IlluminatedFocus: Vision Augmentation using Spatial Defocusing

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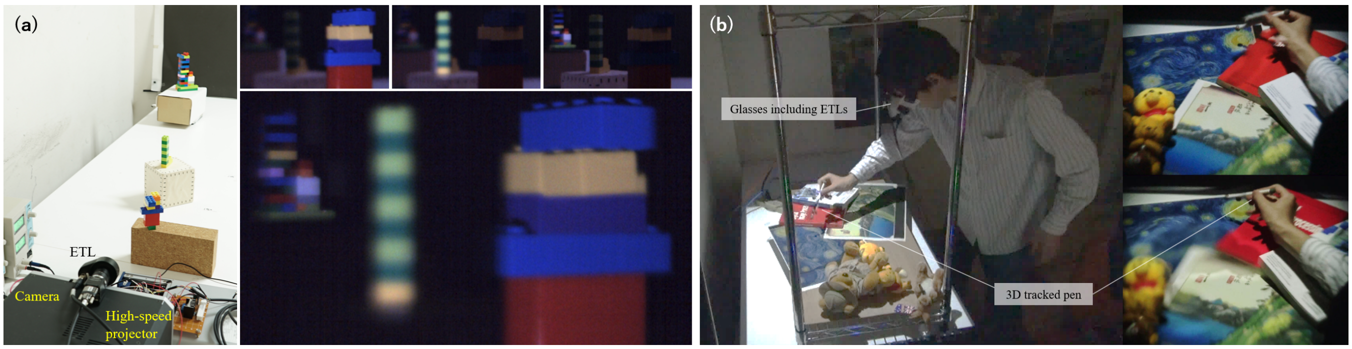

Figure 1: (a) Spatial defocusing of real objects. (b) Interactive defocusing application.

ABSTRACT

We propose IlluminatedFocus, augmented reality (AR) glasses enabling depth-independent spatial defocusing of a human vision. Our technique spatially manipulates the depth-of-field by synchronizing a periodic focal sweep of head-worn electrically tunable lenses and fast illumination control with a high-speed projector. In this demonstration, we show a system that switches focused and defocused views independently at each area of a 3D real scene. We realize various vision augmentation applications based on our method to show its potential to expand the application field of optical see-through AR.

CCS CONCEPTS

• **Human-centered computing** → **Augmented reality**;

KEYWORDS

Augmented reality, focus control, projection mapping

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1 INTRODUCTION

Defocus blur is one of the natural visual effects. This has been widely used in photographs and movies to control the visual saliency of a specific area, i.e., perceptually conceal the area from an observer and at the same time emphasize the other area to attract the attention. For example, defocus blur can be applied to hide unpleasant objects such as insects for people with entomophobia and human faces for privacy protection. The attention attraction can be used for visual guidance [Hata et al. 2016]. In addition, we can control the perceived depth, and consequently, the miniature feeling of a target object by blurring its background [Okatani and Deguchi 2007].

In this paper, we envision augmented reality (AR) glasses that can spatially control the depth-of-field (DOF) of our human vision to realize vision augmentation applications as described above. Such glasses can be easily realized using video see-through (VST) displays, because refocusing process is digitally implemented as a convolution of images with a defocus kernel. However, VST displays limit user's field-of-view (FOV), and their color and spatial resolution are not consistent with our real world. The same concept may be achieved in spatial augmented reality (SAR) by applying a recent radiometric compensation technique [Grundhöfer and Iwai 2018]. However, due to the limited spatial resolution and dynamic range, the appearance of real world cannot be perfectly controlled, and thus, defocus blur effect cannot be reproduced in SAR. Although optical see-through (OST) displays do not suffer from these technical limitations, our target (i.e., depth-independent focus control) is not achieved with typical OST displays.

We propose IlluminatedFocus, AR glasses to achieve this goal. A typical lens allows an observer to focus only on objects locating at the same distance depending on the lens's inherent optical power, and cannot present spatially-varying and depth-independent defocus blur. To overcome this limitation and achieve our goal (spatially defocusing specific parts in a scene regardless of their distances),

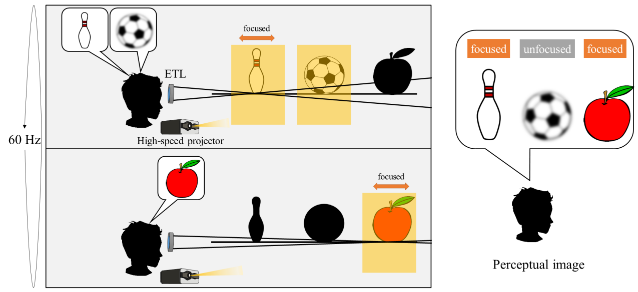

Figure 2: Technical details of IlluminatedFocus. Periodical repetition of focal sweep and fast illumination change at more than 60 Hz allows a user to perceive an image in which only the intermediate object (ball) appears blurred.

we propose a system that combines electrically focus tunable lenses (ETLs) and a high-speed projector. A user of the system wears the ETLs. The optical power of the ETL is periodically modulated at greater than 60 Hz, and the high-speed projector is synchronized to illuminate the target scene at appropriate timing to provide a desired defocus blur effect at each part of the scene (Fig. 1 (a)-Left, Fig. 2).

