The Analysis of Information Transfer Efficiency in Medical Image Display

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ABSTRACT

Image display is the last step of imaging chain in which the diagnostic information is transformed into perceivable intensities and transfered to observer's eye-brain system. In this process, a certain part of information may be efficiently transfered and another part may be inefficiently transfered leading to information loss.

In this study, the visual perceptual properties of image display on CRT monitor has been investigated. Psychophysical experiment of target image detection has been performed using CRT monitor for various background grey levels, and the threshold difference grey levels required for visual discrimination have been predicted by computer simulation with visual model.

I. INTRODUCTION

Visual display techniques are widely used for efficient communication of informations in various fields. Specifically, in medical imaging, as the diagnostic information is conveyed via visual channel, the efficient visual display with respect to information transmission is of critical importance. Since most of the modern medical imaging modalities produce digital images, and use Cathode-Ray Tube(CRT) monitor as visual display medium, images can be easily displayed in versatile way through image processing. However, this potential will truely become beneficial only when the properties of information transmission between CRT monitor and observer's visual system will be understood and properly incorporated in image processing. In this paper, the visual perceptual properties of image display on CRT monitor have been investigated to provide basic data which will be usefully and directly applicable to image processing for efficient visual display.

Three sets of experiments were performed; the first was to measure the luminance response of CRT monitor and to find out the best fitting equation, and the second was the psychophysical experiment measuring the threshold difference grey levels between the target image and background required for visual discrimination for various background grey levels, and the third was computer simulation of visual perceptual process in psychophysical experiment with visual model.

II. LUMINANCE RESPONSE OF CRT MONITOR

The image display unit used in this study consists of the graphics board(Vectrix) and high resolution CRT monitor(Moniterm), which displays 1024 x 1024 resolution image with 256 grey levels in progressive scanning mode with 60 Hz vertical frequency. The luminance response of CRT monitor was measured with digital lux tester (National) in contact with the monitor for various background grey levels. The measured data L are closely approximated by

$$L = k\,G^{2.2} + B \quad \text{--------(1)}$$

where G is grey level, k is scale facter, B is bias luminance.

Fig. 1 shows the experimental results of luminance response of CRT monitor.

III. PSYCHOPHYSICAL EXPERIMENT

The frame buffer of display unit was filled with a uniform grey level, and a circular target image was generated at random position on CRT monitor by computer. The size of target image was 1.4 cm in diameter subtending the visual angle of 120 minute of arc to the observer at 40 cm from the monitor. The grey level inside the target image was initially set the same as background, and then increased until the observer discriminated the target image. This procedure was repeated for various background grey levels of 0, 10, 20, ---,250.

Repeating this experiment 10 times for each of 2 observers, we obtained the threshold difference grey levels between target and background required for visual discrimination. We performed this experiment under 2 different illumination conditions to examine the effect of ambient light, which were relatively dark condition of 2.5 lux with light off, and general working condition of 170 lux with light on.

IV. COMPUTER SIMULATION

It is well known that human visual system is contrast sensitive within quite wide range of luminance intensity. However, when background luminance is too dark or too bright, the contrast sensitivity varies with background luminance. Hecht[1] derived the photochemical visual model from the differential equation of the photo-chemical system in retina which describes the behavior of human visual system, as Eq.(2).

$$Ct = \left(\frac{dL}{L}\right)_{th} = K_1\left(1 + \frac{1}{\sqrt{K2L}}\right)^2 \quad \text{--------} \quad (2)$$

where Ct is threshold contrast and L is background luminance to which human visual system has been adapted, and K1, K2 are reaction constant. In this equation, it is assumed that the ambient light is completely shut out and visual sensitivity is determined only by background luminance.

However, in practical enviroment, some illumination is needed, and visual sensitivity is influenced also by the ambient light. Therfore we modified Eq.(2) as Eq.(3), which was the visual model used in this experiment, to include the effect of ambient light,

$$Ct' = \left(\frac{dL}{L'}\right)_{th} = K_1\left(1 + \frac{1}{\sqrt{K2L'}}\right)^2 \quad \text{--------} \quad (3)$$

$$L' = L + Ls$$

where L is the background luminance by the light only from CRT monitor, and Ls is the scatter equivalent background luminance which amounts to the light intensity from ambient light being scattered by the eye optics and falling on the retinal site corresponding to the adjacency to the target image on CRT monitor.

In this study we obtainded Ls by weighted integral of light distribution with point spread function of eye optics described in [2].

For computational convenience, the light distributions from inside and outside the CRT monitor were approximated to be isotropic and constant over the whole range of visual angle. Applying Eq.(1) for the relation between L and grey level G, and substituting Ls obtained above to the visual model as Eq. (3), the threshold contrast between target image and background on CRT monitor could be predicted for various background grey levels, and then corresponding threshold difference grey level was obtained using Eq.(1) again. In Fig. 2, the results of psychophysical experiment and computer simulation are shown.

V. DISCUSSION

As shown in Fig. 2, the threshold difference grey level increases rapidly as background grey level goes lower than 50, which is due to the low luminance change of CRT monitor in this region. This fact suggests that the grey levels in this region be avoided for use in visual communication of important informations such as medical image display.

Computer simulation shows that the predicted threshold difference grey levels have high correlated well with most of the measured values, which indicates the possibility that the visual model as Eq.(3) can be usefully utilized in image processing for efficient visual display.

REFERENCES

1. Hecht. S, A theory of visual internsity discrimination, J. Gen. Physiol., 1935, 18, pp.767-789.
2. Brent Baxter, H. Ravindra, R.A. Normann, Changes in lesion detectablility caused by light adaptation in retinal photoreceptors, Invet. Radiol., 1982,17,pp.394-401.

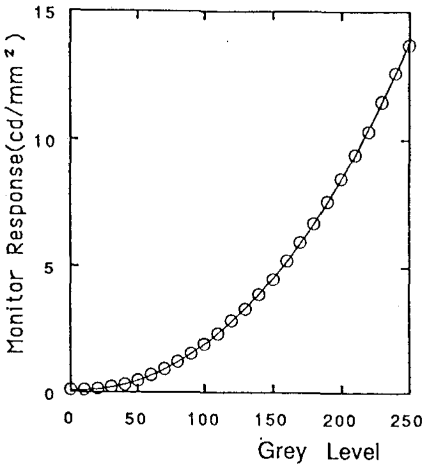

Fig. 1. The luminance response of high resolution CRT monitor.

o measured data — calculated value by Eq. (6)

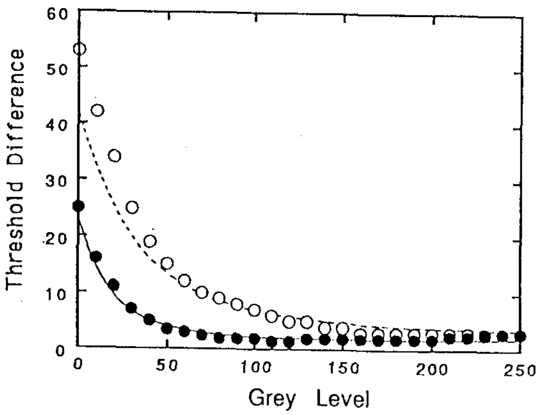

Fig. 2. The results of the psychophysical experiment for visual discrimination and computer simulation using visual model.

• measured data for light off o measured data for light on

— predicted value for light off ---- predicted value for light on