The Study of Contrast Sensitivity Character of Human Vision

Jing Shen
Department of Computer Science and Technology, Shaanxi University of Technology, Hanzhong 723000, China
E-mail: shenjingyjc@yahoo.com.cn

Abstract: The human eye as an optical information processing instrument, the contrast sensitivity of the human eye to observed goal with different contrast caused by luminance and color is to measure one of the main indicators of the human eye characteristics of the space vision. The contrast sensitivity function of human vision is to describe the relationship between the contrast sensitivity of the human eye to target (that is the reciprocal of detection contrast threshold) under different conditions and the spatial frequency. Modern optical and opto-electronic imaging technology have opened up a new way to expand the application and technology of human visual characteristics so as to make the contrast sensitivity function model of human vision be done a great deal of research by home and abroad researchers, and a number of models be put forward, so far. However, the contrast sensitivity function models of human vision are different because of different research and measurement methods, and exist certain deviation with raw data. In this paper, the human vision contrast detection threshold is measured by 21 young people observation targets which are displayed by a CRT display, at first. And based on least-squares fitting and measurement data, a new optic transfer function model of human vision is put forward, and calculated the deviation of the contrast threshold of part of the frequencies between the model and measurement data. It is resulted that deviations are very small so as to show that the fitting model is a very good transfer function model of vision system.

Keywords: human vision; contrast detection threshold; least-squares fitting

1 Introduce

The characteristics of the human vision system are the basis for image technologies of displaying, processing and understanding. The human eye as an optical instrument, the contrast sensitivity of the human eye to observed goal with different contrast caused by luminance and color is to measure one of the main indicators the of the human eye characteristics of the space vision. The contrast sensitivity function (*CSF*) is one of important and special characteristics of human vision system. *CSF* is to describe the relationship between spatial frequencies and contrast sensitivity which is described by the reciprocal of contrast detection threshold. However, measurements of visual contrast sensitivity are a psychological physics experiment process and are influenced by many factors, such as instruments performance, precision of metering equipments, experimental environment, experimental technique, and so on, and the contrast sensitivity function models of human vision obtained through experimental measurements and theoretical analysis are different because of different research and measurement methods, and exist certain deviation with raw data. So it attracts some researchers to be about vision and image technology at all times. The early researches of *CSF* mainly concentrate on luminance contrast sensitivity. So far, researches and the applications of human vision color transmission characteristics only are started. But *CSF* has more application value in the electro-optical image technology. And with the development of the computer, the network and digital technique, the monitor is becoming the primary carrier of information, and image technology based on the monitor has more comprehensive application. Therefore, measurements of visual contrast sensitivity on the monitor and obtaining of *CSF* model have more important and practical application value.

In this paper, the human vision contrast detection threshold is measured by 21 young people observation targets which are displayed by a CRT display, at first. And based on least-squares fitting and measurement data, a new contrast sensitivity function model of human vi-

Project supported by the Natural Science Foundation of Shaanxi Province China (No: 2009JM1012) and Scientific Research Plan Projects of Shaanxi Education Department of 2010 (No: 112Y045).

sion is put forward, and we calculated the deviation of the contrast threshold of part of the frequencies between the model and measurement data.

2 Methods

2.1 Calibration and Set of the Display

In the test, observed targets are made up of some gratings with the different spatial frequencies and contrast, which are displayed by SONY-520 CRT monitor driven by a PC through a 3×10 bit color resolution MATROX video card. The CRT monitor is 21 inch in size, has been used for two years, approximately 4500 hours, whose displaying effect is basically as good as that of a new one. The white point was set to luminance D_{65} calibrated by X-Rite colorimeter and resolving power 1024 × 768. Screen chronometer is made by American X-Rite Corporation. Screen photometer is model of ST-86LA with the measuring luminance range between 0.01~19990cd/m^2, made by Electro-optic Instrument Factory of Beijing Normal University. To achieve accurate luminance results, with the method of LUT to characterize the monitor and according to the requests of measuring contrast detection threshold, the duplication both of the monitor and of the measuring system and the precision of the measuring equipments in short, intermediate and long terms are studied. The experiments show four findings. The first one is that characteristic precision of LUT method has three chromatic aberrations of *CIELAB*, *CIE*94 and *CIEDE*2000 which are 0.84, 0.40 and 0.42 respectively. The second one is that it usually takes about 2 hours to get to characteristic precision and stability of the color of the monitor. The third one is that repetitive precision of the monitor and the chromometer of the chromatic aberration are *CIELAB* 0.08, *CIELAB* 0.15, and *CIELAB* 0.26 respectively in short, middle and long term. The fourth one is that the precision of brightness on the chronometer ranges is ±0.01 cd/m^2 and the precisions of the chromaticity of x and y are both between ±0.0001. We repeated the calibration procedure periodically to ensure accurate luminance reproduction.

