Towards a Design Guideline of Visual Cryptography on Stereoscopic Displays

Shih-Lung Tsai[1] and Chao-Hua Wen[2]

[1] Chunghwa Picture Tubes LTD., Taoyuan, 334, Taiwan
Tsaihsl@mail.cptt.com.tw
[2] Graduate Institute of Color and Illumination Technology,
National Taiwan University of Science and Technology, Taipei, 10607, Taiwan
chwen@mail.ntust.edu.tw

Abstract. This paper proposed a new visual cryptography scheme with the stereoscopic display which showed and accurately decrypted the hidden information for gray images. Results indicated that contrast ratio and pixel disparity of the decrypted stereo-image were key problems that would impact on the perceived quality of the decrypted image. Next, this research performed a subjective experiment of shifting pixels between both of left and right images to investigate the disparity effects of decrypted information on a full HD stereo-display with film-pattern-retarder technology. In addition, the effects of font size and contrast ratio were addressed as well. Results revealed that the thresholds of pixel disparity were between 2 and 7 pixels. To alphabets, the font size of 50 points was lower boundary to show the decrypted information. To numeric, the font size of 45 points was lower boundary over different contrast ratios.

Keywords: Visual cryptography, Stereoscopic display, Design guideline.

1 Introduction

With the advanced development of science and network technologies, multimedia information is usually delivered over the Internet conveniently. While using secure images, the importance of secure issues cannot be overemphasized because hackers can easy to steal secure information which they need in the Internet. Two popular studies are considered, in general, information hiding is categorized in Watermarking and secure sharing as Visual Cryptography (VC).

Visual Cryptography was proposed firstly by Naor and Shamir [1]. Information of an original image is separated to two or more images. And people just only stacked all encrypted images to decrypt information of original image with Human Visual System. In order to improve the quality of decrypted image, there are many algorithms have been developed to improve the encryption for gray or color images. There are various measures on the performance of many kinds of VC schemes, but rare studies on exact stereo-reproduction in visual cryptography. This study provided a method to

M. Kurosu (Ed.): Human-Computer Interaction, Part III, HCII 2013, LNCS 8006, pp. 78–84, 2013.

amend VC of encryption side and decryption side. Through a series of experiments, visibility requirements of the decrypted information were addressed.

2 Method

Noar and Shamir proposed the (k, n) threshold scheme or k out of n threshold scheme which illustrated a new paradigm in image sharing [1]. In this scheme a secrete image is divided into n share images. With any k of the n shares the secret can be perfectly reconstructed, while even complete knowledge of (k-1) shares reveals no information about the secret image.

This research is expected to answer two questions, 1) what is reasonable disparity in pixels for the decrypted secure image with wearing 3D glasses and 2) what is the limited viewing condition to avert data revealing without wearing 3D glasses. Following sections will describe the basic VC scheme, stereoscopic visual cryptography for gray images and experimental design.

2.1 Basic VC Scheme for Binary Images

The (2, 2) VCS is illustrated to introduce the basic concepts of threshold visual secret sharing schemes as shown in Fig. 1. During the encryption, every secret pixel is split into two shares, and each share belongs to the corresponding share image. For instance, a secret white pixel, the dealer randomly chooses one of the first two rows of Fig. 1 to encode Share1 and Share2. The possibilities of the two encoding cases are equally likely to occur independently whether the original pixel is black or white. Thus, neither Share1 nor Share2 exposes any clue about the binary color of pixel. In the decryption, the two corresponding shares are stacked together, using OR/AND, to recover the secret pixel. Two shares of a white pixel are of the same while those of a black pixel are complementary. Consequently a white pixel is recovered by a share with the stacked result of half white sub-pixels and a black pixel is recovered by all black. Using this basic scheme, the contrast ratio of the decrypted image is reduced results from halving intensity of the white secret pixels.