2 IMPLEMENTATION

IlluminatedFocus assumes that a user wears the ETLs under a dark room condition. We built a prototype system consisting of two ETLs, a high-speed projector, a digital-to-analog converter (DAC), and a PC. The ETL (Optotune EL-16-40-TC) modulates optical power by a periodic electric signal. The high-speed projector (Tokyo Electron Device Limited DynaFlash) performs 1,000 Hz, 8 bit monochrome projection synchronized with the ETLs by the DAC (National Instruments USB-6343). The PC controls the DAC and the projection images according to the shape of the real objects. In the control of the ETL, a sinusoidal electrical signal is sent to the ETL to realize a periodic fast focal sweep. The ETL's driving frequency is 60 Hz, which is the critical fusion frequency (CFF) of human. Therefore, up to 16 blur sizes can be presented in this system (i.e., $\frac{1,000}{60} \fallingdotseq 16$). This value can be improved by setting the CFF to a lower value or by using a projector with a higher frame rate.

3 APPLICATION

IlluminatedFocus can be applied to various real objects (Fig. 1 (a)-Right). We have created several vision augmentation applications. One application is to hide objects naturally from a user's view. For example, it can be used to hide unpleasant objects such as insects from entomophobes (Fig. 3 (a)). It also protects people's privacy by hiding certain documents when working with multiple people at a tabletop. If a user needs to focus on her/his work or study, obscuring unrelated smartphone screens or comics may help her/him stay focused on the work instead of distracting the user.

In addition, the proposed system can be used for a visual guidance (Fig. 3 (b)). For example, in guidance for museum exhibits, guides with arrows found in typical AR systems might reduce the user's sense of immersion in the exhibits. We believe that a more natural visual expression can be provided by guiding the exhibits

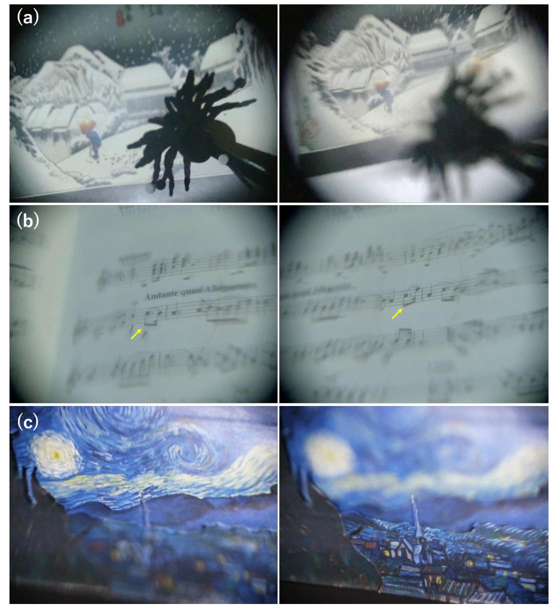

Figure 3: Example applications: (a) Hiding an undesirable object. (b) Visual guidance. (c) Amplifying the perceived depth of a painting.

by operating the defocused area than the arrow. If a user removes the IlluminatedFocus and looks at the exhibits, it appears to be uniformly illuminated by the projector so that the exhibits can be enjoyed as usual. Since the proposed system can change the defocused area in real time, it is possible to implement a painting tool for setting the defocused area by oneself (Fig. 1 (b)) and an application for guiding a musical instrument player to a performance position on scores following a music piece.

For example, a painting can be divided into multiple layers, and multiple blur sizes can be used to provide the perceived depth or the miniature feeling (Fig. 3 (c)). Furthermore, the perceived DOF of a human can be changed by the defocus blur effect, thereby amplifying the perceived depth of a planar object.

4 CONCLUSION

This demonstration presents IlluminatedFocus, an AR glasses enabling depth-independent, spatial optical defocusing of a human vision. We realized various vision augmentation applications based on our method to show its potential to expand the application field of optical see-through AR.

ACKNOWLEDGMENTS

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