

System development of fatigue-less HMD system 3DDAC(3D Display with Accommodative Compensation): System implementation of Mk.4 in light-weight HMD

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Abstract: This paper describes the development of the 3DDAC mk.4 system, which is a brand new implementation in our research program. The 3DDAC is a fatigue-less stereoscopic display system that is provided with a compensating function of accommodation for binocular disparity 3D image representation. The mk.4 system also features a light-weight HMD style.

Keywords: 3D display, accommodation, convergence, binocular disparity, system design and implementation, ophthalmological fatigue

1. Objective and background

In recent years, we have been developing a fatigue-less stereoscopic display system called the 3DDAC (3D Display with Accommodative Compensation)[1]. The principle idea of 3DDAC is a compensating accommodation with binocular disparity 3D image representation by using real-time display screen movement. We have already developed the experimental prototype level 3DDAC mk.1 and mk.2 system. Both mk.1 and mk.2 are desktop style stereoscopic display systems using CRT monitors. We have also developed the experimental prototype level HMD (Head Mounted Display) style 3DDAC which is called the mk.3 system. Through the mk.1 to mk.3 development, we were able to certify the basic idea and the effectiveness of compensation functionality of 3DDAC and also gained experience with way of implementation. In this paper, we describe the 3DDAC mk.4

system development in this series of our research program. The 3DDAC mk.4 is a brand new implementation. The major goals of the mk.4 system development are as follows:

- (1)light weight and small size HMD style implementation.
- (2)practicallity and ease of use for actual application.

To achieve these goals, we focused on simple and robust system design and implementation, system integration and enhancement with additional equipment, and the capability to host connectivity.

2. System Overview

As many previous works have pointed out, the binocular disparity stereoscopic image representation methodology is simple and practical for actual applications. Generally speaking, it is more commonly used with computer graphics and motion images than other

types. However, because the binocular disparity methodology generates only one of the various stereoscopic cues, e.g., motion parallax, accommodation, pictorial cues and so on, a binocular disparity 3D display results in an uncomfortable feeling and physical and mental fatigue for users. This is mainly caused by the mismatching of convergence and accommodation[3]. As figure 1 shows, there is a difference between the vergence distance and the accommodation distance, and this inconsistency becomes a physical and mental work load, which invokes serious fatigue.

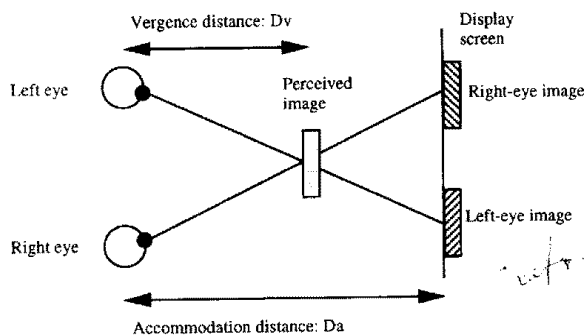


Figure 1: Relationship between vergence distance and accommodation distance in binocular disparity display.

We intended to improve this inherent weak point of the binocular disparity methodology in the 3DDAC development program. The principle idea of compensation is very simple. As figure 2 shows, there is a gaze detection mechanism and a movable display screen within the same system. The gaze detector detects the viewpoint of the image, and the system's host CPU calculates the distance of that viewpoint and controls actuator that drives movable screen to provide correspondence between the vergence distance and accommodation distance.

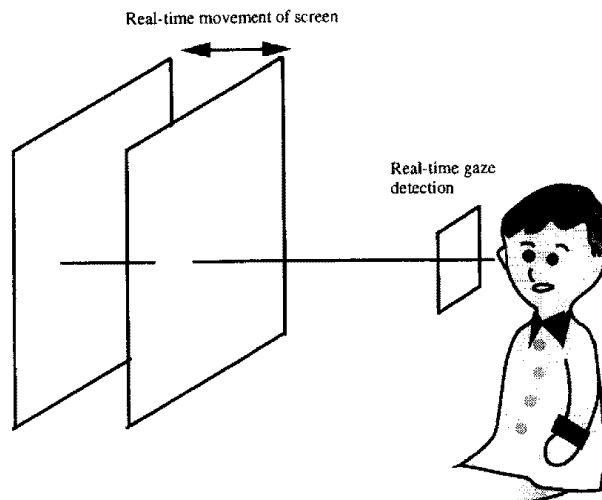
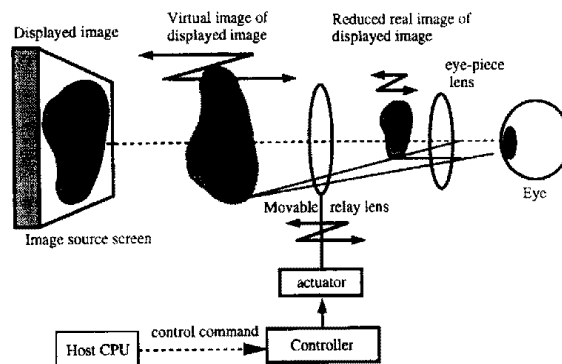
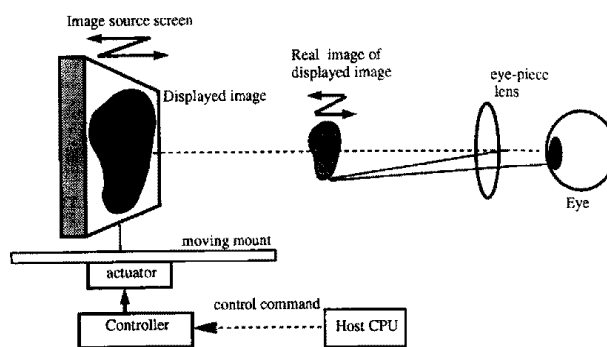


Figure 2: Principle idea of compensation in 3DDAC



(1) Moving virtual image of displayed image on source screen: Mk.1, Mk.2 and Mk.3 implementation



(2) Moving source image screen : Mk.4 implementation

Figure 3: Principle idea of screen movement

In the 3DDAC program, we have already tried two implementation methods for screen moving. One way was a straightforward implementation of the 3DDAC principle: driving the screen unit directly. The other was moving a

virtual image of the displayed image on the screen by using optical components, which is equivalent to moving the screen unit itself (figure 3).