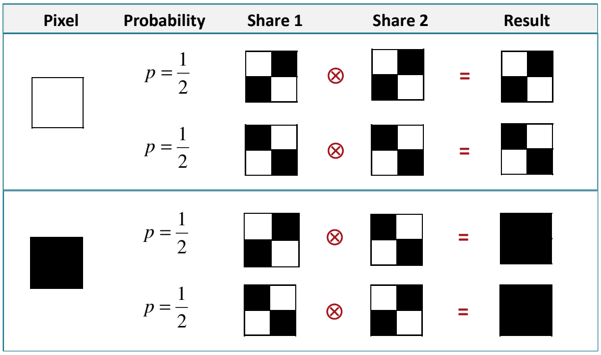


Fig. 1. Encoding scheme for a binary pixel into two shares

2.2 Stereoscopic Visual Cryptography for Gray Images

First we used error diffusion to decompose the gray-scale secret image. And then the halftoning resultant image was processed by the encryption of a basic visual cryptography scheme [2-3]. A 23” LG® D2342P monitor with TriDef® 3D supports was used in this study, the odd rows display the left view and the even rows display the right view in 3D mode. Therefore, it is necessary to rearrange the two encryption share images to match the display format as decrypting the secret images. The VC algorithm for side-by-side file format of stereo polarized displays is described as follows.

Encryption and decryption. Here uses an example of a full HD binary image (1920×1080) to simplify the encryption procedure. First step is to down scale the input binary image. Quarter down-scaling is performed in horizontal direction, e.g., 1920×1080 pixels to 480×1080 pixels. Second is to create the encrypted shares. Based on the basic binary VC, we apply diagonal shares to build a pair of Share1 and Share2. Due to the basic VC scheme, the image size of the Share1 and Share2 are extend to double in horizontal and vertical direction, e.g., 960×2160. After then, we take out the odd row of Share1 and Share2. Third is to rearrange the configuration of Share2. It found that the monitor with TriDef® 3D deals with the odd rows of Share1 to the left eye and the even rows of Share2 to the right eye. For next stage of decryption, it is necessary to switch Share2’s the first row to the second row, the third row to the fourth row, and so forth. Fourth is to combine both share images (960×1080) into a full HD encrypted image with side by side format, Share1 is on left side and Share2 is on right side. Fig. 2 illustrates the framework of the stereo visual cryptography scheme for stereoscopic displays in this article. In decryption stage, the encrypted side-by-side image can directly be played on the monitor in 3D mode, and then the secret image can be decrypted clearly without wear glasses. Fig. 3(a)-(c) shows an original secret image, an encrypted side-by-side image and a simulated resultant by our stereoscopic visual cryptography scheme respectively.

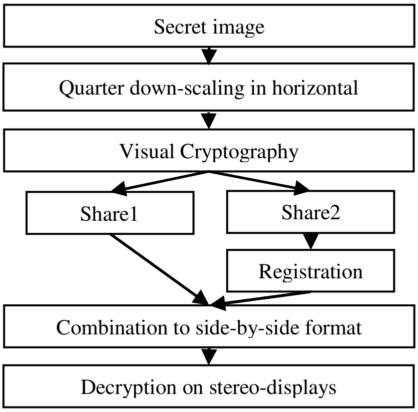
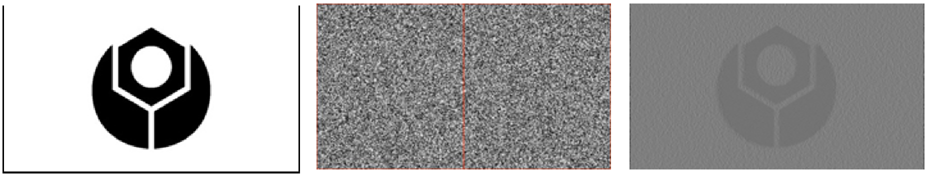

Secret image
Quarter down-scaling in horizontal
Visual Cryptography
Share1
Share2
Registration
Combination to side-by-side format
Decryption on stereo-displays

Fig. 2. Framework of the stereo visual cryptography scheme for stereoscopic displays



(a) secret image

(b) two encryption shares (Left/Right format)

(c) simulated decryption 3D image

Fig. 3. An example of stereoscopic visual cryptography

Changing disparity (pixel shift). For changing disparity, we just move pixels in horizontal of each share with same shift but opposite directions. It is known of increasing disparity can enhance depth perception cues. That is the main reason of decrypted secure image with wear 3D glasses and limited viewing condition to avert data revealing. In this works, it is interesting about how many amount of disparity is a suitable setting for VC. This study investigated six different shift pixels on disparity, such as 0, 4, 8, 16, 24 and 32 pixels. For example, Share1 (left image) is shifted sixteen pixels on the right and Share2 (right image) is shifted sixteen pixels on the left, so the total disparity is thirty-two pixels for side by side image. As the same way, we can finish six disparities for encryption side.

