Chapter 7
Watermark Embedding for Multiscale Error Diffused Halftone Images by Adopting Visual Cryptography

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ABSTRACT

Error Diffusion has been widely adopted in the printing industry due to its good visual quality and simple implementation. However, error diffusion still possesses its own deficiencies. Thus multiscale error diffusion (MED) has been developed, and this method outperforms traditional error diffusion according to extensive research results. The majority of previous halftone image watermarking techniques cannot be directly applied to MED halftone images. Since there is no halftone visual watermarking (HVW) method for MED halftone images in existing methods, we propose the first HVW method for MED halftone images, Copyright Protecting Multiscale Error Diffusion (CoP-MED), in this paper. By adopting the visual cryptography principle, CoP-MED can effectively embed a secret pattern into two MED halftone images, where the secret pattern can be decoded clearly by simply overlaying the two stego halftone images or performing not-exclusive-or operation between them. Parameter selection is also discussed based on the experimental results. Later, in comparison tests, CoP-MED shows superior performance compared to existing works.

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1. INTRODUCTION

Nowadays, printed multimedia content, such as newspapers, magazines, books, etc., is still serving as an important aspect of people's daily lives. With the massive usage of printed content, illegal distribution of such content has become an important issue. To protect printed content, halftone image watermarking has been developing rapidly over the past few decades.

A printed image, for which people usually employ the name 'halftone image' as the formal representation, is different from a normal digital image because a halftone image (greyscale) is 1-bit per pixel; i.e., it only possesses two colors, black and white. With only two colors per pixel, a halftone image can still visually resemble the original image (greyscale) when being perceived from a certain distance. Note that a color halftone image works similarly to a grayscale halftone image. The generating process of a halftone image is called the halftoning process, such as ordered dithering (Bayers, 1973), error diffusion (Floyd & Steinberg, 1976; Jarvis, Judice & Ninke, 1976), dot diffusion (Knuth, 1987; Mese & Vaidyanathan, 2000; Guo & Liu, 2009) and direct binary search (Goyal, Gupta, Staelin, Fischer, Shacham & Allebach, 2013; Kim & Allebach, 2002).

An ordinary watermarking technique such as Least Significant Bit (LSB) Embedding (Moulin & Koetter, 2005) cannot be directly applied to halftone images because of its 1-bit property. From the 1990s, halftone image watermarking technologies have been investigated by researchers. Usually, halftone image watermarking techniques can be classified into two classes. Class 1 techniques embed a secret bitstream into single or several halftone images, where the secret bitstream can only be decoded by carrying out certain decoding algorithms (Fu & Au, 2000; Fu & Au, 2001; Fu & Au, 2002; Guo & Liu, 2011; Pei & Guo, 2006). Class 1 techniques are also being considered as data hiding techniques for halftone images. Class 2 techniques embed a secret pattern (watermark) into halftone images (usually two), such that when the halftone images are overlaid or not-exclusive-or (XNOR) operation is carried out between them, the secret pattern will be visually decoded (Chang, Chan & Tai, 2006; Fu & Au, 2003; Guo, Au, Fang & Tang, 2011; Guo, Au, Fang, Tang & Yu, 2011; Guo, Au, Tang, Pang, Sun, Xu, Li & Zhang, 2013; Guo, Au, Tang & Pang, 2014; Guo & Tsai, 2011; Pei & Guo, 2003), and halftone visual watermarking (HVW) is employed to represent Class 2 techniques in this paper.

When developing HVW techniques, some initial ideas were borrowed from visual cryptography (VC) (Naor & Shamir, 1994), as shown in Figure 1. With the HVW principle, some HVW methods (Fu & Au, 2001; Fu & Au, 2003; Guo & Tsai, 2011; Pei & Guo, 2003) will only make amendments in one halftone image, while generating the other halftone image with the regular halftoning process. Other HVW methods (Chang, Chan & Tai, 2006; Guo, Au, Fang & Tang, 2011; Guo, Au, Fang, Tang & Yu, 2011; Guo, Au, Tang, Pang, Sun, Xu, Li & Zhang, 2013; Guo, Au, Tang & Pang, 2014) will make amendments in both halftone images.

As time went on, researchers of VC were also inspired by HVW, such as generating meaningful halftone shares instead of traditional noise-like shares (Liu & Wu, 2011; Wang, Arce & Crescenzo, 2009; Yang, Yang, Chen & Ye, 2008; Zhou, Arce & Crescenzo, 2006), using random-grid VC to eliminate the pixel expansion problem (Chen & Tsao, 2011; Hou, Wei & Lin, 2014; Lee, Wang & Chen, 2013; Wu & Sun, 2013), developing XOR-based VC schemes (Tuyls, Hollmann, Van Lint & Tolhuizen, 2005; Wu & Sun, 2014; Yang & Wang, 2014) and developing VC schemes which generate color shares (InKoo, Arce & Lee, 2011; Liu, Chen & Zhang, 2013; Liu, Wu & Lin, 2008; Wu, Wang & Yu, 2008; Wu, Wong & Li, 2010). After years of development, HVW and VC seem similar, but they are still distinguishable, with different origins. In this paper, we will focus on HVW methods rather than pure VC techniques.