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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	情報工学 系 情報工学 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ 工学 ）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Optical See-Through Head-Mounted Displays (OST-HMDs) directly overlay images on the wearer's field of view (FoV), which facilitates applications in Augmented Reality (AR) and vision augmentation. Reproducing realistic appearances in OST-HMDs encourages the wearer to make correct judgments and actions in these applications. Conventional OST-HMD technologies are, however, tend to focus on reproducing the objects' appearance, such as their contrast and depth of field (DoF).

Visual appearance is perceived by a combination of the various light property reaching the eye and the wearer's vision. Hence, reproducing a realistic visual appearance requires two factors: a display system that can reproduce rich light information and an eye measurement system that estimates ocular characteristics. In contrast, conventional OST-HMD technologies utilize devices based on digital image processing, such as cameras and displays. We focus on that the limitations of conventional OST-HMDs arise from the imaging procedure ignoring the rich information of light entering and leaving the eye.

In this dissertation, we propose an OST-HMD system that addresses the above limitation by directly measuring or modulating the light entering and leaving th eye. My technology basis includes: (1) an OST-HMD with improved contrast and DoF fidelity by direct modulation of incoming light, (2) contrast enhancement in the first-person view via the OST-HMD based on the measurement of light entering the eye using co-axial optics, and (3) vision augmentation by fusion of the proposed OST-HMD and machine vision using deep learning.

Our first contribution is focal surface occlusion, reproducing DoF for multiple virtual objects at continuous depths in an Occlusion-Capable OST-HMD (OCOST-HMD). An OCOST-HMD realizes high dynamic range (HDR) presentation by inserting an occlusion mask into the optical path. An amplitude-only spatial light modulator (ASLM) is commonly used as the occlusion mask to selectively attenuate the incoming light. Although reproducing the DoF on objects on this occlusion mask greatly facilitates depth perception, there is a trade-off among the fidelity of DoF, the display's FoV, and spatial resolution.

Our focal surface occlusion additionally inserts a phase-only SLM (PSLM) that acts as if a dynamic free-form lens into an OCOST-HMD. By approximating the focal length of the PSLM with a curved surface to align the depth of the virtual scene, our concept can reproduce multiple and continuous focal blurs while maintaining the spatial resolution and an FoV. To reduce the distortion of the see-through view while reproducing DoF, I established an optical design based on afocal optics and edge-based optimization to exploit the property of the occlusion mask. The prototype with the PSLM and transmissive ASLM can reproduce DoF on the occluded objects at multiple and continuous depths with an FoV of 14.6°.

To reproduce realistic appearances according to the user's ocular characteristics, we need to measure the light perceived by the eyes from the user's eye position. Our second contribution is AdaptiVisor, a vision augmentation system that assists the brightness adaptation of the eye. This system uses a high-dynamic-range (HDR) camera to acquire the light information entering the eye from the viewpoint using a coaxial optical system.

Based on the acquired images, the OCOST-HMD selectively darkens or brightens a part of the FoV so that the user does not feel the sudden change in brightness. Experiments show that the proof-of-concept system reduces the overexposed portions of the scene by 1/15 and the underexposed portions by half with a delay of 0.5 seconds.

If we can reproduce various appearances by combining light information measurement on the viewpoint and high-contrast OST-HMDs, then we can freely redesign the vision according to the situation. As such a system, our third contribution is DehazeGlasses, a vision augmentation system to remove haze from the first-person view using an OCOST-HMD. The system converts the viewpoint image to HDR through a dehazing algorithm, and selectively modulates the intensity of light entering the eye. The proof-of-concept system can dehaze the scene closer to the ground truth under a perceptual metric.

In summary, this dissertation aims to take a step toward realizing AR that freely manipulates the personal vision for a future in which OST-HMDs are worn daily like prescription glasses. We investigate an OST-HMD with directly measuring or modulating the light in terms of the display, eye measurement, and potential applications.