2.2 Measurement Method and Layout

Before the measurements all patterns presented on CRT with different contrast and frequencies had finished beforehand. These patterns with average luminance of 10, 60 and 90cd/m^2 were composed of bright and dark stripes with luminance of $L_{dark}=\overline{L}-\Delta L$ and $L_{bright}=\overline{L}+\Delta L$. The tested subject was seated 2m away from the screen. Tested patterns showed eleven spatial frequencies of 0.41, 0.82, 1.23, 1.97, 3.08, 3.79, 4.93, 7.04, 9.86, 16.43, 24.64cpd. The orientation of the grid was randomly set to be either horizontal or vertical. The size of every pattern was 85mm×85mm.The viewing angle of one period was 2.4347°. The procedure of the measurement was to choose spatial frequency as a fixed parameter and increased the contrast of two luminance stripes until the measurement subjects could identify the orientation of the grating. Measurements were taken on eleven different spatial frequencies, however, the highest frequency resulted in the size of a pair of bars being below the resolution threshold of the human eye, and therefore none could accomplish this task. Three measurements were taken at each spatial frequency. Measurements were carried out in a dark room and three kinds of lightings. The background luminance behind the tested pattern was the same with average luminance. In order to assure equal luminance adaptation status and pupil size for each subject, they were adapted to the monitor white before each measurement. What's more, we must adapt all observers to every viewing condition for thirty minutes before each measurement, because surround luminance adaptation played a constant role in regulating our perception.

2.3 Manufacture Tested Patterns

In the test, plenty of patterns finished beforehand with different contrast value and different frequencies need be displayed on a CRT monitor. Because common CRT monitor with 3×8 bit color video card only can produce 256 luminance levels, the luminance of pattern on the screen with decimal RGB value couldn't be measured accurately and luminance or contrast's controlling was more difficult if we use digital value 0 to 255 for RGB value. So in the test, the patterns were presented on the CRT monitor driven by a PC through a 3×10 bit color resolution MATROX video card. 1024 luminance levels can be produced. Three digital values can be in-

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terposed between continuous two RGB values. In the test, we measured only luminance OTF, RGB value corresponding to luminance of pattern is R=G=B. Many patterns were needed in the measurements, which was manufactured according to the following. If we adopted the methods to characterize the monitor for forecasting or controlling luminance and contrast, the precision of measurement for contrast detection threshold wouldn't be able to be satisfied. So we adopt other method that the luminance of patterns was directly measured if RGB value of patterns was continuous integer and the luminance of patterns was interposed linearly if RGB value of patterns was decimal. In the experiment, a narrow range of luminance of patterns with RGB value of continuous integer would be obtained with the X-Rite colorimeter. Luminance of patterns with decimal RGB values was obtained with linear interpolation. Among the narrow range of luminance measured and interpolated, a medial luminance thought as average luminance would be selected, the corresponding RGB value was thought as central RGB value. According to these RGB values, we selected at random two of them as the RGB value of bright and dark strips, but the midpoint of two RGB values must be central RGB value. The contrast of pattern could be calculated when substituting the luminance for RGB value. With the method we could manufacture many patterns needed in the test. In order to be able to carry out contrast value of pattern displayed on CRT to get to the minimum and keep average luminance constant. The minimum interval RGB value of bright and dark strips was 0.25.