Minimum contrast ratio for binary VC. In this article, we define contrast ratio using Michelson contrast according to the measurements during display profile creation via Eye One Pro by X-Rite®. The Michelson contrast is commonly used for patterns where both bright and dark features are equivalent and take up similar fractions of the area. The Michelson contrast ratio CR is defined as Equation (1),

$$CR = (I_{\max} - I_{\min})/(I_{\max} + I_{\min}) \tag{1}$$

Here I_{max} and I_{min} representing the highest and dark luminance. The denominator represents twice the average of the luminance. The luminance of white pixel and black pixel were obtained from the color profile. The gamma values of red, green, blue were 2.11, 2.25 and 2.28 respectively. In this article, there are five contrast ratios with gray level are investigated, including 100% (I_{max} = 1; I_{min} = 0), 98% (I_{max} = 0.791; I_{min} = 0.006), 91% (I_{max} = 0.609; I_{min} = 0.028), 73% (I_{max} = 0.452; I_{min} = 0.0691), and 42% (I_{max} = 0.321; I_{min} = 0.13).

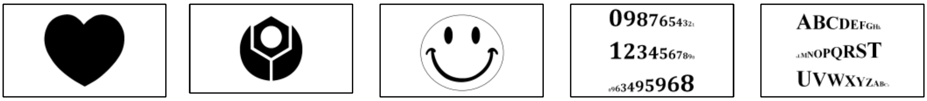
2.3 Experimental Design

Participants. Seven male and six female students between 22 and 26 years of age in National Taiwan University of Science and Technology were participated in the experiment. All of them had a normal or corrected to normal visual acuity and passed the stereopsis test according to RANDOT® Stereotests.

Stimuli. Five contents (1920 x 1080 pixels) included three logo icons, a series of Cambria numbers with varied sizes range from 20 to 110 points, and a series of Times New Roman alphabets with varied sizes range from 100 points to 10 points as shown in Fig. 4. At decryption stage, this study investigated six different shift pixels of disparity, such as 0, 4, 8, 16, 24 and 32 pixels. We used Michelson contrast ratio according to the measurements as making the display profile. There were five levels of contrast ratio 100%, 98%, 91%, 73% and 42% respectively. Therefore, there were a total of 150 secret images as visual stimuli in this article.

Experimental task and procedure. The experimental task was a visual detection task. The ambient condition is about average 700 lux. Viewing distance was 50 cm to 70 cm from the display dependent on observer's comfortable viewing position. This study asked participant to watch the contents started from disparity 0 to 32 pixels in five levels of different contrasts from 42% to 100%, then to answer whether perceive the depth clearly or not. At the beginning of the experiment visual acuity and stereopsis were assessed. The experimental procedures are listed as follows.

1. To adjust the monitor set and posture to allow view images at the optimal viewing angle as comfortable as possible;
2. To show a series of a kind of a stimuli on the stereodisplay began to perceive disparity can ascent from 0 pixels to 32 pixels until the subjects do not perceive depth of the original image;
3. To show contents began to perceive disparity can descent 32 pixels to 0 pixels until the subjects can perceive depth of the original image;
4. To record the disparity value, disparity range and calculate the threshold of disparity by font size and contrast ratio;
5. After each stimulus content, a short break could be taken in which the experimenter changed the condition and prepared the experimental software and displays for the next steps. All experimental lasted approximately 90 min.



Heart icon NTUST logo Smile icon Numbers Alphabet

Fig. 4. Five stimulus contents

3 Results and Discussion

In the following sections, the results about disparity threshold and contrast threshold for 5 contents will be presented, followed by the discussion of relationships between CR and font size.

3.1 Disparity Threshold and Contrast Threshold

Here demonstrates the results of disparity threshold which is the acceptable level or range for applications of stereoscopic visual cryptography. Cormack et al. used a random-dot stereogram and found a cube-root dependency of stereoacuity on contrast at superathreshold levels of contrast [4]. And the difference is probably due to the different spatial-frequency content of the stimuli used in the experiment. Therefore, this study reexamined and also found the disparity threshold was an important comparison among different types of content and contrast.

Fig. 5 depicts the relationship between contrast ratio and disparity threshold. Results revealed that the highest disparity threshold was occurred between CR 91% and 98% and the lowest disparity threshold occurred at CR 42%. Additionally, we confidently concluded that disparity threshold range between 2 and 7 pixels over different contrast ratio. Due to shift two pixels with Share1 and Share2, we cannot see any information on the stereo-display without glasses. Therefore, we need to take out disparity threshold two pixels downward. Fig. 6 illustrates the relationships between different contents and disparity threshold. In evidence, here is the highest disparity threshold in the smile image and the lowest disparity threshold in the Alphabet and Numbers image.

