Picture Illusion by Overlap

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1 Introduction

Picture Illusion by Overlap is a method to hide a color image (called *target*) into two different color images (called *sheets*) in such a way that the target is observed without any calculation when the two sheets are printed onto slides and stacked together. The proposed system takes three input color images, i.e., one target source image and two sheet source images, and generates two sheets. By stacking these two sheets together, the viewer achieves the target image, as illustrated in Figure 1. The intended applications of this method lie in a wide variety of field such as entertainment, printing and publishing, advertisement, artistic venues, etc. One closely related research field of this is visual secret sharing[Naor and Shamir 1995; Nakajima and Yamaguchi 2004]. It discusses how to encode a message into multiple slides such that when a legitimate combination of slides are stacked together, the message can be viewed with no decoding calculations while no illegitimate combinations can yield the hidden information. Since our intended applications are more focused on entertainment rather than security, our research differs from visual secret sharing in the following sense. In our method, preserving color for both sheet and target as much as possible is very important, while in visual secret sharing, the first priority is the security of the hidden message. In other words, our image hiding scheme is not secure. You may guess the pixel colors of the target by carefully analyzing a sheet.

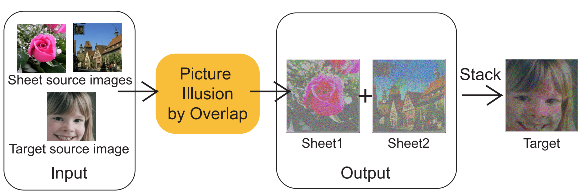


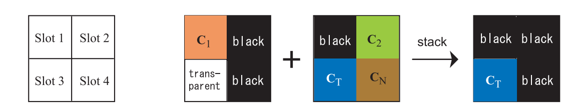
Figure 1: The basic idea of the proposed system.

2 Image hiding scheme

Each of the two sheets are referred as sheet 1 and sheet 2 when we need to identify them. We assume the sizes of the three input images to be the same. The resulting sheets are modified version of the sheet source images and their widths and heights are twice as large as the input images. By overlapping the two sheets and viewing them, a viewer observes a modified version of the target source image, whose contrast shrunk to $\frac{1}{4}$. The image hiding is a pixelwise procedure using masks and *neutralizing colors* as follows. Each pixel of the two sheet images consists of four subpixels as shown in Figure 2, and each subpixel location within a pixel is referred as a "slot." The first slot in sheet 1 is filled with the color of sheet 1 source image, $\mathbf{C}_1$. Slot two is black. For slot three and four, transparent and black subpixels are assigned. The first slot in sheet 2 pixel is set to black. The second slot is set to the color of sheet 2 source image, $\mathbf{C}_2$. The color of target source image, $\mathbf{C}_T$, is set to the third slot and for the fourth slot, the neutralizing color $\mathbf{C}_N$ of $\mathbf{C}_T$ is assigned, which we describe in detail later. Therefore, when the two sheets are stacked together, the colored slots are masked by the other sheet except for one with target color, $\mathbf{C}_T$, and the result is three black and one target color subpixels, as shown in Figure 2 (d). The pairs of third and fourth slots of sheet 1 and sheet 2 are interchangeable, and all slots can be shuffled within a pixel as long as the correspondence between sheet 1 and 2 is preserved. The colors of sheet 1 and sheet 2 source images can be just copied into the corresponding slots regardless of the source images' colorspace. A neutralizing color $\mathbf{C}_N$, however, is an output-device-dependent color which cancels the target color $\mathbf{C}_T$, in order to avoid viewers' attention to the target information within the sheets. We choose the neutralizing color that produces 50% gray by additive color mixing with the target color. We used the CIE-XYZ linear colorspace to calculate neutralizing colors, and the information of the printer color gamut is achieved by experiments using a spectrophotometer.

Within a printer color gamut, a neutralizing color $\mathbf{C}_N$ is chosen so that the midpoint of $\mathbf{C}_T$ and $\mathbf{C}_N$ coincides with the midpoint of black and white. If $\mathbf{C}_N$ happens to lie outside of the gamut, we modify the saturation value of $\mathbf{C}_T$ so that both $\mathbf{C}_T$ and $\mathbf{C}_N$ are within the gamut. In this way, the neutralizing color can negate the effect of target color within a sheet. Our experiment confirmed that the target can be revealed successfully by stacking the two sheets, printed by an ordinary ink-jet printer.

However, the calculation of neutralizing color can be improved further. The color negation method may be effective enough to distract viewers from the target information from a sheet. However, $\mathbf{C}_T$ and $\mathbf{C}_N$ do not achieve a stable 50% gray throughout the images, since the perception of color is strongly dependent of the viewing conditions and environments.



(a) Subpixel slots (b) Sheet 1 (c) Sheet 2 (d) Resulting target

Figure 2: An example of a pixel construction.

3 Conclusion

We developed a method to hide a color target into two different sheets using masks and neutralizing colors. The resulting output confirms the promise of the idea, but more work and experiments should be done especially with refining the concept of neutralizing color and its calculation method. Further, the overall image quality of both sheets and target should be enhanced.

References

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