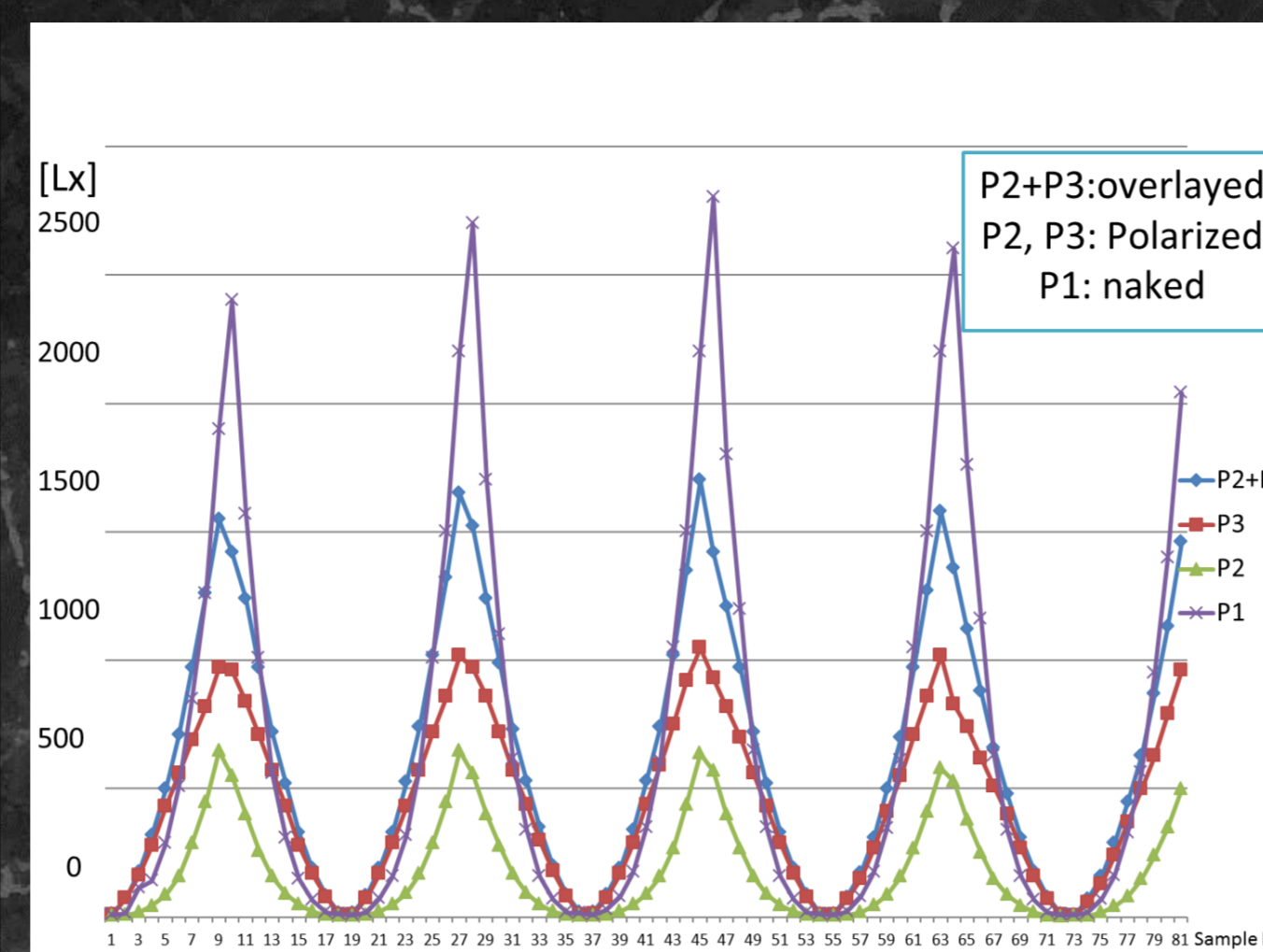
