Eye Movement Measuring System for 3-D Virtual Display with Liquid Crystal Glasses

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Abstract

On a project of High-Tech Research Center of Hokkai Gakuen University, we made an eye movement measuring system equipped with liquid crystal glasses (LCG). This system allows us to measure some aspects of eye movements of subjects who look at the 3-D virtual world through LCG. The measuring system is composed of two instruments. One is a brand new eye marks recorder EMR-8 made by NAC. The other is a display system by a DOS/V computer with liquid crystal glasses SB300 made by Solidray Co. Ltd.

We have made the graphic software for the display system. The software is written in Borland C++ Builder 3 with its visual component library (VCL). By use of the software, a picture for the right eye can be displayed in the upper half of the CRT, and a picture for the left eye can be displayed in the lower half of it. The synchronizer makes each picture twice large in its vertical size and displays the right picture when the right shutter of LCG is opened, and displays the left picture when the left shutter is opened. When each picture has visual dispersion, we can recognize virtual 3-D space.

By the system, we statistically compared eye movements in a virtual vision and in a real vision for some subjects.

1. Introduction

In the representation of the binocular visual field, almost all cortical cells are binocular. This is expressed a certain extent by the ocular dominance of cortical cells. The binocularity of cortical cells does not necessarily imply that they show binocular interactions. Binocular interactions refer to neuronal responses to binocular stimulation differ-

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ent from the sum of responses to stimulation of each eye in isolation. Binocular interactions are far more important for the understanding of binocular vision than ocular dominance. In addition to binocular fusion and rivalry, binocular interactions underlay the coding of a special class of visual parameters referred to as disparities i.e. differences between the eyes with respect to a given attribute. These disparities are important to binocular vision in two ways. On the one hand they have to be discarded by the visual system so as to allow fusion of the two slightly different retinal images to one cyclopean image. On the other hand they have to be used by the system in order to extract the information they contain on the third dimension of space. Researchers of stereopsis have mainly investigated the influence of position and orientation disparities, both cues for static depth perception (i.e. perception in depth of stationary objects). With respect to dynamic depth perception (i.e. perception of objects moving in depth) both binocular cues (difference in velocity and direction between both eyes) and monocular cues (changing size) have been investigated.

The present apparatus will be useful for researching both in static depth perception and dynamic depth perception.

2. Measuring systems

The system is composed of three major components. Two of them are hardware parts, and the other is a software part.

2.1 Hardware

The hardware parts of the measuring system are as follows. One is a brand new eye marks recorder EMR-8 with software made by NAC. The other is a display system by a DOS/V computer with liquid crystal glasses (LCG) SB300 made by Solidray Co. Ltd.

The eye marks recorder is divided into 5 parts: a head unit assembled in a baseball cap, a controller, an eye marks detecting unit, a software for eye movements analysis and an AC adapter. The head unit is a 1/4 inch color CCD camera, it captures an image of visual field in front of subjects. Weight of the camera is almost 300 gr. The eye marks detecting unit is a 1/3 inch CCD camera. Its measuring scope is within 40 deg., its detecting procedure is pupil/cornea reflection and its detecting rates are both in 60 Hz (monocular) and 30 Hz (binocular). The controller has detection power of less than 0.2

deg. Outputs of controller are compositions of images of visual field, images of the pupil and RS-232C serial data (XY coordinates, diameters of the pupil, conversion angles and number of frames). The software is composed of a graph of eye marks, values of diameter of the subject's pupil in a time series, results of analysis of fixation points, a graph of conversion angles in a time series, etc. displayed on a CRT by use of the Windows NT. The software runs on a data processing board and a graphic control board.

The display system is divided into 4 parts: a DOS/V computer, a vertical synchronizer (SB300T), active liquid crystal glasses (LCG; SB300G) and graphic software. The SB300T has inputs that are frame synchronized signals (TTL), composite video signals (RS-343—A compatible) or separate horizontal and vertical synchronized signals NTSC/PAL, and vertical synchronized signals. The SB300G has a more than 26% transmittance and liquid crystal shatters have less than 0.5 msec closing time and less than 2.8 msec opening time.

2.2 Software

The graphic software for the 3-D virtual display is developed in Borland C++ Builder 3 with its visual component library (VCL). The software has two menus. One is a "Display menu", and the other is a "Parameter setting menu".

By the "Display menu", stimulus pictures are able to be displayed on the CRT. A picture for the left eye is displayed in the upper half of the CRT, and a picture for the right eye is displayed in the lower half of it (Fig.1). Each picture consists of two random dots patterns. One pattern is large rectangle that has no visual disparity between upper and lower pictures. The other pattern is two pictures of a small rectangle included in a large rectangle. These pictures are displayed in the upper half and in the lower half of the CRT, respectively. These small rectangles have a visual disparity between the upper and the lower pictures. By means of active LCG system, subjects are able to recognize the small rectangle is nearer or farther than the large rectangle in the virtual 3-D space.