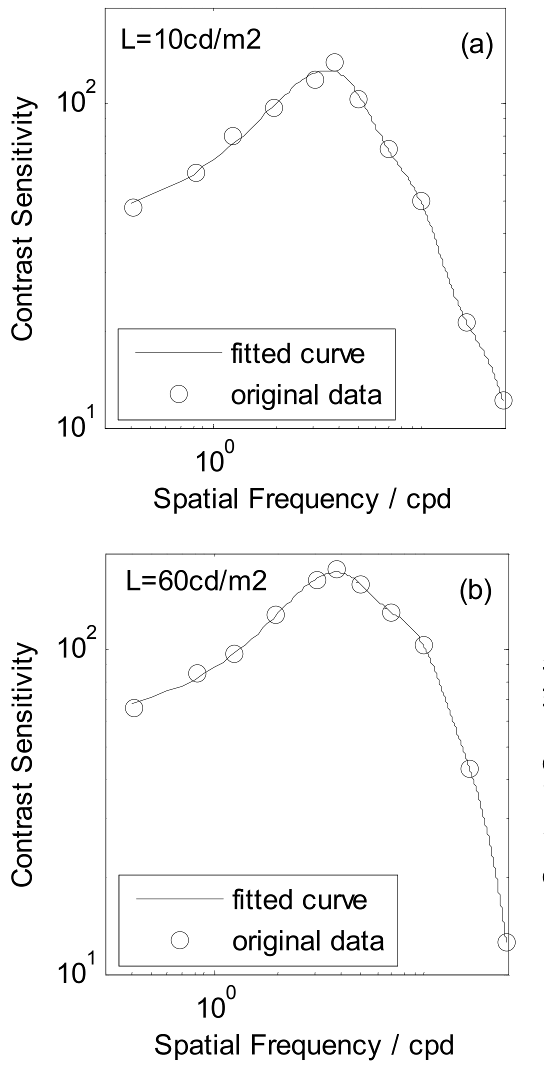
2.4 Measurement Subjects

Twenty-one normal color vision people were chosen for the measurements. All of them are 20–30 years old males. Observers viewed the display binocularly in four viewing condition. All subjects who were all master students majored in color vision, color science and technology, took part in the experiments. They were all tested for normal color vision using Ishihara plate and normal or corrected-to-normal spatial acuity before the experiment. Prior to the actual test all of them achieve some experience of threshold test and were trained with the actual tested grating and procedure for twice or third.

3 Results and discussions

The human vision contrast detection threshold is obtained by observation of 21 young people. And based on least-squares fitting and measured data, through theoretical analysis, a new contrast sensitivity function model of human vision is put forward, which is interpreted with following equation (1). And relational curve and original data have been obtained, which are interpreted with following Figure 1.

$$OTF = Ae^{(-(\frac{f-B}{c})^2)} + De^{(-(\frac{f-E}{F})^2)} + Ge^{(-(\frac{f-H}{I})^2)} \quad (1)$$



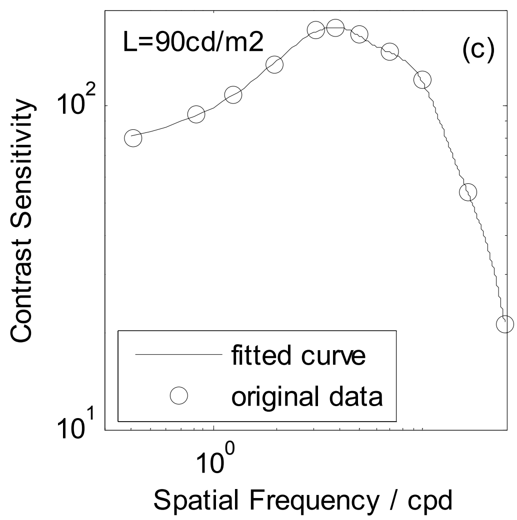


Figure 1. *CSF* model curve and original data

Table 1. the percent error of the contrast threshold of part of the frequencies

F	0.4107	0.8215	1.2322	1.9714	3.0801	3.7913
10cd/m^2	0.0384	0.0074	0.0604	0.0150	0.0532	0.0620
60cd/m^2	0.0373	0.0328	0.0074	0.0039	0.0190	0.0231
90cd/m^2	0.0152	0.0174	0.0053	0.0140	0.0107	0.0069
F	4.9290	7.0410	9.8570	16.4290	24.6400	3.7913
10cd/m^2	0.0376	0.0154	0.0056	0.0015	0.0008	0.0620
60cd/m^2	0.0125	0.0044	0.0014	0.0016	0.0070	0.0231
90cd/m^2	0.0016	0.0001	0	0.0007	0.0011	0.0069

And by calculated the deviation of the contrast threshold of part of the frequencies between the model and measurement data, the result is interpreted as follows.

The table 1 shows that percent error is very small.

4 Conclusions

When doing the image manipulation, manipulated effect is decided by the human eye. Therefore we need a matching contrast sensitivity function model which can really reflect human vision sensitivity characteristic to light. In the study, we have obtained an *CSF* by lots of measurement, and the percent error shows the *CSF* is a accurate model. So it is hoped that the model will be able to be applied adequately.

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