DES3/INP2-4
Invited

Augmented Vision: The Future of Upgrading Your Vision via Optical See-through AR Displays

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Keywords: Augmented vision, Augmented reality, Optical see-through display

ABSTRACT

This invited talk presents vision augmentation technology that assists and enhances the human vision by overriding it with optical see-through near-eye displays (OST-NED). We first present the recent advancement of OST-NED technology that brings augmented reality (AR) images closer to reality and then existing vision augmentation applications and their prospects.

1 INTRODUCTION

In this invited talk, I will present a visual augmentation technology, an emerging research area that assists and enhances human vision by overriding human vision with an optical see-through near-eye display (OST-NED, Fig. 1, [9]).

Our society has developed by "expanding human capabilities through technology," as the automobile expands human mobility, electronic mail accelerates human communication, and electronic calendars supplement human memory.

The significance of these technologies is that they not only enable us to do things that are impossible to do with our bodies but also create a society in which all people, young and old, male and female, can benefit from them and live without any inconvenience.

Eyeglasses are one of the technologies to enhance human perception. The earliest example of visual augmentation in history is probably the spectacle glasses. Already in 1600, we have a certain portrait of a clergyman wearing a spectacle[1]. In the current era, there are even smart eyeglasses that dynamically adapt the lens diopter [1].

Vision enhancement is an extension of this technology; it is a technological framework for reinforcing and enhancing human vision.

2 VISION AUGMENTATION WITH OST-NEDs

In vision augmentation, we work on the technology that realizes advanced perceptual information presentation to the eye to adaptively assist human vision with image stimuli via OST-NEDs (Fig. 2). In particular, we have developed a technology to improve the reproducibility of image stimuli in OST-NEDs.

Fig. 1: Comparison of VR headset and OST-NED. Left: A commercial VR display (Facebook's Oculus Quest 2). Right: A commercial OST-NED (Microsoft's Hololens 2). Photos were taken by the author and the subject's permission in the photo is granted.

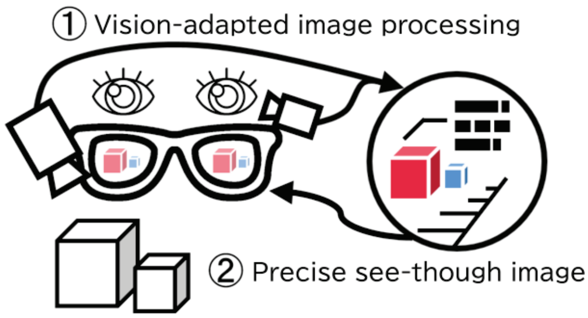

Fig. 2: A conceptual drawing of vision augmentation with OST-NEDs. The system needs to understand the world, estimate the current status of the user's vision, and render a precise image as computed.

In the AR field, OST-NEDs can overlap virtual contents into the user's view directly while maintaining the real view of the user (Fig. 1 right). Unlike virtual reality (VR) displays and video see-through displays, OST-NEDs can render an image in the real field of view of the user using a beam combiner. OST-NEDs have been widely used in many AR applications, including education, medical, and industry.

Examples include incorporating an eye-tracking device into the OST-HMD to improve the spatial registration of AR contents in the user's field of view [4] (Fig. 3).

In addition to these, we also developed the light

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[1] *Portrait of Fernando Niño de Guevara*, 1600, by El Greco.

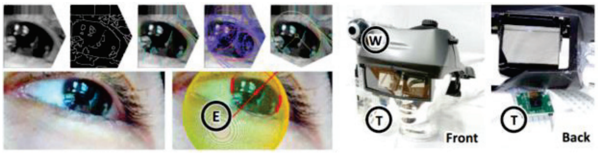

Fig. 3: Registering AR images in the field of view can be more accurate with 3D eye tracking [4]. We installed an eye-tracking camera in an OST-NED and computed the projection matrix from the 3D space to the image screen

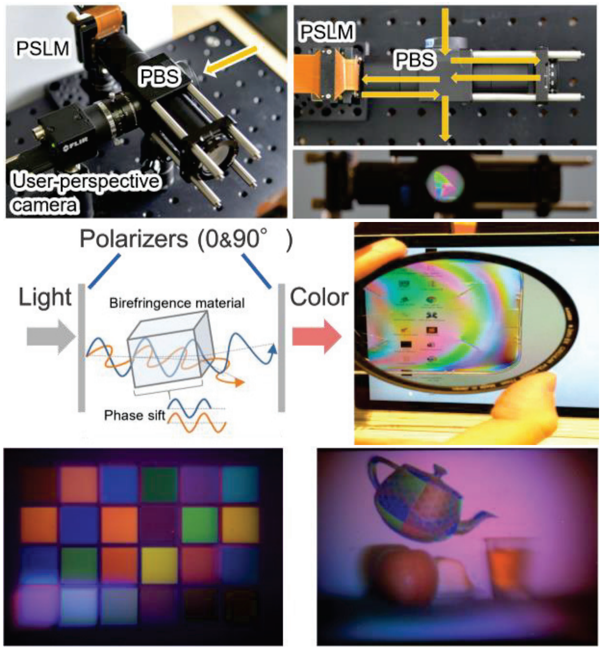

Fig. 4: Light attenuation display [5,8]. Unlike traditional OST-NEDs, our system creates colors by *subtracting* light from the scene by using polarization interference.

attenuation display, a color subtractive OST display that is complementary to existing OST-NEDs [5,8] (Fig. 4).

In the light attenuation display, we create colors via polarization interference with a phase-only spatial light modulator. Thanks to the nature of this display the user can see a bright image in a daylight environment.