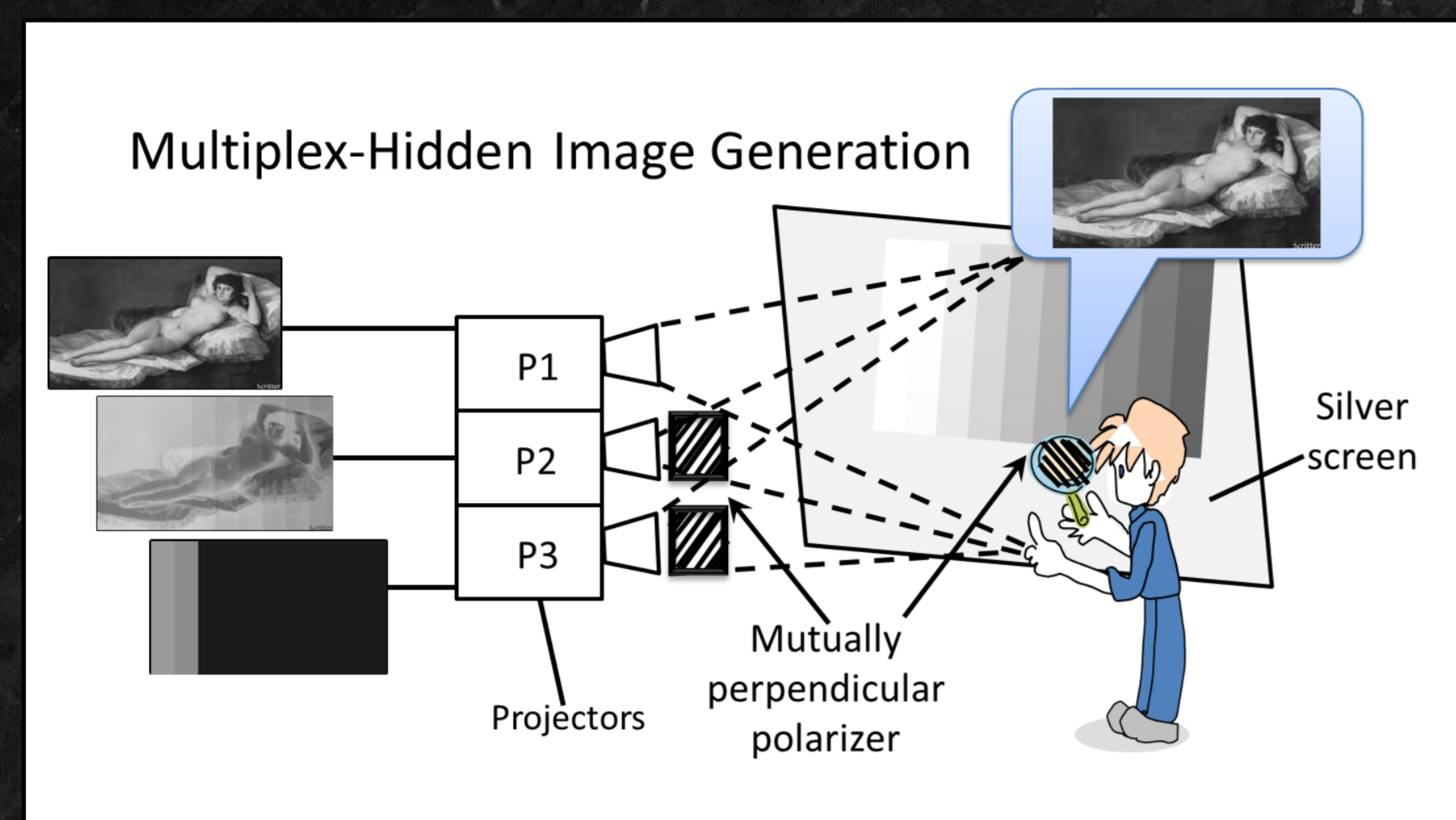
