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An Improved On-Board Post-Transform Image Compression Algorithm

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Abstract. The shortcomings of sparse representation of remote sensing images and the on-board post -transform-based image compression algorithm are analyzed. In this paper, an improved post-transform based compression algorithm is proposed. The algorithm is improved in terms of computational complexity, optimal post-transform basis selection and post-transform entropy coding algorithm. Experimental results show that the improved compression algorithm has higher compression performance, compared with the traditional compression algorithm, the SNR is improved 0.3-1.1dB. Which effectively solves the problem of sparse representation of wavelet transform and low efficiency of post-transform. And suitable for on-board CCD camera applications.

1. Introduction

Post-transform [1, 2] is a transformation of multi-base dictionaries. This requires that each coefficient block be subjected to inner product of 15 base (Bandelet[3] basis),and then one of the post-transforms is selected according to the Lagrange rate-distortion minimum criterion. As a result of the Lagrangian rate-distortion minimization approach, this requires quantization of the 15 post-transform representations and minimization of the Lagrangian rate distortion. The computational complexity of the whole algorithm is the inner product of the 15 post-transforms of a block, and it is necessary to quantize 15 times for each post-transform, and to compute 15 quantized post-transform representations Lagrangian rate distortion function, finally the minimum Lagrangian rate distortion function is required. And each use a relatively large number of adders and multipliers. At the same time, a large number of memory cache dictionaries in the base of all transform coefficients and quantized coefficients are needed, which is not conducive to hardware implementation. Although post- transformation is less computationally intensive than bandelet transform, it is still relatively large for the post-transformation of this multi-base dictionary. It takes up a lot of storage resources, which is very important for on-board image compression using hardware.

Using Lagrangian rate-based distortion function to determine the optimal base to minimize needs high computational complexity on the one hand. On the other hand, the 15 post-transform block coefficients are quantized using a standard scalar quantizer. This problem is the same as the Lagrangian selection method, which uses a uniform quantizer, and the step size q of the uniform quantizer is fixed. The quantization is performed at a fixed step size, and the Lagrangian method selects the best post-transform basis to be used. In order to determine the best post-transform base, it is necessary to determine the quantization step size q. Assuming that the target bit rate is p1, it is known from [4] that at high bit rates, the quantization step is $q=2^{H(x)-p1}$. Therefore, it is necessary to determine the quantization step size by calculating the entropy H (X) in order to select the optimum post-transform, which is very difficult. In addition, on-board compression algorithms usually require that the codestream be embedded, which may be truncated at any bit rate. Therefore, it is not realistic to use the code rate to obtain the quantization step size. Therefore, it is necessary to improve the optimal post-transform basis selection so as not to be affected by the quantization step size.

The purpose of post-transformation is to eliminate coefficient redundancy in wavelet high-frequency subband. Because of the use of multiple directional-based dictionaries, the post-transform disrupts the zerotree relationship of high-frequency subband of wavelet coefficients, which is very important for the entropy coding algorithm, such as SPIHT and CCSDS[5,6] algorithm using the wavelet sub-band zerotree feature makes the wavelet coefficient coding complexity is low. Therefore, SPIHT and CCSDS algorithms cannot be used to encode multi-base dictionary post-transformation. JPEG2000 BPC coding algorithm can be used, but the complexity ofJPEG2000 BPC coding algorithm is too high, whose hardware implement is difficult. Usually, the post-transform compression algorithm uses arithmetic coding, Huffman coding, etc. However, the arithmetic coding method does not have the characteristics of progressive coding. At present, the more and more progressive entropy coding methods mainly include SPITH, BPS of CCSDS and BPC of JPEG2000. However, the SPIHT algorithm encodes the whole image bit by bit. When the transmission error occurs, the whole reconstructed image will be faulty, which is not suitable for on-board application. The calculation complexity ofJPEG2000 BPC is too high to achieve hardware. In this paper, CCSDS-IDC bit-plane coding transform coefficient. Therefore, it is necessary to improve the post-transform coefficients to realize the progressive coding.

Considering the problems in post-transformation of the multi-dictionary base, it is improved from complexity of post-transformation and hardware resources to realize feasibility and entropy coding. In this paper, we propose an optimal post-transform selection method based on the l_0 and l_p norm minimization methods. Aiming at the high computational complexity of multi-base dictionaries, a post-transform on-board compression algorithm based on single base dictionaries is proposed. In order to make the post-transform compression algorithm have the characteristics of progressive coding, the single-base dictionary post-transformation combined with CCSDS-IDC bit-plane coding is improved to make it more suitable for on-board applications.