Other than this research work, we also developed an image presentation technology that reproduces key perceptual information such as color reproduction, optical occlusion, and brightness range. Thanks to these fundamental display technologies, we have developed various vision augmentation applications.

3 APPLICATIONS

Based on these basic technologies, we proposed a series of vision augmentation systems to support visual functions. This technology can be either optically modulate our field view and/or adding new visual capabilities to enhance our perceptual tasks.

We developed smart sunglasses called AdaptiVisor that

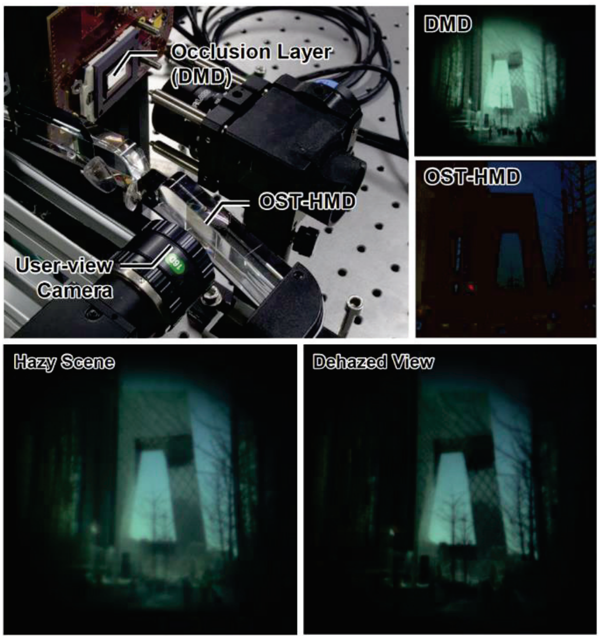

Fig. 5: DehazeGlasses [3]. A vision augmentation system to *optically* dehaze the view via an occlusion-capable OST-NED.

Fig. 6: Chromaglasses [10]. A vision augmentation system for compensating color blindness.

can adaptively control the brightness of the world based occlusion-capable OST-NEDs [2]. The system was able to make a bright part in the view darker by the occlusion mask and to make a dark part in the view brighter by overlapping the scene image taken from a scene camera which has a high light sensitivity.

As an extension of AdaptiVisor, we developed DehazeGlasses that can optically remove haze from a hazey scene and makes our view clearer (Fig. 5) [3]. To achieve this goal, the OST-NED system had to analyze the scene and estimate the haze component of the scene to how much it needs to compensate for the scene brightness.

We also developed ChromaGlasses, a color compensating eyeglasses that analyze the color vision of people with color deficiencies and reproduce the optimal color tone using OST-HMD to alleviate color vision deficiencies in humans [10] (Fig. 6). In this work, we build a system to assist color perception under color-blindness.

The system is tuned for the type of color-blindness a

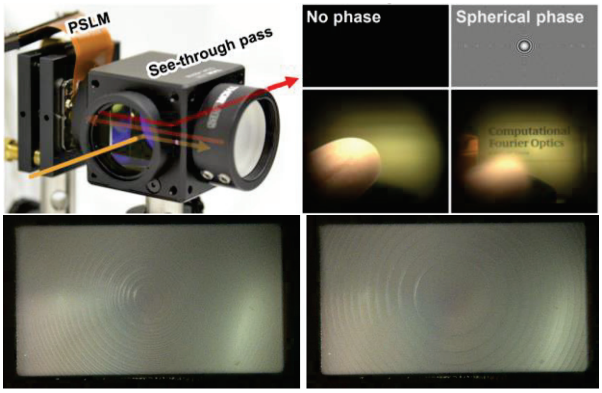

Fig. 6: Computational eyeglasses [6]. A vision augmentation system for compensating color blindness.

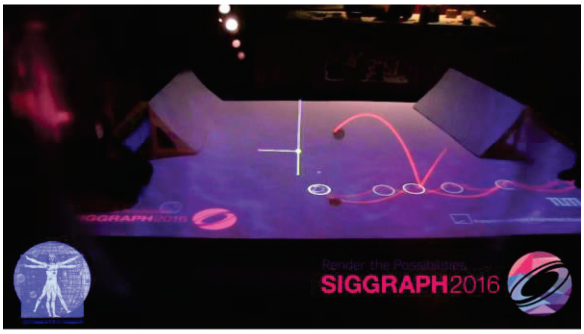

Fig. 7: Laplacian Vision [7]. A vision augmentation system to assist human's naïve physics, a skill how we predict the physical world.

user has, and augment colors into the view with a color-processed scene image taken by a scene camera.

Another example is a programmable liquid crystal lens system for automatic optimization of visual acuity [6] (Fig. 6). Where we utilized a phase-only spatial light modulator to drive it as a programable lens. Because we can render a lens onto this programable lens, one can dynamically modulate the focal length of the glasses or realize an auto-focusing effect on the system.

Vision augmentation is not limited to augment the scene light condition. We developed LaplacianVision, an optical system that can predict the physical state of the real world in real-time and can visually feedback the state to the user via AR images (Fig. 7) [7]. LaplacianVision aimed to enhance human spatial cognition through this feedback.

4 CONCLUSION

In this invited talk, I overviewed vision augmentation, an emerging AR technology utilizing OST-NEDs. By pioneering this research field, we envision that a society where many people wear vision augmentation systems daily, like smartphones, eyeglasses, and hearing aids, may become a reality in the future. Vision augmentation technology is expected to help people maintain and improve the quality of life by assisting them in their perceptual information processing abilities, which have deteriorated.

5 ACKNOWLWGEDMENTS

A part of our research presented in this talk was supported by JST PRESTO Grant Number JPMJPR17J2 and JSPS KAKENHI Grant Number JP20H04222, Japan.

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