Temporal Phase Shift: Visual Illusion by Phase-Shifted Light Projection and Its Applications

Jun Rekimoto[1,2]

[1] The University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo 110-0033, Japan
rekimoto@acm.org
http://lab.rekimoto.org
[2] Sony Computer Science Laboratories, Inc.
3-14-13 Higashigotanda, Shinagawa-ku, Tokyo 141-0022, Japan

Abstract. Understanding the mechanism of human visual processing is important as a foundation for human computer interaction research, because many interactive systems are primary relying on visual information. In this paper, we report a new visual illusion caused by phased shifted light projection using our customized digital micromirror projector that appears to be related to human eyes' saccades and microsaccades. We examine the cause of this illusion, and propose possible applications using this effect.

1 Introduction

When we are looking at the fixed position, our eyes are still continuously and imperceptibly jumping and jiggling. This phenomenon is called *microsaccades*, in contrast to larger voluntary eye movements known as saccades [2,4,1]. Microsaccades are believed to be an important mechanism for visual processing, and several researches are going on to investigate its correlation to human's higher mental status such as concentration and emotion [2,4].

Meanwhile, there are a number of visual illusions are found and studied [5]. These illusions are important tools for understanding the mechanism of visual perception, and also important for creating interactive media and entertainment.

In this paper, we report a new visual illusion that occurs by using a modified DMD (digital micromirror device) projector [3] that projects images with flickering phase are slightly different. We named this effect "temporal phase shift illusion".

2 Temporal Phase Shift Illusion

Figure 1 shows a system configuration that causes this illusion. A normal projector using DMD has a configuration as shown in Figure 1 (a). A DMD device

C. Stephanidis (Ed.): Posters, Part I, HCII 2013, CCIS 373, pp. 503–506, 2013.

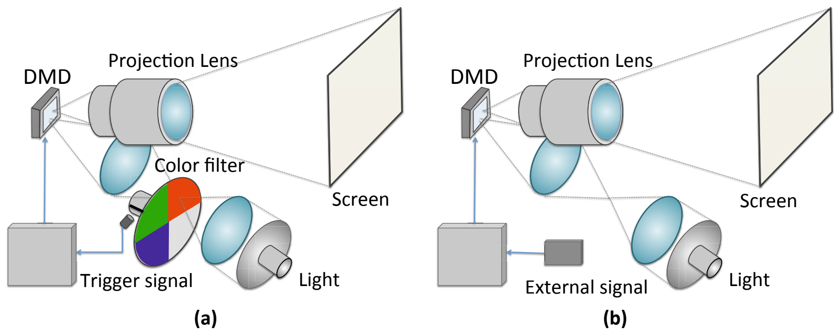

Fig. 1. Configuration of projectors: (a) normal DMD projector, (b) our customized projector to create visual illusion

has an array of micro-mirrors that control reflections of incoming light, and thus it can control projected pixel intensity. A rotating color filter is used in combination to change color from the light source. When the angle of a micro mirror is synchronously selected with color filter, it can project any selected color with selected intensity. As a result, a DMD projector can control each pixel's RGB brightness.

In contrast, our modified DMD projector, shown in Figure 1(b), has a single light source, and the color filter is removed. With this projector, light patterns those have the same brightness, the same flicker frequency, but different flicker phases can be projected.

The difference of these patterns should be imperceptible for human eyes, because the projector's flickering frequency (120Hz) is well higher than Critical Flicker Frequency (CFF, which is normally around 50Hz), at which rate our eyes are incapable of separating consecutive light stimuli. However, we found that boundaries of these patterns are still noticeable especially when our eyes' move (i.e., saccade) (Figure 2(b)). We named this effect "temporal phase shift illusion".

This effect causes when we intentionally move eyes, but it also causes (but becoming less noticeable) when we looked at one particular point on a screen. Thus we consider this effect is related to both saccades and microsaccades. Furthermore, we expect that it should be possible to measure the frequency of microsaccades occurrences by counting the noticed number of this illusion, which would be useful for knowing user status such as concentration.

Our current explanation of this effect is this. Human retina's bipolar cell has structures such as on-center or off-center so that the cell is activated when there is a difference of light stimulation at the center and the peripheral areas. This mechanism normally detects edges, but the same mechanism detects phase differences, although light stimulation's flickering frequency is much higher to be detected by photoreceptor cells (Figure 3).

