Chapter 9
A Novel Multilevel DCT Based Reversible Data Hiding

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ABSTRACT

DCT and wavelet based techniques have been widely used in image processing, for example, the applications involving JPEG, MPEG and JPEG2000. To combine the advantages of DCT and wavelet, we introduce in this chapter a novel multilevel DCT decomposition method by exploiting the modified inverse Hilbert curve. The experimental results showed that the proposed multilevel decomposition can extract characteristic DCT coefficients and assign the coefficients to new neighborhoods with distinct frequency properties. We discuss a powerful reversible data hiding algorithm in JPEG images based on this new multilevel DCT. This lossless data hiding algorithm features a key-dependent (multilevel structure) coefficient-extension technique and an embedding location selector, and it can achieve high quality reconstructed images with disparate content types.

1. INTRODUCTION

Discrete Cosine Transform (DCT) and wavelet transform are widely used in image processing such as compression, recognition and information hiding. DCT, a sub-optimal transform, is favorably close to the optimal Karhunen-Loeve Transform (KLT). The popular JPEG image format adopts the DCT as the core transform technique owing to its low computation cost, good decorrelation and energy compaction properties (Rao et al., 1990). In the past decades, another efficient transform, the wavelet transform has been developed to exploit the multi-resolution property in signals. It was then successfully employed in the new image format standard known as JPEG 2000. The applications of DCT and wavelet transform span from signal compression, recognition, feature extraction (Ma et al., 2004; Chen et al., 2006; Jing

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et al., 2004; Guo et al., 2005), information retrieval, to clustering and biometrics (Zhang et al., 2004; Galvão et al., 2004; Kokare et al., 2005). Recently the multilevel DCT decomposition methods have been developed to combine the features of these two transforms. The success of these methods has been demonstrated in the fields of image compression and steganalysis (Xiong et al., 1996; Jeong et al., 1998; Agaian et al., 2005). However, two challenges remain present in multilevel DCT decomposition: firstly, how to efficiently exploit the position information of DCT coefficients, and secondly, how to extend this efficient decomposition to new application areas. In our previous work (Agaian et al., 2005), a template was utilized to rearrange DCT coefficients and to achieve multilevel decomposition. Then it was applied to detect hidden information.

In this chapter, we present a novel multilevel DCT decomposition method that use the modified inverse Hilbert curve (MIHC). A new reversible data hiding algorithm is developed based on this novel decomposition.

The first novelty of the present method is the introduction of the Hilbert curve, which takes position property into account. The Hilbert curve belongs to the family of space-filling curves, which has continuous mapping from a unit interval onto an N-dimensional unit cube where $N < \infty$ (Peano, 1890; Hilbert, 1891).

A Hilbert curve or Hilbert scanning order is considered as a scanning or a one-to-one mapping from a point in 2-dimensional (2D) space to a point in 1D sequence. The most important feature of the Hilbert curve is that it scans the proximate entry in 2D space continuously and then this scanning order preserves the point neighborhood properties (Peano, 1890; Hilbert, 1891;Gotsman et al., 1996).

The Hilbert curve had been applied in the areas of image analysis (Linnainmaa, 1988; Kamata et al., 1993), image compression (Stevens et al., 1983; Kamata et al., 1993; Kamata et al., 1996), image encryption (Quweider et al., 1995; Bourbakis et al., 1992), vector median filtering (Chung et al., 1998), ordered dither (Refazzoni et al., 1997), expression for pseudo color image display, database access analysis (Zhang, 1998; Stevens et al., 1983), bandwidth reduction (Asano et al., 1997), segmentation, classification, texture analysis and enhancement (Jafadish, 1997; Pajarola et al, 2000; Nguyen et al, 1982; Perez et al., 1992). These applications of traditional Hilbert curves are mostly focused on the spatial domain and the operations are in the forward direction, which scans the 2D space data into a 1D sequence.

A key contribution of this chapter is to extend and modify the Hilbert curves to achieve multilevel DCT decomposition. In image processing, the traditional scanning procedure employed in multilevel decomposition is essentially a raster scanning or column by column scanning, which overlooks the position information and the relationship among transform coefficients. We propose a modified inverse Hilbert curve approach to capture the position-specific information to achieve an efficient multilevel decomposition. Unlike the classic Hilbert curve approach which employs a 2D-to-1D scanning, the modified inverse Hilbert curve (MIHC) is a scanning which achieves the 1D data mapping to a 2D space. One obvious advantage of MIHC is its full preservation of neighborhood information in 2D. It also maintains the same multi-resolution property seen in the Hilbert scanning order approach due to the local hierarchical structure.

The second novelty of the present method is the application of MIHC multilevel DCT in reversible data hiding in JPEG images. In our experiments, good performance is indicated by the high peak signal-to-noise (PSNR) values for reconstructed images with high embedding capacity (high capacity of payload).

Reversible data hiding embeds hidden information (known as payload) into a digital media in a lossless or distortion-free mode (Barton, 1997). It is mainly used for the content authentication of multimedia

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