Chapter XVIII
Image Watermarking Algorithms Based on the Discrete Wavelet Transform

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ABSTRACT

In the last decade, many digital image watermarking algorithms have been proposed and implemented; however, algorithms based on the discrete wavelet transform (DWT) have been widely recognized to be more prevalent than the others. This is due to the wavelets' excellent spatial localization, frequency spread, and multiresolution characteristics, which are similar to the theoretical models of the human visual system. In this chapter, we describe three DWT-based digital image watermarking algorithms. The first algorithm watermarks a given image in the DWT domain, while the second and third algorithms improve the basic algorithm by combining DWT with two powerful transforms. The second algorithm is a hybrid algorithm in which DWT and the discrete cosine transform (DCT) are combined. The third algorithm is also a hybrid algorithm in which DWT and the singular value decomposition transform (SVD) are combined. Performance evaluation results show that combining DWT with DCT or SVD improved the imperceptibility and robustness performance of the basic DWT-based digital watermarking algorithm. Finally, the ideas described in the chapter can be easily extended to watermarking multimedia objects that include audio and video data contents.

INTRODUCTION

Advancements in digital image processing and computer networks have considerably facilitated the acquisition, representation, storage, and distribution of images in digital format. These advancements, however, made the unauthorized manipulation and reproduction of original digital images an easy pro-

cess. Consequently, the design and development of effective digital image copyright protection methods have become necessary. Traditional image security methods include encryption, authentication, and time stamping (Furht & Kirovski, 2006). However, the emerging digital watermarking technology has been recently advocated as the best solution to the multimedia copyright protection problem (Cox, Miller & Bloom, 2002; Katzenbeisser & Petitcolas, 2000; Langelaar, Setyawan & Lagendijk, 2000; Potdar, Han & Chang, 2005). It is expected that digital watermarking will have a wide-span of practical applications such as digital cameras, digital libraries, medical imaging, image databases, surveillance imaging, and video-on-demand systems, among many others (Arnold, Schumucker & Wolthusen, 2003).

Digital image watermarking has been proposed to prevent illegal and malicious copying and distribution of digital images by embedding unnoticeable information (called a watermark) into the image content. The watermark is usually a random number sequence, copyright messages, ownership identifier, or control signal identifying the ownership information. In order for a digital watermark to be effective, it should be robust to common image manipulations like compression, filtering, rotation, scaling cropping, collusion attacks, among many other digital signal processing operations. The watermark should also be imperceptible, which means that the addition of the watermark should not degrade the perceptual quality of the host image. In general, it is not difficult to achieve imperceptibility. Robustness is usually the kernel that decides the success of watermarking algorithms.

Current digital image watermarking techniques can be grouped into two major classes: spatial-domain watermarking techniques and watermarking frequency-domain techniques (Cox et al., 2002). Spatial-domain techniques embed a watermark in a host image by directly modifying its pixels (Chan & Cheng, 2004; Sebe, Domingo-Ferrer & Herrera, 2000). These techniques are easy to implement and require few computational resources; however, they are sensitive to alterations and are not robust against common digital signal processing operations such compression. On the other hand, transform-domain watermarking techniques modify the coefficients of the transformed image according to a predetermined embedding scheme. The scheme disperses the watermark in the spatial domain of the image, hence making it very difficult to remove the embedded watermark. Compared to spatial domain techniques, frequency-domain watermarking techniques proved to be more effective with respect to achieving the imperceptibility and robustness requirements of digital watermarking algorithms (Cox et al., 2002). Commonly used frequency-domain transforms include the Discrete Wavelet Transform (DWT) (Mallat, 1989), the Discrete Cosine Transform (DCT) (Rao & Yip, 1990), and the Discrete Fourier Transform (DFT) (Mitra, 1998).

DWT has been used in digital watermarking more frequently than other transforms. This is due to its excellent spatial localization, frequency spread, and multiresolution characteristics, which are similar to the theoretical models of the human visual system (Vetterli & Kovačević, 1995). By virtue of these properties, an efficient relationship between the transform and coefficients and visual masking properties of the human visual system has been constructed (Wolfang, Podilchuk & Delp, 1999). Effective utilization of this relationship facilitated the development of many imperceptible and robust DWT-based watermarking algorithms. Further performance improvements in DWT-based digital image watermarking algorithms could be obtained by combining DWT with other frequency transforms such as the DCT, or linear algebraic transforms such as the SVD transform (Deprettere, 1988). The idea of applying more than one transform is based on the fact that combining two transforms could compensate for the drawbacks of each other, resulting in effective watermarking techniques.