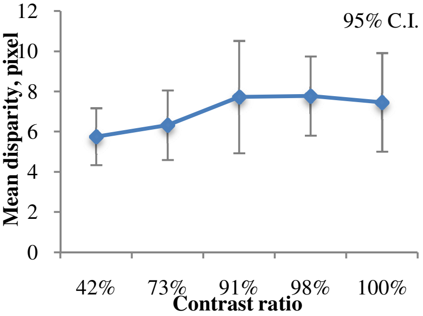


Fig. 5. Plot of the mean disparity threshold as a function of the contrast ratio

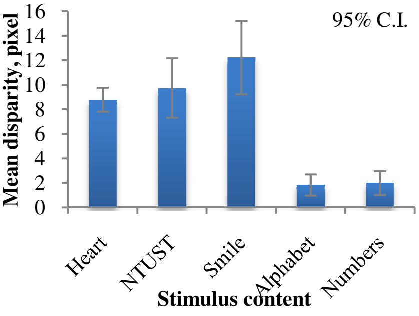


Fig. 6. Mean disparity pixel for 5 stimuli contents

3.2 Relationship between Contrast Ratio and Font Size

Fig. 7 reveals the relationship between font size and contrast ratio in the alphabet size and number character. The alphabet size is blue line with diamond marks; here is the highest font in the 91% contrast ratio and the lowest font in the 100% contrast ratio. The number character is red line with square marks; here is the highest font in the 91% contrast ratio and the lowest font in the 100% contrast ratio.

This experiment tried to find out the disparity threshold of contrast ratio for different content. Results indicated that disparity threshold range is between 2 and 7 pixels over different contrast ratios. For the minimum requirement of alphabet size for decryption, the font size is 50 points upward (visual angle is about 0.95 degree) in the different contrast ratio. For number characters, the font size is 45 points upward (visual angle is around 0.85 degree) in the different contrast ratio.

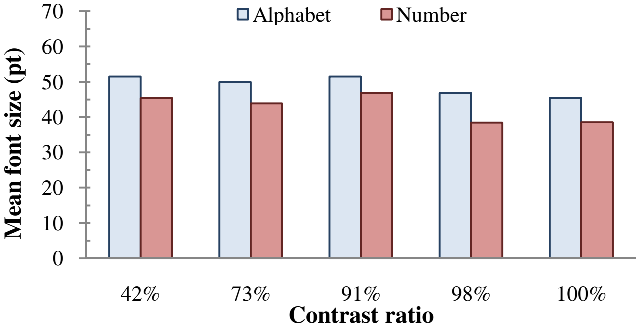


Fig. 7. Mean font size (pt) for different contrast ratio

4 Conclusions

This study proposed a new visual cryptography scheme with the stereo polarized display which can rendering decrypted stereo gray images accurately. For stereo secret images, this method only uses two encryption share images and the decryption can be performed via a side-by-side file format of 3D displays.

Hereby the future works are summarized as follows. First, it is obvious that a lot of time and effort have been dedicated to visual secret sharing using visual cryptography. The trends have been identified within visual cryptography [5]: contrast improvement, share size improvement, wider range of suitable image types, efficiency of VC schemes, ability to share multiple secrets. Finally, because emerging 3D TV, it needs more research on how to use different stereoscopic display with optimal disparity to control suitable and comfortable content protruding.

References

1. Naor, M., Shamir, A.: Visual cryptography. In: De Santis, A. (ed.) EUROCRYPT 1994. LNCS, vol. 950, pp. 1–12. Springer, Heidelberg (1995)
2. Lin, C.C., Tsai, W.H.: Visual cryptography for gray-level images by dithering techniques. Pattern Recognition Letters 24(3), 349–358 (2003)
3. Wen, C.H.: Visual Cryptography on Color Video Displays. In: The 17th International Display Workshop, Fukuoka, Japan, pp. 2105–2108 (2010)
4. Cormack, L.K., Stevenson, S.B., Schor, C.M.: Interocular correlation, luminance contrast and cyclopean processing. Vision Research 31, 2195–2207 (1991)
5. Weir, J., Yan, W.Q.: A comprehensive study of visual cryptography. Springer Transactions on DHMMS 5, 1–10 (2010)