) Prediction & Experimental Results: The results are illustrated by the following Fig. 7.



(a) Output " R" (b) Output " Prob"

Fig.7. Prediction Results of Experiment One

As indicated in Fig. 7, from experiment 1.1 to 1.12, the more uniform the sustain pulse configuration, the smaller the probability of the occurrence of flicker. This result agrees with the practical observation and analytic results. From experiment 1.13 to 1.17, only two subfields with 128 sustain pulses emitted light, the same as experiment 1.1 to 1.12, the more uniform the two subfield configurations, the smaller the probability of the occurrence of flicker. The minimum value appears in the experiment 1.16, because the two subfields have the most uniform configuration. From experiment 1.18 to 1.21, we changed the number of sustain pulses in the two subfields into 180 and 76. The result values increased obviously.

B. Experiment Two

1) Experimental Conditions: In this experiment, the various mean luminance and similar sustain pulse configurations (Uniform) are utilized. It is known that, with the increase of mean luminance, contrast flicker sensitivity increases. Although all of the sustain pulse configurations are uniform, they also caused the signals which has a quite different flicker levels. We predicted these flicker levels and compared them with the results of the experiments. The detailed experiment conditions are illustrated as the following:

- Amount of Sustain Pulse: 12 ~ 900
- Mean Luminance: 2 ~ 810 Candela/ m^2
- Mean Retinal Illumination: 46~2573 Trolands

Various sustain pulse configuration: refer to Table.I and Table.II

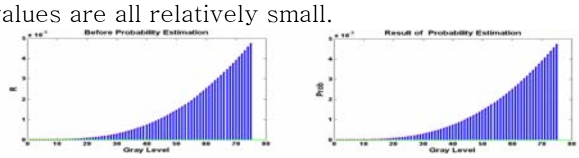
Table I. Experiment Two: Sustain Pulse

Subfield No.	1	2	3	4	5	6	7	8	9	10	11	12	Sum
Sustain Pulse	1	1	1	1	1	1	1	1	1	1	1	1	12
Sustain Pulse	2	2	2	2	2	2	2	2	2	2	2	2	24
Sustain Pulse	3	3	3	3	3	3	3	3	3	3	3	3	36
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Sustain Pulse	73	73	73	73	73	73	73	73	73	73	73	73	876
Sustain Pulse	74	74	74	74	74	74	74	74	74	74	74	74	888
Sustain Pulse	75	75	75	75	75	75	75	75	75	75	75	75	900

Table II. Experiment Two: Subfield Mapping

Subfield No.	1	2	3	4	5	6	7	8	9	10	11	12	Sum
Subfield Mapping	1	1	1	1	1	1	1	1	1	1	1	1	12

2) Prediction & Experimental Results: The results are illustrated by Fig. 8. In this experiment, we verified how the flicker sensitivity increases with the mean illumination. As shown in Fig. 8, the flicker sensitivity increases with the mean illumination nonlinearly (linear in log axis). Because only uniform sustain pulse configurations were utilized, the result values are all relatively small.



(a) Output " R" (b) Output " Prob"

Fig.8. Prediction Results of Experiment Two

Ⅳ. CONCLUSION

In this paper, we proposed a computational model to predict the flicker phenomenon in PDP Devices. The quantitative output of the predictor presents the probability of occurrence of flicker.

First, the basic function has been realized, which gives the quantitative measurement of the degree of fluctuation of signal waveform from PDP. This degree is indicted by the probability of occurrence of flicker.

Second, it is natural that this simulation model can predict the threshold of occurrence of flicker, since, after successfully predicting the degree of fluctuation of waveform, the only things needed to do for threshold prediction are to set a criteria for the device condition and observation environment. (As presented in Section II-B-3, how to decide constant " C")

In addition, it might be more helpful to reduce system error by improving the approximating method of factors that had been incorporated into the system. For example, an exact description of signal from PDP, or more precise eye-like transfer function with light adaptation. These are going to be done in future work.

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