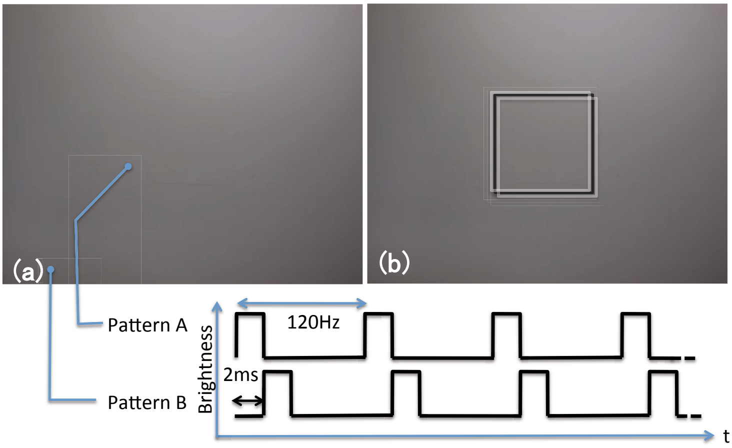

Fig. 2. Temporal Phase-Shift illusion: when flickering light patterns with the same frequency but different phases, the boundary becomes noticeable even when the frequency itself is much higher than the ability of human visual perception.((a): actual image, (b):simulation result of human visual perception)

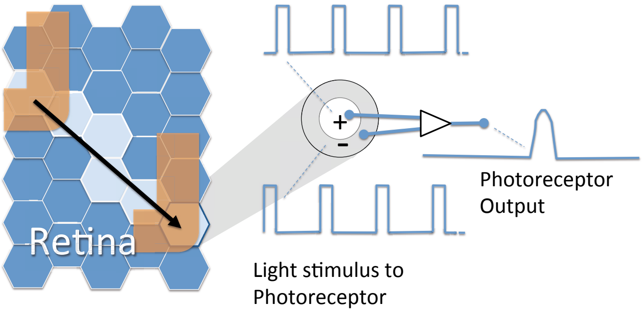

Fig. 3. A possible mechanism that causes Temporal Phase Shift Illusion: receptor detects phase difference before and after (micro-)saccades

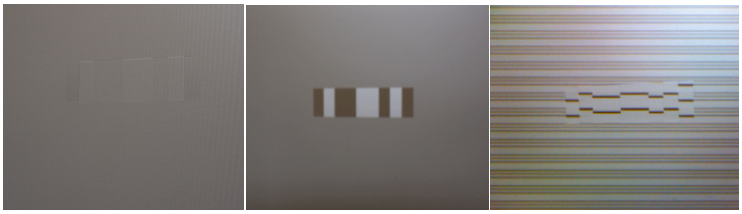

Fig. 4. Invisible barcode: left: viewed from human eyes (simulated by low-speed camera), middle: image taken by high-speed camera (1/200s), right: image taken by CMOS camera of the smartpohne

3 HCI Applications

This effect itself is interesting for understanding human visual perception mechanism. We now discuss the possibility of new HCI applications using this effect.

The first one is a measurement method for user concentration. By controlling the phase shift to determine the shortest phase shift that cause this illusion, we expect that it should be possible to measure user concentration status.

The other application is to use the feature of our customized projector itself, to create invisible barcodes. The phase difference of patterns are also detected by CMOS imager that are widely used as a imaging device for mobile phones, because there is also a time difference of light exposure on CMOS imaging device. As a result, information can be encoded as phase difference which is less noticeable for human eyes (Figure 4).

4 Conclusion

In this paper, we report our newly found visual illusion caused by phase-shifted lite projection. Although its mechanism is not perfectly explained, it should be related to our eye's saccades or microsaccades. We also reported possible HCI applications using this effect.

References

1. Bharath, A., Petrou, M.: Next Generation Artificial Vision Systems. Artech House (2008)
2. Findlay, J.M., Gilchrist, I.D.: Active Vision. Oxford University Press (2003)
3. Hornbeck, L.J., Nelson, W.E.: Bistable deformable mirror device. OSA Technical Digest Series Spatial Light Modulators and Applications 8, 107 (1988)
4. Martinez-Conde, S., Macknik, S.L.: Windows on the mind. Scientific American 297(2), 56–63 (2007)
5. Murakami, I., Cavanagh, P.: A jitter after-effect reveals motion-based stabilization of vision. Nature (395), 798–801 (1998)