A Modified Wheatstone-Style Head-Mounted Display Prototype for Narrow Field-of-View Video See-Through Augmented Reality

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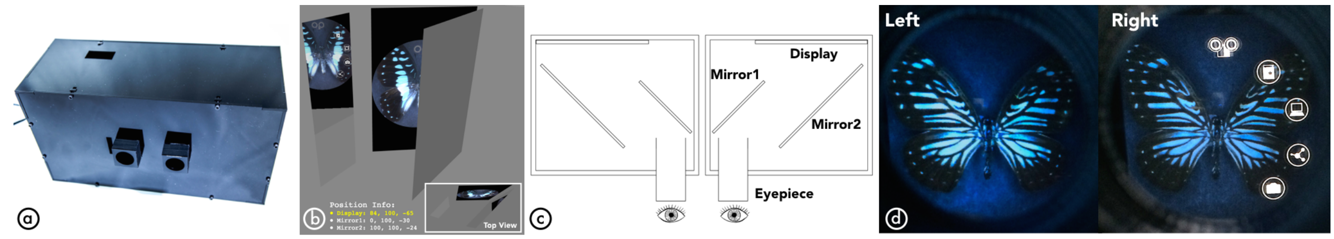

Figure 1: *(a) Our HMD prototype. (b) The software we developed to generate a recommended optical configuration by setting specific parameters. (c) Details of our prototype system. (d) Near-field augmented reality application "Butterfly Observation" through our system.*

Keywords: augmented reality, narrow field-of-view, interpupillary distance adjustment, Wheatstone stereoscope, stereo microscope

Concepts: •**Hardware** → **Displays and imagers;** •**Computing methodologies** → *Mixed / augmented reality;*

1 Introduction

Users always got bad experiences while using the general virtual reality head-mounted displays (HMDs) because of the low pixel density through optical lenses. For this reason, the narrow field-of-view (FoV) and high pixel density are the main goals we are going to pursue in the near-field video see-through augmented reality (AR) applications with sophisticated operations, such as the biological observation with AR microscope (e.g. Scope+ [Huang et al. 2015]), the AR surgery simulation, and telescope applications. Therefore with high resolution to see tiny objects clearly is the most important concern in this paper.

Besides, users can not get comfortable stereo vision without correct interpupillary distance (IPD) of HMDs. Some of the devices can provide customized IPD by moving the lens horizontally (Fig 2b), however, the FoV can be restricted due to large amount of movement (the range of IPD is 52 to 78 mm). To solve this problem, 2 separated panel are used in our system which can be moved while adjusting IPD to keep constant user experience between different users (Fig 2c).

In order to generate the optical configuration for different panels and parameters, the reflected ray was calculated by our system (Fig 1b). The prototype we built (Fig 1a) is a modified Wheatstone Stereoscope [Devernay and Beardsley 2015] by replacing the stereoscopic pictures with two high-definition LCD panels (Fig 1c). Therefore users can have a narrow FoV but high pixel density display with adjustable IPD and a comfortable accommodation distance by adopting our system.

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2 Prototype and Result

The original Wheatstone Stereoscope, which was too large because of the long path of light, used stereoscopic pictures placed in parallel with perpendicular mirrors in the middle. We modified this mechanism based on certain parameters, such as the size of panels, the visual acuity (for the comfortable reading distance of human) and the size of the field-of-view, to generate an optimized optical configuration with the best viewing distance (Fig 2a). In detail, we used CHIMEI panels (6.95" LCD, 1280 × 800) for each eye with a pair of parallel mirrors in a double-reflection arrangement to build a high pixel density with 559.4 ppi (see through the Mirror1) and narrow FoV (32°) in standard VR application or field diameter 65mm while applying to a magnified application such as AR microscope (Scope+). In addition, we placed the comfortable accommodation distance at 20cm, which could extend the use time of VR headsets for users. Also, users could easily shift one of the display module to adjust the IPD (Fig 2b) with separate panel for each eye, which was different from the general HMDs. By conducting the user study, most of the subjects were amazed by the high resolution and comfortable viewing distance while experiencing this new HMD prototype (Fig 1d). We believe that the modified Wheatstone-style HMD design generated by the algorithm we implemented and the prototype we built afterwards, will be a great solution to the near-field, narrow FoV video see-through AR HMD.

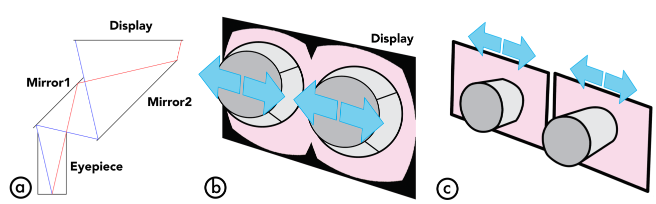

Figure 2: *(a) Optical configuration. (b) The interpupillary distance (IPD) adjustment in general HMDs. (c) The IPD adjustment in our prototype, which can be adjusted by shifting one of the display modules.*

Acknowledgements

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