By the "Parameter setting menu", a user can choose several parameters in the "Parameter dialog" (Fig. 2). Items of the "Parameter dialog" are as the followings. The visual disparity is so selected that it will be displayed on the CRT at random or an order given in a data file.

In a case when "Random" is selected, the following features are available to set.

R1. The maximum and minimum values of visual disparity.

R2. Directions of visual disparity. When a positive value is set, we recognize the small

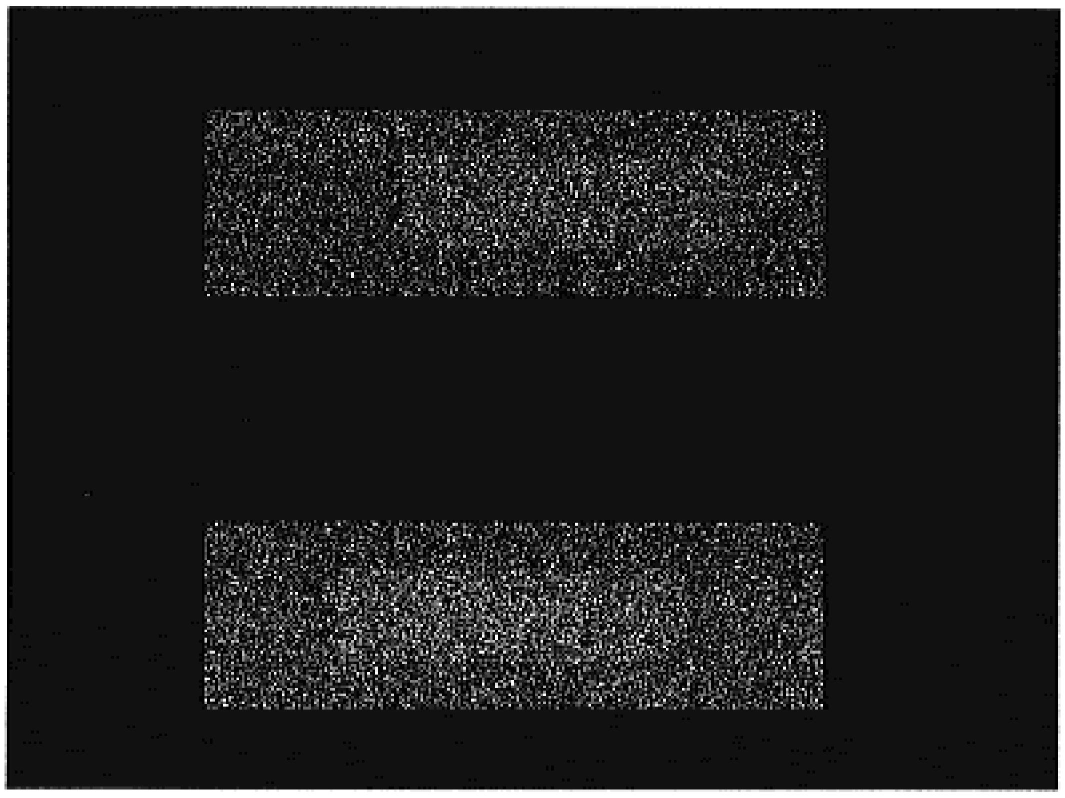

Fig. 1 An example of pictures displayed on the CRT.

rectangle is nearer than the large rectangle. When a negative is selected, we recognize it oppositely. When both values are selected, we recognize it either, relative to the positive and the negative.

R3. An interval time between stimulus pictures.

R4. A display time of stimulus pictures.

In a case when "by data file" is selected, the following features are available to set.

F1. A name of data file.

F2. A display of content of data file by a viewer like a text editor.

F3. An automatic creation of the content of data file and manually also available.

F4. The maximum and minimum values of visual disparity when automatic creation is selected.

3. Experiment

By the active LCG system and the graphic software, we made an experiment to investigate eye movements when subjects watch the 3-D virtual pictures with LCG.

We prepared for a set of three patterns of pictures. One pattern consists of pictures