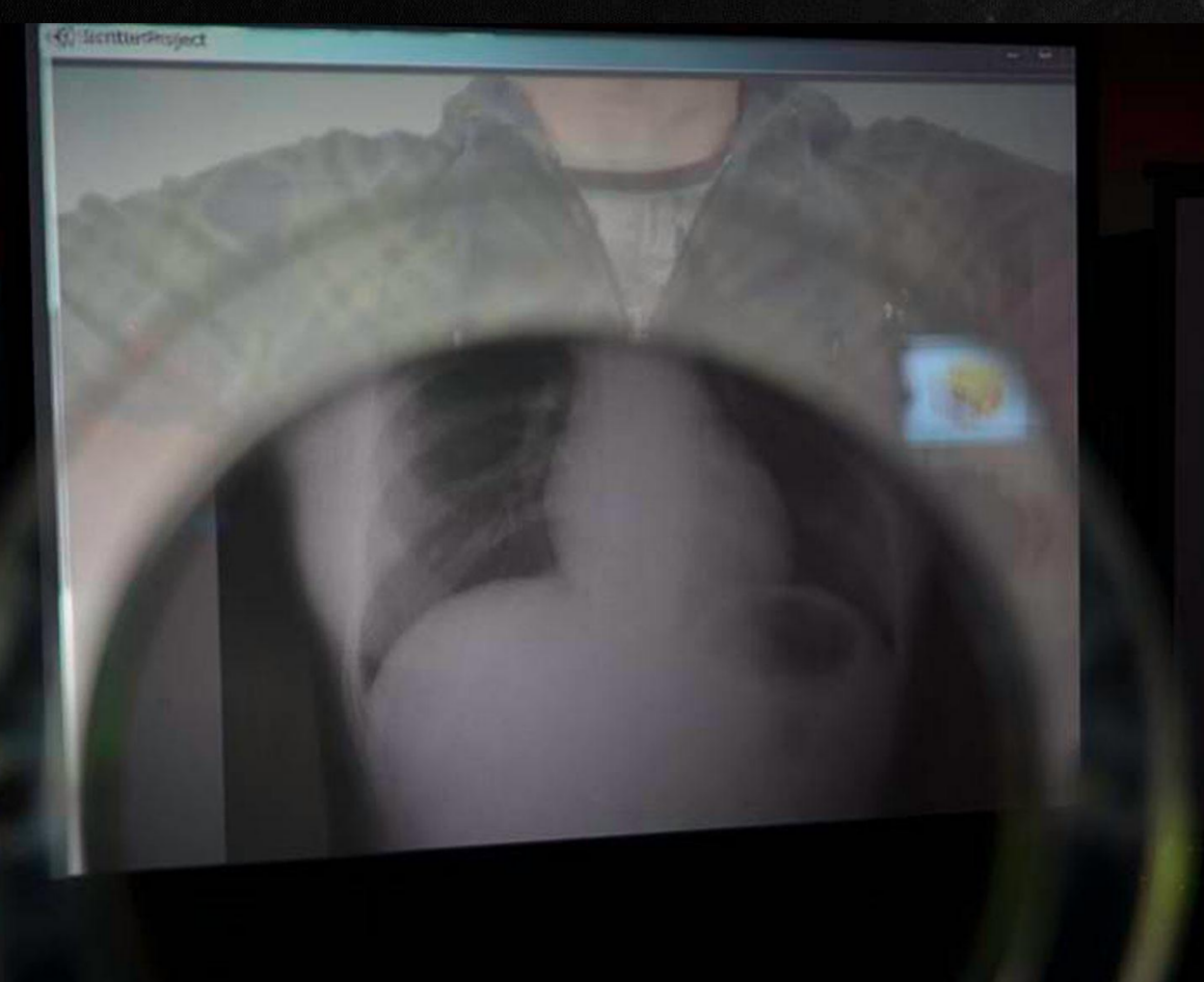


