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Ergonomic evaluation of a field-sequential colour projection system

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Abstract

A field-sequential colour projection system can display colour images using a single panel. Such a system, however, produces characteristic trichromatic separation, or "colour breakup". Colour breakup is the perceived splitting of the white portions of an image into its red, green, and blue components when the image is projected with the colour sequential method and the viewer's eyes are moving rapidly. Viewing images containing colour breakup may cause visual fatigue and other symptoms of asthenopia. In this study, the authors examine the various subjective symptoms of asthenopia that can be caused by colour breakup.

Keywords: Asthenopia; Colour breakup; Colour sequential projector; Digital light processing (DLP); Ergonomic evaluation; Visual fatigue

1. Introduction

Digital light processing (DLP) colour projection systems are already available and increasing their market share. DLP projectors form a binary image by means of a digital micromirror device (DMD). DLP projection systems use either a single chip or three chips to create a colour image. The cheaper and more popular DLP projectors use only a single chip. In a projector with a single chip, the colours are produced by placing a colour filter wheel between the lamp and the chip [6]. The colour filter wheel contains red, green, blue, and sometimes white (clear) filters. The wheel spins very rapidly, creating a sequence of red, green, blue, and white images that are combined into a single full colour image (Fig. 1). This technique is called "field-sequential". Time sequential RGB images are typically composed of one full colour image every 1/60th of a second. Although the use of a single panel can reduce both projector size and costs, the system's field-sequential colour projection mechanism can cause the observer to perceive trichromatic separation during times of rapid eye movement [1–3].

Colour breakup is the perceived splitting of the white portions of an image into its red, green, and blue components when the image is projected with the colour sequential method and the viewer's eyes are moving rapidly. This trichromatic separation is called "colour breakup" (Fig. 2). Colour breakup is a phenomenon related to the mechanisms of human visual perception. A recent research suggested that colour breakup is perceived because of the imperfections in visual stability. Colour breakup affects visual fatigue in people with congenital nystagmus [4]. And this phenomenon may cause the normal viewer to feel discomfort and even visual fatigue [5].

In this study, we focused on colour breakup as a characteristic problem of the field-sequential colour projection system, and examined its effects as manifested through subjective asthenopic symptoms.

2. Experiment 1

2.1. Purpose

The purpose of this experiment was to determine the characteristic symptoms of asthenopia caused by colour

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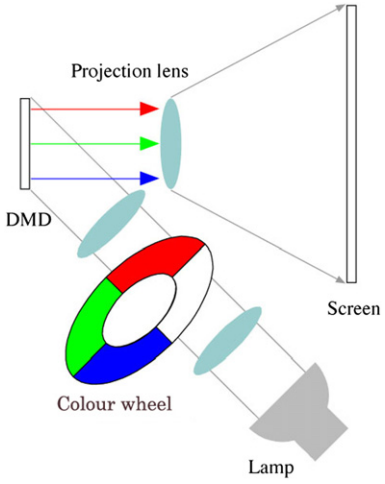

Fig. 1. Field-sequential colour projection system.

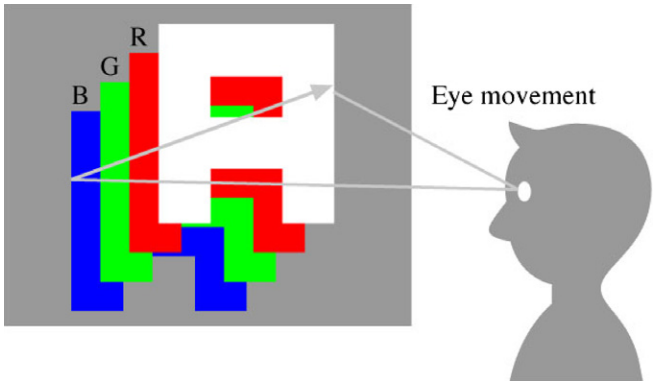

Fig. 2. An image showing colour breakup.

breakup. The symptoms of the asthenopia were classified into a lot of items due to the factor and symptom. Many researchers in Japan use questionnaires of 37 subjective symptoms referring to the list of symptoms of visual fatigue. However, it covers a wide range of symptoms including visual fatigue symptoms directly unrelated to colour breakup. Moreover, the characteristics of the projection methods are difficult to determine. Movies and similar form of content are too complex to evaluate subjectively using a questionnaire. Therefore, we measured the symptoms of asthenopia using a simple field-sequential colour stimulus and extracted notable symptoms from observers experiencing colour breakup. We compared the field-sequential colour projection system and LCD projection system. We also used a DLP projector from which the colour filter wheel had been removed in order to avoid any influence from the projection system itself.

2.2. Methods

Three types of projectors were used in the experiment: a field-sequential colour projector (colour DLP), a field-sequential monochrome projector (monochrome DLP), and a liquid crystal projector (LCD projector). Colour DLP created the image by rotating colour wheels at 2× speed. And the resolution of the projected image was XGA (iLC300, IBM). Monochrome DLP was also used a DLP projector from which the colour filter wheel had been removed for the experiment. Monochrome DLP was functionally the same as colour DLP except for no colour breakup. LCD projector was selected a similar projector functional (EMP-74, EPSON). This projector used three individuals LCD panels to produce images, so there was no colour breakup.

The stimulus was the same for all three projectors: an image that generated significant colour breakup when projected using a colour DLP projector. The projectors were selected in random order and the stimulus was projected for 10 min. The visual targets were three geometric figures: a square, a circle, and a triangle. These were alternately presented in random order to the right and left sides of the screen at 5-s intervals, causing the eyes of the subjects to move horizontally every 5 s to view a new figure. In order to ensure that subjects paid full attention to the visual targets during image presentation, they were required to click a hand-held button whenever the circle appeared (Fig. 3). The projectors were used in random order and each projected the image for 10 min at a time.

The stimuli were presented on a 100-in. screen that had been adjusted so that its center point corresponded to the height of the observer's eyes. The observers were seated in a chair placed directly in front of the screen at a viewing distance of 250 cm. Asthenopic complaints were evaluated using Suzumura's 37 subjective symptoms of asthenopia [7]. The subjective symptoms of asthenopia were rated before and immediately after viewing the image using a 5-point self-rating method. The five stages were: (1) no symptoms; (2) mild; (3) fair; (4) strong; and (5) severe. The observers rested for 10 min after viewing each stimulus.

The observers were eight university students (five males and three females). All were in good health and had normal or corrected vision (by self-report), and had normal colour vision as assessed by Ishihara's tests for colour deficiency [8]. The average and the standard deviation of the subjects' age was 26.37 ± 5.31 years old.

2.3. Results

Each subjective symptom was rated before each viewing in order to establish a baseline rating. After each viewing, the subjective symptoms were again rated, and the difference between the two ratings was used to calculate the change. Results of each experiment are shown in Table 1. The score represents changes in factor scores and the higher the score, the worse the symptoms. For five subjective symptoms – Eye fatigue, Eye oppression, Eye pain, Eye heaviness, and Sensitivity to bright light – the colour DLP projector produced larger rates of change than the other two projectors (Fig. 4).