FPD Grayscale Modulation Based on Human Visual System

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Abstract. In order to meet the requirements of FPD's development which FPD must process more and more information, a new modulation method is proposed. Firstly, some available modulation technologies are introduced; secondly, the principle of the human visual system is provided so as to describe the grayscale modulation principle of FPD; thirdly, one human visual model is constructed to provide a basis for the grayscale modulation; finally, the grayscale modulation based on human visual system is used in FPD control system, and the experimental results show that this method is able to break the bottleneck of the FPD grayscale modulation.

Keywords: FPD, grayscale modulation, human visual system.

1 Introduction

FPD (Flat Panel Display, FPD) has been widely used in various occasions. It includes LCD (Liquid Crystal Display, LCD), PDP(Plasma Display Panel, PDP), LED (Light Emitting Diode, LED) and so on. At present, there are many challenges for the development of FPD. One the one hand, the size of FPD becomes more and more large; one the other hand, there are more and more information which FPD have to display with the development of video process technology and digital transmission technology, The control system of FPD must process more and more information, so as to meet the requirments of the display quality [1-4].

The process of grayscale modulation is one of important process for the control system of FPD. The control system is able to process more information and save amount of source if the method of grayscale modulation is good. There are some grayscale modulation technologies which are the time-division method, the frame-division method, pulse width modulation and so on. These available modulation technologies can not meet the requirements of FPD's development. Therefore, a new modulation method must be proposed to break this bottleneck [5-8].

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2 Background

Human visual is a complex and sophisticated optical information processing system whose horizontal cross-section is shown as Fig.1. The human visual is combined mainly with the comea, sclera, iris, pupil, lens, retina and so on [9-11].

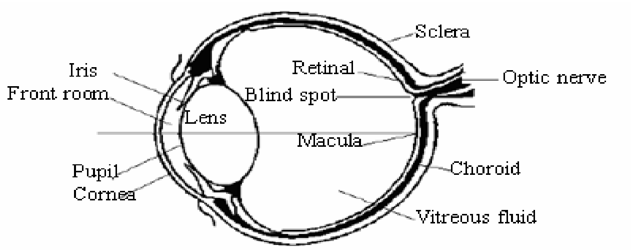

Fig. 1. Construction of the human visual

Most of the human visual characteristics result from subjective factors, and these characteristics has more or less links.

Sensitive role of the human visual is able to automatically adjust with the intensity of light of the outside world. This ability to regulate is called the brightness adaptation. It includes the regulating role of pupil and the adjust function of visual cells.The brightness of uisual system feeling is known as the subjective brightness. Many experimental data show that the subjective brightness is a logrithmix function of the light intensity into the human visual. The brightness adaption has two parts which are dark adaptation and light adaptation. It is called dark adaptation that the light intensity into the human visual change from strong to weak; and it is called light adaptation that the light intensity into the human visual change from weak to strong.

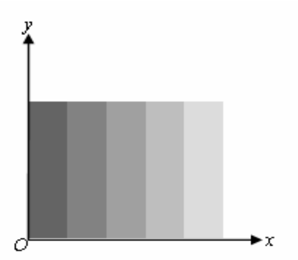

Fig. 2. Vertical distribution of the gray band image

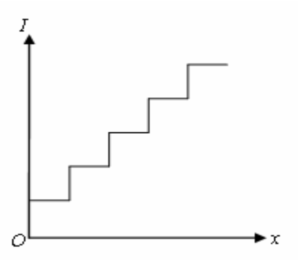

Fig. 3. Intensity distribution of each gray band

There is a vertical distribution of the gray band image as shown in Fig.2. Grayscale intensity of each band is evenly distributed, and the brightness difference between adjacent bands is constant as shown in Fig.3. The human visual feels that the left bertical brightness in band darker than the right while viewing. This phenomenon is called Mach Effect. This is a result of the spatial frequency response of the human visual. The human visual feels the light side lighter and the dark side darker because the human visual's responding to intermediate frequency signal is higher than the responding to high frequency signal or low frequency signal.