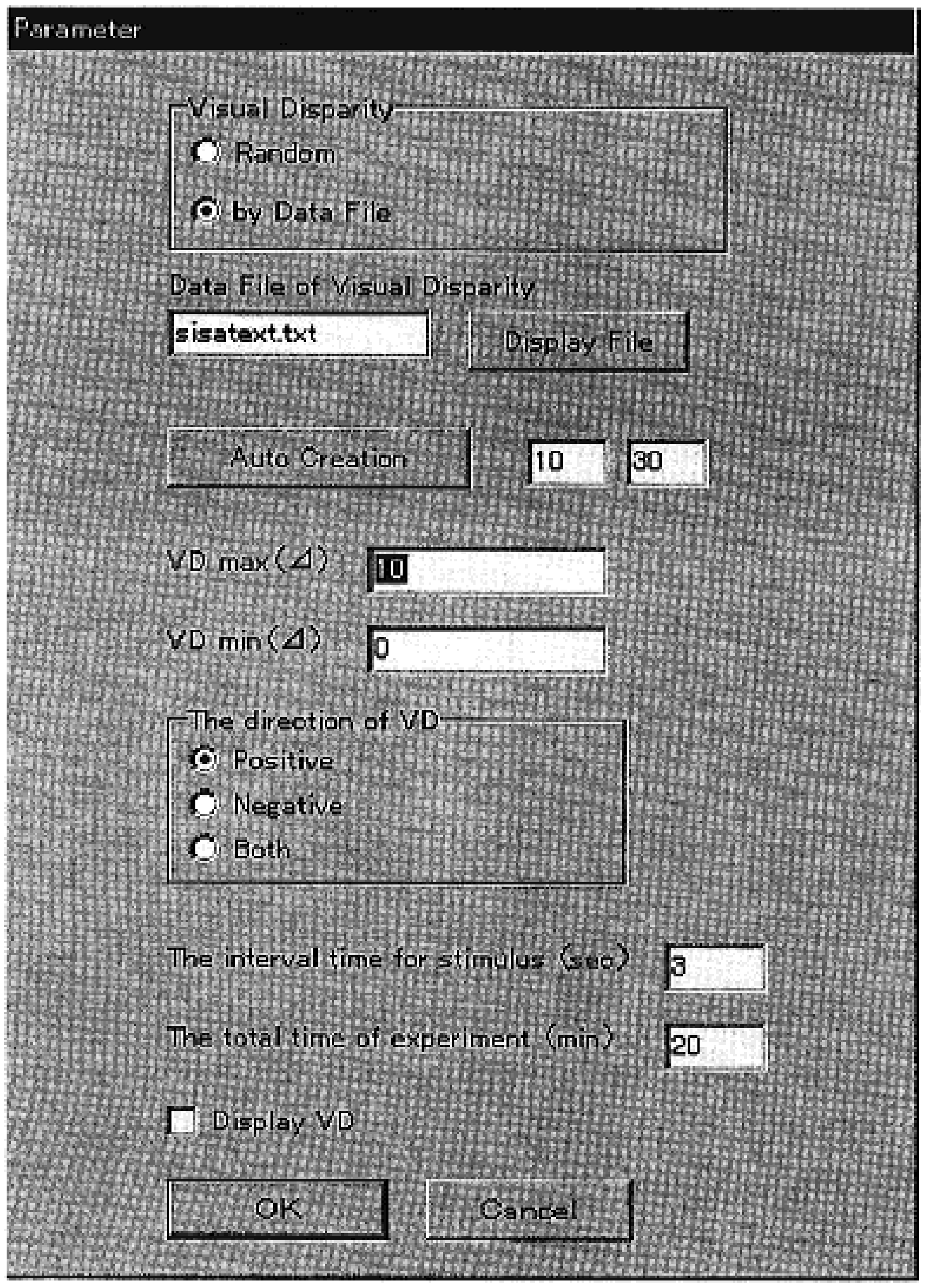

Fig. 2 Parameter setting menu

with large visual disparities (x_1), another pattern is with small visual disparities (x_2), and the other is with no visual disparities (x_3). Each picture has five examples, so 15 pictures exist in total, and each of them is chosen at random. In the experiment, we showed these pictures to a subject who puts on a cap attached with the eye marks recorder and the LCG. Each picture is displayed on the CRT for 5 seconds, the experiment is repeated 15 times. By use of the system, we recorded the vergence and the eye positions of a subject, etc., and analyzed the recorded data.

Table 1 shows a mean and a standard deviation of vergences of eye movements for each pattern.

Tables 2 and 3 show the results of tests for means. In the tables, we can find statistically significant differences between vergences in 2-D and 3-D pictures. They also show the system is effective to measure eye movements for 3-D virtual space, because the subjects are supposed to discriminate 3-D pictures to 2-D pictures.

Table 1. Mean and standard deviation of vergence angles

Disparities	large	small	no
Mean	3.96	5.15	4.62
Standard deviatoin	0.37	0.34	0.26

Table 2. Tests for mean between large (3-D) and no(2-D) disparities

Statistic	28.26
Degree of freedom	679
1 percentile	2.33
Probability	4.7E-117
Judgement	Significant

Table 3. Tests for mean between small (3-D) and no(2-D) disparities

Statistic	−24.09
Degree of freedom	712
1 percentile	−2.33
Probability	1.5E-94
Judgement	Significant

4. Conclusions

By the measuring system equipped with liquid crystal glasses and the software, we measured eye movements of subjects and statistically compared vergence angles for 3-D pictures with for 2-D pictures

Although these experiments are the first step, they showed the system is effective to investigate further aspects of eye movements of subjects who look at the 3-D virtual world.

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