2. Design thought of compression algorithm

In order to reduce the computational complexity of the post-transform, this paper will modify the best post-transform selection method. The following is an explanation of the modified idea. The goal of selecting the best basis is to find a base b such that f's representation at this base b has a minimum rate distortion and a minimum code rate. Minimizing distortion aims to maintain energy maximization in the decoded block. From the energy compression point of view, most of the energy is concentrated in a small number of coefficients, these coefficients in the previous bit plane coding, so these energy blocks in the decoding side will be used first. However, the need for minimized bits requires that as many coefficients as possible be low amplitude. These low-amplitude coefficients are unimportant, but they are important in the following bit planes. Therefore, these coefficients do not need to be coded in the preceding bit planes, so that overhead rates are not incurred. In this paper, we propose different optimal post-transform selection methods for low bit-rate and high bit-rate respectively.

First, it proposes one best post-transformation method which is suitable for low bit-rate L_0 norm minimization selection.

For the transform coding [4], the code rate satisfies the formula (1).

$$R \approx \gamma_0 M, \gamma_0 = 7 \tag{1}$$

Where M is the number of non-zero quantized coefficients. Thus, at low bit rates the code rate depends on the number of non-zero quantized coefficients. The more sparsely transformed coefficients, the less the nonzero coefficients will be. In this sense, the choice of post-transform is actually a sparse evaluation criteria. According to this idea, this paper proposes the best post-transformation based on the L_0 norm method. According to the theory of signal sparse representation, it is usually used to measure the sparseness of a given signal representation method. The smaller the coefficient is, the more the signal is concentrated, the better the decorrelation effect is. Thus, the sparsity is defined as the proportion of zero samples in the components of the post-transform block F for a given post-transform block F to be selected (f^0, f^1, ... f^b, ... f^{Nb}) The sparsity of the signal is stronger. According to this definition, the most direct measure of the sparsity of the post-transform block is the L_0 norm of the post-transform block,

$$f^{b*} = \arg\min_{f^b, b\in[0,N_b]} \left\| f^b \right\|_0 \; s.t. \left\| f^b \right\|_0 = \sum_{m=1}^{16} I_m, I_m = \begin{cases} 1, \lfloor |a_b[m]| \rfloor \neq 0 \\ 0, \lfloor |a_b[m]| \rfloor = 0 \end{cases} \tag{2}$$

Where a_b [m] is a coefficient in the post-transform block. In the low bit rate, remove the whole operation does not affect the rate of judgment. Since a_b [m] is known, it can be seen from Eq. (2) that only the adder and the comparator are needed to select the best post-transform block. At the same time, there is no quantization operation. It can be seen, it is simpler than the traditional Lagrange method, and easier to hardware implementation. From the perspective of rate distortion, this criterion implies that f^b contains many low-amplitude coefficients by minimizing the number of nonzero coefficients in the post-transform block, thus minimizing the coding f^b code rate R ($f^b{}_q$). Since the post-transform is an orthogonal transformation, the energy off is the same as the energy of f^b. Therefore, searching for f^b using the minimum L_0 norm is equivalent to the most significant coefficient of f^b, Most of the energy in the front bit plane has been restored, and rate distortion D ($f^b{}_q$) is also the smallest.

Second, suitable for high bit-rate optimization of l-p norm minimization selection of the best post-transformation method.

At high bit rates, the code rate satisfies (3).

$$R \approx h(x) - \log_2 q, H(X) = -\sum_{i=1}^{N} p_i \log_2 p_i \tag{3}$$

Where h (x) is the entropy of the transform coefficients and q is the quantization step size. In this case, when the quantization step size q is fixed, the code rate interval is entropy of the transform coefficients. It is difficult to determine the coefficient entropy. In this paper, the L_0 norm is extended to the L_p norm. Therefore, the sparseness can be modified by the L_0 norm to select the best posterior transformation. The best post-transform block is selected before the corresponding post-transform in the dictionary is quantized, and only the best post-transform block is quantized. In this case, the optimal post-transformation selection problem is transformed into the $L_p$norm optimization problem as shown in (4).

$$f^{b*} = \arg\min_{f^b, b\in[0,N_b]} \left\| f^b \right\|_p \; s.t. \left\| f^b \right\|_p = (\sum_{m=0}^{15} |a_b[m]|^p)^{\frac{1}{p}} \tag{4}$$

When p = 2, it is L_2 norm. The energy or L_2 norm of the block projected onto each orthonormal basis is still constant. Therefore, the p-size is taken as $0<p\leq1$. The concrete choice may decide according to the actual project application. When p = 1, it is L_1 norm. The calculation of the L_1 norm involves only adders and comparators. L_{-p} and L_0 norm method, remove the quantization process, which is relatively simple than the traditional method, and very suitable for on-board applications[7-9].

3. Experiment results

The effect of the correction of the best post-transform selection criteria on the compression performance is analyzed below. Four remote sensing images are selected as shown in Figure 1.