3 Human Visual Principle

The human visual will produce a sense of flickering flashes if the frequence of the light stimulus is not too high. However, the human visual will not feel flickering if the frequence is greater than a particular value. The minimum frequence that does not cause feeling of flicker is called critical flicker frequcncy and CFF is its short title. The human visual feels the light stimulus like a constant light if the frequency of the light stimulus is higher than CFF. At this time, the intensity of the constant light is caculated by Eq. 1.

$$I = \frac{1}{T}\int_0^T L(t)dt \tag{1}$$

In Eq. 1, $L(t)$ is the real brightness of the light stimulus, T is the period of the light stimulus. The brightness of the human visual feeling is the average brightness of the light stimulus in one period. The brightness of the light stimulus can influnence CFF, and the relationship between CFF and lgI is shown in Eq. 2.

$$n = a \cdot \lg I + b \tag{2}$$

In Eq. 2, n is the critical flicker frequency, a and b are two parameters. CFF increased with light intensity enhancing.

Visual inertia is the feeling of the human visual's brightness will not immediately appear oder disappear but have a dealy time. The human visual response characteristics is shown as in Fig.3. In Fig.3 the solid line denotes the light stimulus, and the dotted line denotes the corresponding human visual response. The retina can not form a stable subjective feeling but takes some time from A to B, when a certain intensity of light stimulus go into the human visual suddenly.

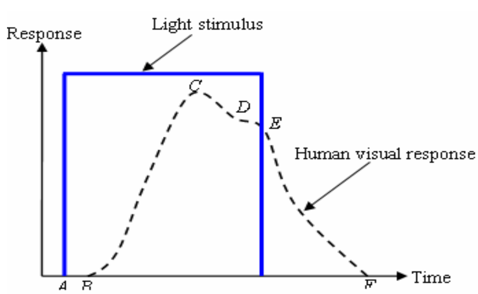

Fig. 4. Human visual response characteristics

4 Human Visual Model

The human visual system is similar to a sophisticalted optical imaging system. This system is a two-dimensional linear optical system as shown in Fig.5. In Fig.5, $f(x, y)$

and $g(x, y)$ represents the input and output image of this system respectively. $H(u, v)$ is the transfer function.

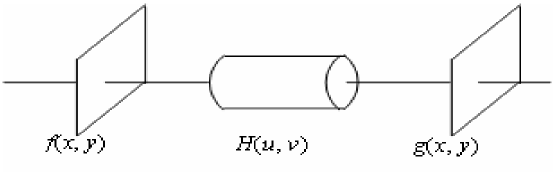

Fig. 5. Optical imaging system

The characteristic of this system can be expressed by the two-dimensional optical transfer function. $F(x, y)$ and $G(x, y)$ is setted to represent the input and output image of the system respectively, and the relationship between the input and output image is shown in Eq. 3.

$$G(u,v) = H(u,v)F(u,v) \tag{3}$$

In Eq. 3, u and v represents the spatial frequency componets in x-axis and y-axis. The transfer function $H(u, v)$ can be expressed by Eq. 4 if $F(x, y)$ and $G(x, y)$ are known.

$$H(u,v) = \frac{G(u,v)}{F(u,v)} \tag{4}$$

In the actual process of applying, the absolute ratio of the frequency of the input and output image is payed more attention, that is

$$|H(u,v)| = \frac{|G(u,v)|}{|F(u,v)|}. \tag{5}$$

$|H(u, v)|$ is called the modulation transfer function for this two-dimensional linear optical system. A possible mathematical expression for the modulation transfer function is shown as Eq. 6.

$$\begin{cases} |H(u,v)|^2 = (1+0.05D^2)\exp\{-(D/50)^2\} \\ D^2 = u^2 + v^2 \end{cases} \tag{6}$$

Summary, the human visual model is shown as Fig.6.

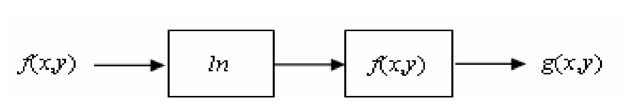

Fig. 6. Human visual model

5 Experimental Results

The grayscale modulation based on human visual system is applied to a experimental platform which is combined with four parts as shown in Fig.7.

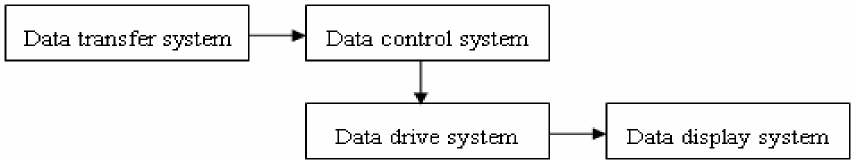

Fig. 7. Experimental platform

These four parts are FPD data transfer system, FPD data control system, FPD data drive system and FPD data display system. The experimental results show that this method is able to break the bottleneck that the abailable modulation technologies can not meet the requiremen of the FPD's rapid development.

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