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Wavelet transform based on Meyer algorithm for image edge and blocking artifact reduction

Ming-Te Wu

Department of Information Technology, Kao Yuan University, Kaohsiung 82151, Taiwan

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ABSTRACT

In this study, a wavelet transform based on Meyer algorithm with edge-angle tracking capability is proposed for edge and blocking artifact reduction of an image, during image compression processes. This new proposed scheme is quite different from the conventional curvelet scheme, which can be viewed as using post-processing, after wavelet transform, to track only the edge of a high-frequency section of wavelet coefficients. However, the proposed wavelet transform scheme based on Meyer algorithm is with a complete wavelet design procedure, which is suitable for multiresolution analysis; it possesses the orthonormal property of conventional wavelet transforms. From computer simulation, we verify the merits of the proposed scheme over the conventional approaches, in terms of achieving better performance based on the subjective and objective (e.g., the peak signal-to-noise ratio) analysis.

1. Introduction

Discrete cosine transform (DCT) [16] is the block transform used in JPEG standard for image compression, while the discrete wavelet transform (DWT) is another significant block transform employed in JPEG2000 [15]. In fact, the wavelet transform has been one of the significant multiresolution techniques used in computer vision for tasks, e.g. object recognition as well as image compression, where notion such as resolution and scale are very intuitive. In JPEG2000 the original $N \times N$ color source image is, first, decomposed into YUV (Y implies luminance and U, V imply chrominance) format image components and each image component is decomposed into rectangular tiles, sub-image with the size of $(N/2 \times N/2)$. In consequence, a DWT transform is applied on each tile and the tile can be decomposed into different resolution levels to satisfy a specific compression ratio. The decomposition levels are made up of subbands of coefficients that describe the frequency characteristics of local areas of the tiles, rather than across the entire image. The subbands of coefficients are then quantized and collected into rectangular arrays of "codes blocks". The bit planes of the coefficients in a code block are entropy coded [19] and the coding can be done in such a way that certain regions of interest can be coded at a higher quality than the background. Markers are added to the bitstream to allow for error resilience, which is to improve the performance of transmitting compressed images over error-prone channels. The code stream has the main header at the beginning that describes the original image and the various decomposition and coding styles that are used to locate, extract, decode and reconstruct the image with the desired resolution, fidelity, region of interest or other characteristics.

A channel watermarking scheme for copyright-protection of color images using DWT was present [7] to improve the security of watermark against various image processing attacks and the watermark coefficients are split into two parts and embedded into two different streams separately. To provide robust security of host image, [3] inserted watermark image in

E-mail addresses: t90078@cc.kyu.edu.tw, mint.wu@msa.hinet.net

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low-low sub-band of host image by splitting it using DWT, in addition, 8×8 blocks DCT is applied on low-low sub-band and watermark is embedded into the last pixel of each block. A denoising algorithm based on the exponential threshold function was proposed [20], which has the arbitrary order derivative and retain more wavelet coefficients. An audio watermarking method is proposed [6], using Arnold transformation with DWT and DCT, and embedded by executing enough level of approximation of audio signal with DWT and packetized approximate function, then taking DCT where scrambled watermark image is embedded. All of the audio segments are then reorganized, and the scrambled watermark is done by Arnold transform. A block-based technique utilizes the entropy and edge entropy as human visual system characteristics for the selection of significant blocks to embed the watermark [11], the blocks of the lowest and edge entropy values are selected as the best regions to insert the watermark. In [4], watermarking has been done using least significant bit skill, DCT and DWT transform. It showed that the objective performance is best for least significant bit skill and the normalized cross-correlation value is best for DCT transform. A filtering approach in the wavelet domain for image denoising and compression, based on the projections of detail subband coefficients onto the approximation subband coefficients with less noisy was proposed [12] to acquire a higher compression ratio. Kumar et al. [10] present an adaptive dual-tree complex WT on scalable video, using motion compensated diamond search algorithm with large and small diamond search pattern, to improve the compression rate and visual quality. A watermarking schema with a combined DWT-DCT method for fingerprint image is developed [1]. User facial and identification information in the form of text data are embedded into owner's fingerprint image. Cai et al. [5] proposed a wavelet frame-based image restoration model, estimating the restored image and its singularity set, explicitly treats images as piecewise smooth functions. It can protect singularities and provide enough regularization in smooth regions at the same time. A DCT-DWT based secured method [14], along with Arnold transform to encrypt watermark data, was implemented in the watermarking process against different kind of attacks like cropping, noise, and scaling. Ansari and Buddhiraju [2] applied a various multiscale analysis based on the wavelet, curvelet, and contourlet transforms to recognize each texture class for remotely sensed satellite image.