Mk.1 to mk.3 used the latter method, and had a fixed screen unit and a lens unit for moving the virtual image. Mk.3 was also an HMD style implementation, but it was heavy and had a bulky size.

Mk.4 is the former method, that is an approach to reduce the size and weight and to simplify its optical structure for practical use. We will describe its implementation in the next section.

3. System Implementation

With the aim of reducing development turn around, we decided to reconstruct a commercial HMD product to use with the mk.4 program. When we started this program, we investigated the internal structure of several commercial HMD systems, and found that the OLYMPUS MW-601 "Media MaskTM" had a suitable mechanical structure for a movable display screen. We also tried to disassemble and examine its internal optical alignment. Through this reverse engineering and study of related technical documents, we decided to reconstruct the MW-601 system as basis of mk.4 basis. This decision was made because we found that it had suitable mechanical and optical alignment for a movable screen.

Figure 4 shows a block diagram of the mk.4 system, consisting of the head unit, image control unit, accommodation control unit and host CPU interface. Here, the image control unit receives each left-eye image and right-eye image (3D mode) or monocular image (2D mode) as an

NTSC video signal (Y/C or component RGB) from the host CPU and transfers it to the head unit. The head unit is a head mounted binocular viewer that gives a disparity image to each eye. The accommodation control unit is an actuator controller with a host CPU interface. As mentioned previously, the host CPU calculates the distance of the displayed image and issues a control command for screen movement to the accommodation control unit. The host CPU and accommodation control unit are connected by a serial (RS-232C) line. The accommodation control unit receives this command and controls the actuator unit that drives the movable screen unit in the head unit.

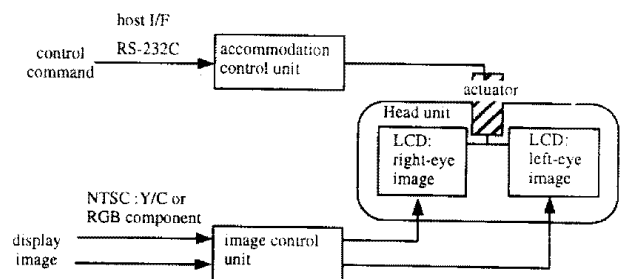


Figure 4: Block diagram of 3DDAC mk.4

Figure 5 shows a block diagram of the internal optical structure of the head unit. It consists of a movable screen unit, an optical component and an actuator unit. The movable screen unit consists of two wide-angle TFT LCD panels with back-lighting units. Both the LCD panels and back-lighting units are moved together. The optical component is a monolithic block of lens and prism and allows outside real images to pass through via an LCD shutter when the mk.4 is in the see-through mode.

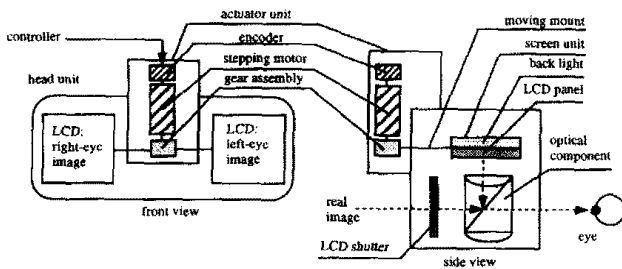


Figure 5: Internal optical alignment of head unit

The actuator unit consists of a stepping motor and gear assembly. It drives the movable screen unit under the control of the auxiliary accommodation control unit.

The developed mk.4 incorporated the following components; TFT LCD panels, lens and prism unit, image control unit and the outer shell of the head unit from the original MW-601. We constructed the actuator unit, and attached it to the original outer shell of the MW-601 head unit. We also developed the accommodation control unit.

4. Conclusions

The mk.4 system has the technical specifications shown in table 1. This system can drive a movable screen at less than 0.3s to move a displayed image distance of 0.25m to infinity, which is a sufficient response for human perception. We have also conducted simple subject experiments for evaluation. We made a stimulus CG image from 3D objects and placed them at various depths in a 3D CG world. We then showed those stimulus images to subjects under different conditions of accommodation compensation control, and interviewed them about their impressions of the relative position of each stimulus object. Every subject reported that it was easy to distinguish the relative position when accommodation was correctly compensated.

Table-1: Technical Specifications of 3DDAC mk.4

| | |
|------------------|--|
| Code Name & Type | 3DDAC Mk.IV system, Head Mounted Stereoscopic Display system w/Accommodative compensation |
| Display Mode | 2D/3D image w/o or w/ Acc. Comp, Sec-through, Video Overlay |
| Display Device | 1.4" TFT-LCD, aspect ratio 16:9, 356 x 160pixel |
| Input Signal | NTSC component RGB, NTSC Y/C, stereo sound |
| Weight | 1.2Kg (Head Unit), 2.5Kg (Video controller), 4.3Kg (Acc. Comp. controller) |
| Acc. Comp. range | 0.25m - infinity |
| Host | SGI IRIS, Win95/NT |
| Option | brightness control unit |

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