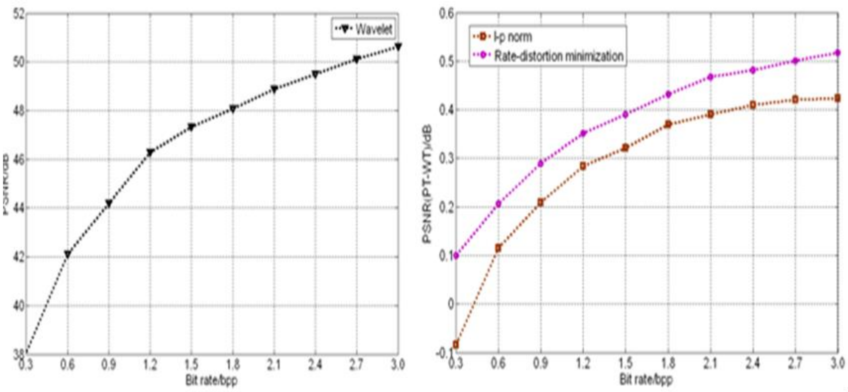

Fig. 1 Signal to noise ratio comparison

The four transforms are post-transformed, and the post-transform base is DCT single-base dictionaries. Two evaluation criteria are adopted respectively. The entropy coding algorithm adopts an adaptive arithmetic coder and is compared with the non-post-transform direct entropy coding. As can be seen from the figure, when the code rate is greater than 0.9bpp, the improved post-transform selection method has a final compression performance of about 0.1 dB lower than that of the Langrange method. When the bit rate is smaller, the compression performance is worse, at 0.3bpp, even lower than the case without using post-conversion. The reason for this is that the method of l-p norm does not use the bit rate to decide the choice of post-transform, so that when using adaptive arithmetic coding, each block needs 1 bit of cost for edge information b coding. This value is important at low bit rates. Table 1 shows the bits of the edge information overhead for the two best post transform selection methods.

Table 1. Shows the comparison of the bit-rate cost for the edge information of the two best post-transform basis selection methods the rate-distortion method is presented in this paper

Index	Rate-distortion method			Our method		
Target bitrate (bpp)	0.5	1.5	3.0	0.5	1.5	3.0
Each side information overhead bit(bpb)	0.273	0.818	1.0	1.0	1.0	1.0
Percentage of total code rate(100%)	3.41	3.4	2.08	12.5	4.16	2.08

As shown in Table 1, the bit-rate overhead of this method is 12.5% of the total code rate, and 2.08% of the total code rate at 3bpp when the code rate is 0.5bpp. For the Lagrangian method, occupies 3.41% under the low bit rate, the change is not big. For this problem, bit-plane coding can be used to eliminate, because the bit-plane for the amplitude of the coefficients in the lowest bit-plane coding, when the code rate is low, the low-level plane is truncated, then edge information does not require coding. The structure of the image compression algorithm with the best posterior transformation is shown in Fig. 2.

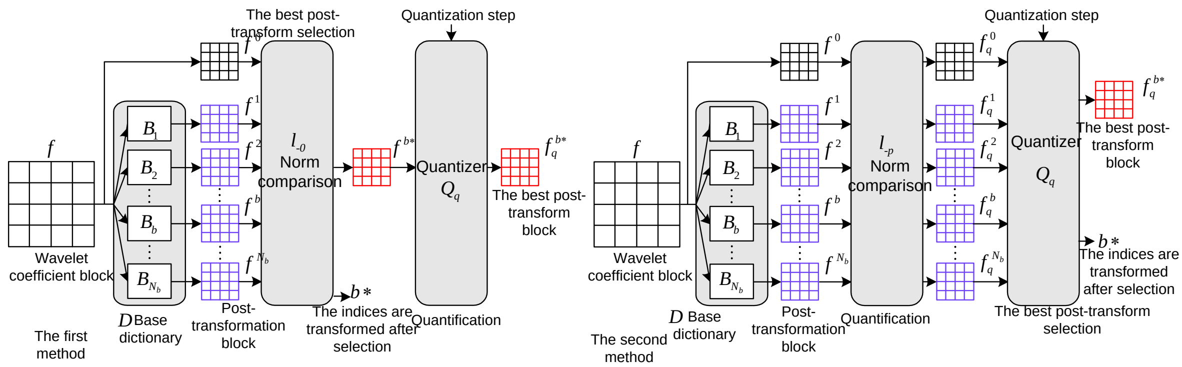

Figure 2. l-p and l-p Norms select the best back edge

As shown in Fig. 2, the posterior transformation selection process of l-p norm only needs to analyze the sparse degree of the coefficients of each post-transform block. The quantization only needs to quantify the best transformed block, and the whole process is simple.

4. Summary

In this paper, the panchromatic image compression algorithm of CCD camera is studied. In order to overcome the shortcomings of DWT sparse representation on satellite images, low complexity DWT domain post-transformation is adopted. Aiming at the complex problem of Bandelet transform, the post-transformation theory is introduced. In this paper, the posterior transformation based on l-p norm is proposed, which is based on the Lagrangian optimal method to select the best basis. Then, the image sparse representation of multi-base dictionary and single-base dictionary is analyzed. Aiming at the high computational complexity of multi-base dictionaries, an image sparse representation based on single base dictionary backtracking is proposed. Experimental results show that the post-transform on-board image compression algorithm proposed in this paper has a great advantage.

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