It is known that the use of the block transforms will introduce the blocking effect in the recovered images; it is also named as the artifact effect. In the image, an edge is characterized by an abrupt change in intensity indicating the boundary between two regions with different grey-level properties. In image processing and coding, the problem of artifact effect reductions, viz., blocking or blurring edge, is very significant and has been studied, recently [17,18]. To circumvent the drawback described above, in JPEG2000 the DWT-based technology has been devised to reduce the edge blurring, but it did not reserve too much portion of high-frequency coefficients, such that the impairment at block boundary was not considered [8,9], especially the image is a close-up one. More, to further alleviate the edge blurring as well as reserve the portion of high frequencies, in [17] the curvelet transform was suggested for image compression. Indeed, the curvelet is based on multiscale ridgelets with a spatial bandpass filtering operation to distinguish different scales. It can be viewed as using post-processing after wavelet transform, to track the edge of a high-frequency section of wavelet coefficients. The curvelet transform first filtered an image into subbands, then each subband is smoothly windowed into "square" of an appropriate scale and each resulting square is renormalized to unit scale. Finally, each square is analyzed in ridgelets, which is a method of analysis suitable for objects with discontinuities across straight lines.

In this paper, a wavelet transform based on Meyer algorithm with edge-angle tracking capability is proposed for further reducing the edge and blocking artifact of an image, during image compression process. This new proposed scheme is quite different from the conventional curvelet scheme. It is with complete wavelet design procedure, which is suitable for multiresolution analysis; it possesses the orthonormal property of conventional wavelet transform, but this is not the case when the conventional curvelet scheme is employed. The superiority of the proposed scheme will be verified using computer simulation; it can be used to achieve good visual quality and good peak signal-to-noise ratio (PSNR), simultaneously. For discussion, this paper is organized as follows; in Section 2, conventional Meyer wavelet transform is first introduced and then the proposed wavelet transform based on Meyer algorithm is proposed, we prove that the proposed transform with the design principle conditions of wavelet function for multiresolution analysis in Appendix. In Section 3, results of the simulation are provided that confirm and demonstrate the effectiveness of the algorithm, in comparison to the conventional JPEG2000 and curvelet scheme, in terms of artifact reduction. Finally, conclusions are presented in Section 4.

2. Proposed wavelet transform

Basically, the wavelet transform can be classified into two catalogues; the time domain and frequency domain approaches. The Morlet, Shannon and Gaussian wavelet transforms are time domain methods, while the Meyer wavelet transform is a frequency domain approach [9,13,19]. In this section, we will focus on frequency domain approach, where a wavelet transform based on Meyer algorithm, with edge-angle tracking capability for edge and blocking artifact reduction of an image, during image compression processes. It adopts the merits of curvelet associated with Meyer wavelet transform to form a new wavelet transform and is referred to as the wavelet transform based on Meyer algorithm. In what follows, the basic idea of conventional Meyer wavelet transform will be briefly reviewed.

2.1. Conventional Meyer wavelet transform

The Meyer wavelet transform proposed in [13,19], is one of the wavelet transforms, which has been extensively used for multiresolution analysis as illustrated in Fig. 1. Basically, a multiresolution analysis possesses a sequence of embedded