ScritterHDR: Multiplex-Hidden Imaging on High Dynamic Range Projection



(a) A multiplex-hidden image

(b) Example of system overview

(c) Measured illuminance from three projectors

Figure 1: (a) The image of the body is visible with the naked eye. The image of the skeleton, invisible with the naked eye, is visible through polarizers. (c) The same grayscale chart is projected from projectors P1, P2 and P3. The purple line illustrates the illuminance of the normal projection P1. The green line and the red line illustrate the illuminance of P2 and P3. The blue line illustrates the illuminance of P2 and P3 combined.

1. Motivation: Multiplex-Hidden Imagery

We propose a system that enables the display of multiplex-hidden images for selected users with highly accessible polarizing filters. This system requires no electronic devices for users. It is designed with high dynamic range (HDR) projection technology and realizes the display of multiplexed content with HDR. Recently, research into HDR projection technology has made a lot of progress. Such HDR technology can realize digital cinemas with high quality and clear visibility of digital content even in daylight. Thus, we expect the system to extend the expression of digital content and to be applicable to future cinemas, digital signage and virtual environments.

2. Image Hiding Algorithm

We have developed an image hiding algorithm in [Koki, N. and N.] allowing the system to display a secret image for certain users while displaying another image for others. While an image is visible with the naked eye, a hidden image is only visible through polarizing glasses. The image hiding technique with active shutter glasses proposed by [McDowall et al. 2004] and [Mistry 2009] can realize multiple channels at the same time for different users, but the complexity of the electronic device degrades the quality of images (e.g. brightness, color management). On the other hand, with our technique, the available contents are easily switchable by putting on and taking off simple polarizing filters (Fig.1-(a)).

In our hiding technique, we divide the available range of pixel values into two using the formulas below to generate a multiplex-hidden image.

$$a' = a \cdot \frac{255 - b_{max}}{255} + b_{max}, \quad b' = b \cdot \frac{b_{max}}{255}, \quad c = a' - b'$$

