A Novel Wavelet Image Coding Based on Non-uniform Scalar Quantization

Guoyuo Wang[1] and Wentao Wang[1,2]

[1] Institute for Pattern Recognition and Artificial Intelligence,
Huazhong University of Science and Technology,
1037 Luoyu Road, Wuhan 430074, China
wangguoyou@hust.edu.cn

[2] College of Computer Science, South-Central University for Nationalities,
Minyuan Road, Wuhan 430074, China
wangwt_long@yahoo.com.cn

Abstract. In this paper, we investigate the problem of how to quantize the wavelet coefficients in the lowest frequency subband with non-uniform scalar method. A novel wavelet image coding algorithm based on non-uniform scalar quantization is proposed. This algorithm adopts longer step to quantize the wavelet coefficients in the lowest frequency subband and uses shorter step for other ones. According as the results of the experiment we design a coding approach by using two labels 0 or 1 to code a coefficient bit of decimal plane. Experiment results have shown the proposed scheme improves the performance of wavelet image coders. In particular, it will get better coding gain in the low bit rate image coding.

1 Introduction

Image compression encoding based on wavelet is one of hot research problem. Several very competitive algorithms, e.g. embedded zero-tree wavelets (EZW) of Shapiro, set partitioning in hierarchical trees (SPIHT) of Said and Pearlman, and embedded block coding with optimized truncation (EBCOT) of Taubman have been developed [1-4]. EZW is effective and computationally simple algorithm. With an embedded bit stream, the reception of code bits can be stopped at any point, and the image can then be reconstructed immediately. SPIHT is an improved version of EZW. It improves the coding performance by exploiting the self-similarity of the coefficients across subbands more efficiently than EZW. Although it is less efficient in coding performance than EBCOT, which forms the basis of the JEPG2000 standard in image coding, it has much lower computational complexity than EBCOT. So there are many researchers have great interest in improving the performance of SPIHT.

In [5], a pre-processing method, which applies the discrete sine transform (DST) or the discrete cosine transform (DCT) to the wavelet coefficients in the highest frequency subbands and in the next highest frequency subbands before the SPIHT encoding, is proposed. First, it gets the correlation coefficients of each of the highest frequency subbands. Second, it applies the DST or DCT according to the correlation

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coefficients of the wavelet coefficients in the subbands. This method can helpfully pack the energy of the correlated coefficients into a relatively few components of a DST or DCT block, but it increases the computational complexity greatly. Reference [6] thinks that the refined and re-refined bit streams of SPIHT in the preceding phase may not transmit and replace them with the bit streams derived from the important coefficients in the next phase. The problem of this method is that it should add some synchronization bits in the bit streams. This will reduce the compression ratio. The rate-distortion (R-D) optimized significance map pruning method [7] uses a rate-distortion criterion to decision the significance coefficients. They all add complexity of the coder algorithm. In [8], DPCM (differential pulse code modulation) and SPIHT are adopted. But it is not fit for the low bit rate encoding.

In this paper, we check the characteristic of the wavelet coefficients of the multi-level wavelet decomposition, especially 9/7 wavelet filter. The Daubechies 9/7 wavelet [9] is one of the most popular ones, since it combines good performance and rational filter length. It is stressed here that the 9/7 wavelet is a default filter of the JPEG2000 standard [10] and included in the MPEG4 standard [11]. From the results of our experiment we find that it is possible to quantize the wavelet coefficients using non-uniform strategy. It is useful to improve the coding ratio. Meanwhile, a new simple and efficient pre-processing coding method: like-DPCM is proposed.

2 Quantization and Coder of Wavelet Coefficient

2.1 SPIHT Coder

The SPIHT coder [2] organizes the wavelet coefficients of an image into the spatial orientation trees by using wavelet pyramid. It uses three types of sets: $D(i, j)$ denoting the set of all descendants of a node (i, j), $O(i, j)$ representing the set of all offspring of the node (i, j), and $L(i, j)$ representing the set of all descendants excluding the immediate four offspring of the node. The SPIHT coder starts with the most significant bit plane. At every bit plane, it tests the tree lists in order, starting with LIP (list insignificant pixels) are coded. Those that become significant are moved to the end of the LSP (list of significant pixels) and their signs are coded. Similarly, set $D(i, j)$ and $L(i, j)$ are sequentially coded following the LIS (list insignificant sets) order, and those that become significant are partitioned into subsets. Finally, each coefficient in LSP except the ones added in the last sorting pass is refined in each refinement pass. The algorithm then repeats the above procedure for next resolution, and then stops at desired bit rates.

2.2 Quantization Plane

Probabilistic quantization model of wavelet coefficients will be influence the performance of wavelet coders. We know that a wavelet coefficient can be represented by a binary polynomial (binary uniform quantization) or a decimal polynomial (decimal uniform quantization). It is show as equation (1).