$$(b_{max} \leq a' \leq 255, \quad 0 \leq b' \leq b_{max})$$

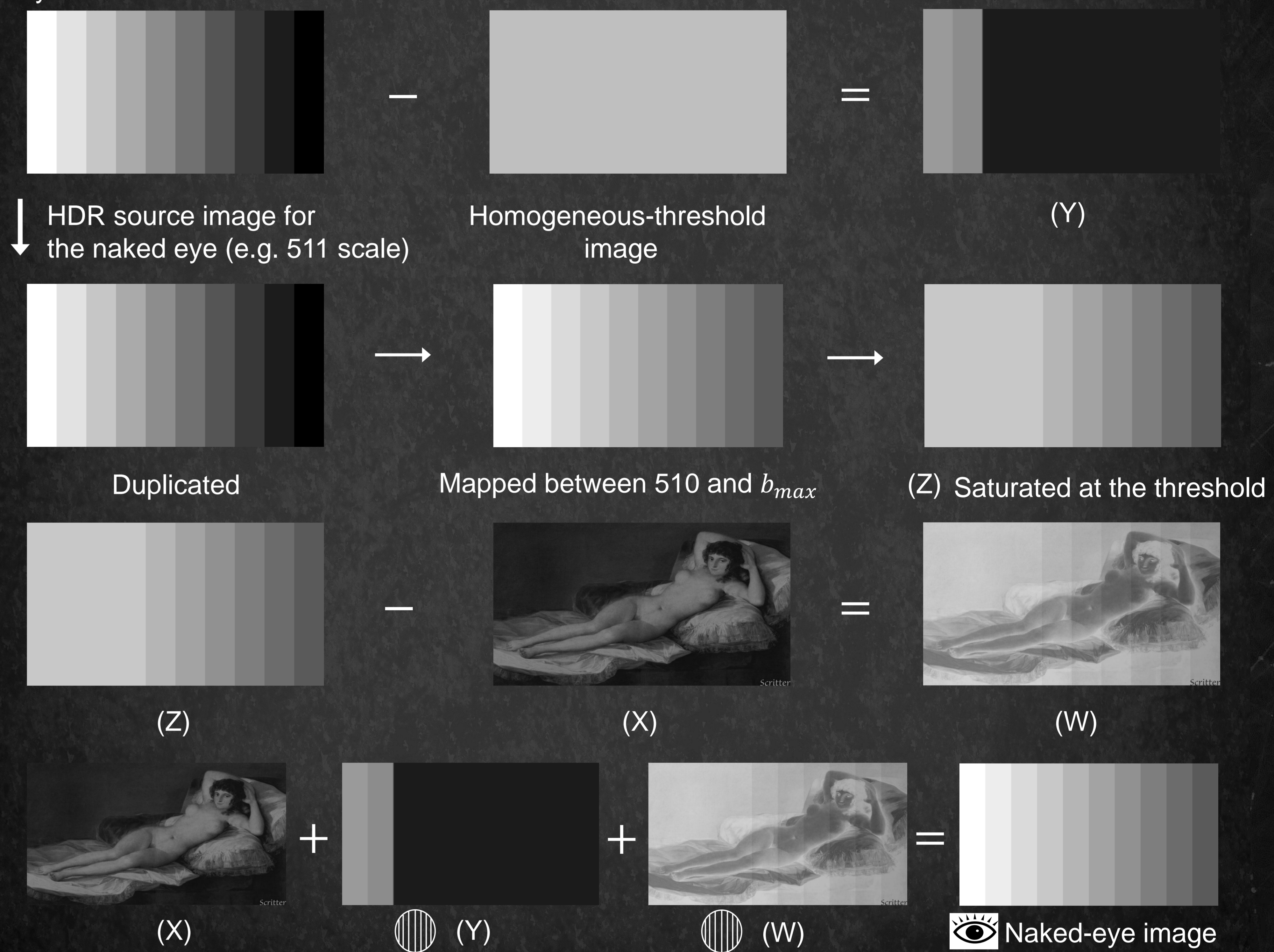
Where a and b are arbitrary pixel values of a naked-eye image and a hidden image respectively. a' and b' denote processed values. b_{max} is the maximum pixel value of the hidden image (as well as the minimum pixel value of the naked-eye image), which can be set to any value from 1 to 255 depending on the content. Superimposing b' and c generates a naked pixel a . A hidden pixel b' is available by canceling c with polarizers (Fig.1-(a)). However the hiding algorithm sacrifices contrast for the sake of displaying multiple channels, so the extent of expression is limited. To improve the potential quality of the projections, we propose a method for displaying multiplex-hidden images using a HDR technique with multiple projectors.

3. Multi-Projection HDR

The HDR projection technique with multiple low dynamic range (LDR) projectors was proposed by [Michimi, I. and H.]. Using a similar, but more simplified technique, we have confirmed the feasibility of HDR projection using three LDR projectors (BenQ model MP515 DLP). In an experiment, we superimposed the same grayscale chart from these projectors onto a silver screen (Fig.1- (b)). We utilized a lux meter to measure the illuminance of each projection on the screen (Fig. 1-(c)). From the results we see high dynamic range is realized with the combination of the two projectors $P2$ and $P3$.

4. Multiplex-Hidden Image Generation Pipeline

An example pipeline for generating a multiplex-hidden image with three LDR projectors is shown here. The LDR (255 scale) image of naked Maja is hidden. The grayscale chart is for the naked eye.



5. Applications

In this article, we proposed a method to improve the quality of content displayed by using a HDR technique with multiple projectors. Our image hiding algorithm realizes the display of multiplexed content that is interchangeable by putting on and taking off the polarizing glasses. This technique can be applied to using multiple subtitles and closed captions in digital cinemas; digital signage; presentation prompts; medical-use displays etc.

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