FAST ALGORITHM FOR REMOTE SENSING IMAGE PROGRESSIVE COMPRESSION

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1. INTRODUCTION

With the rapid development of remote sensing technologies, there are lager and larger amounts of data that have to be transmitted, processed, and stored efficiently. However, in the web-based spatial information services, the network bandwidths are limited. Now the commonly used method is that the data servers provide the image data multi-resolution representations, which are stored and compressed (often by JPEG or PNG algorithm) independently, and transmit specific resolution data according to the needs of clients. However, in this method, there are a lot of redundant data between different resolutions. An ideal way is to employ the multi-resolution progressive compression. After the integer lifting wavelet decomposition, the coefficients are modeled and entropy coded with the resolution progressive compression character. This can eliminate the redundant data between resolutions, and easily allow the transmission of low resolution versions firstly, followed by transmissions of successive details.

Some image compression algorithms with progressive characteristics were used to compress the remote image data, such as the JPEG2000 algorithm [1] [2]. The JPEG2000 algorithm mainly is based on the EBCOT algorithm [3] and the bit-plane coding technology. It has several progressive characteristics, such as resolution, fidelity, and region of interest (ROI). However, JPEG2000 has so high complexity that it affects the efficiency of image data process.

The remote sensing image data often have many high frequency details. In addition, the image compressing algorithm needs to be fast with low computing complexity and several progressive characteristics in the web based spatial information services. However, the above compressing algorithm couldn't meet these needs. Therefore, a new progressive wavelet coding algorithm for the remote sensing image was proposed. This algorithm has three progressive characters (resolution, ROI, and fidelity), low computing complexity and favorable loss compression performance.

2. ALGORITHM SCHEME

The JPEG2000 algorithm run three passes for every bit-plane coefficient and uses the complicated arithmetic coding based on the context to entropy code. The proposed new remote sensing image compressing algorithm didn't use the arithmetic coding. It used an adaptive Golomb_Rice coding for the dyadic sequence

[4] as the entropy coding, which has low complexity and high efficiency. In addition, the coding is run only in one pass. After the 9/7-F integer lifting wavelet decomposition (9/7-F integer wavelet has perfect loss compression performance), every resolution of the transform coefficients was partitioned into many precincts according to the area. Each precinct has three precinct sub-bands (LH, HL, and HH) except the lowest resolution. In each precinct sub-band, there are many continuous zeros in the dyadic sequence of every bit-plane, which are very obvious in the initial high bit-plane. The bits of every bit-plane were modeled and reordered to form three coding sub-processes only in one pass, which can obtain more zero chains to improve coding efficiency. At the same time, the adaptive Golomb_Rice coding is used to entropy code. Lastly, the compressed code streams of the three sub-bands belong to the same precinct were packed and all the precincts were organized according to the resolution and the area to form the final code stream. All these can obtain favorable compression performance and low computing complexity, while has several progressive characteristics. The proposed algorithm is described in the figure 1. The uniform scalar quantization with dead-zone and adjustable parameter was used to obtain more favorable loss coding performance. The decoding is a reverse course.

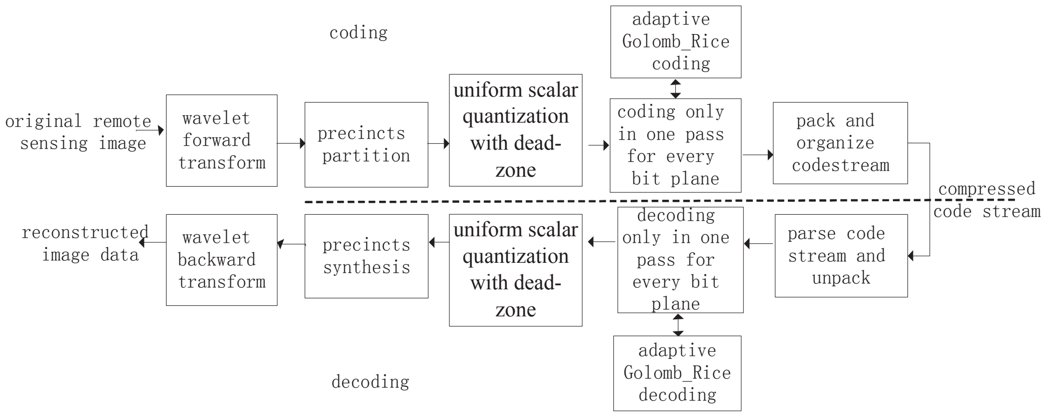

Figure 1. The coding and deco

2.1 bit-plane coefficients modeling and reordering only in one pass.

In each precinct sub-band, the spatio-temporal neighborhood relationship was used to remove redundancies between different bit-planes and neighbors in the same bit-plane, and the bits of every bit-plane were modeled and reordered to form three sub-processes and encoded only in one pass.

When a coefficient' highest bit is coded, the validity state of the coefficient is changed from 0 to 1. The validity state of the coefficient determines which sub-process the bit is in. The three sub-processes are the non-zero neighbors sub-process $P_{n,1}$, the refinement sub-process $P_{n,2}$, and the run-length sub-process $P_{n,3}$. The partition procedure forming the three sub-processes only in one pass is described in the algorithm 1.

In the $P_{n,1}$ and $P_{n,3}$ sub-processes, after the bits are reordered, the 0 percents are often greater than 50%, so the adaptive Golomb_Rice coding can improve the coding efficiency. However, the 0 percent in the $P_{n,2}$ sub-process equals 50% and the entropy coding efficiency is low, so the bits directly are written to the code stream. In each bit-plane of each precinct sub-band, the coding sub-process that need adaptive Golomb_Rice coding ($P_{n,1}$ and $P_{n,3}$) can be described in algorithm 2. It is run only in one pass.

Algorithm 1: three sub-processes partition only in one pass

for each bit in the bit-plane **do**
  if the coefficient validity of the bit is 1 **then** $P_{n,2}$ coding
  else **if** there is at least one coefficient with validity is 1 among the 8 neighbors of this bit at the same bit-plane
   then $P_{n,1}$ coding. if this bit = 1, set validity state to 1
  else $P_{n,3}$ codng. if this bit = 1, set validity state to 1.
  endif
endfor

Algorithm 2: the coding algorithm in one pass for the sub-process which needs adaptive Golomb_Rice coding

for each bit of the sub-process in current bit-plane **do**
  Taking count of 0 in run-length.
  if the 0 run-length equals m or the bit equals 1
   if current sub-process is not the first active sub-process
    then run adaptive Golomb_Rice coding, the coded data and the refinement bits during the process are sent to the code buffer in turn.
   else
    After adaptive Golomb_Rice coding, the coded data are sent to the code stream.
    Data in the code buffer are sent to the code stream
    Buffered refinement bits of current sub-process are sent to the code stream.
    Stop the first active sub-process and clean the corresponding buffers.
   endif
   The parameter k of Golomb_Rice coding in current sub-process is updated adaptively.
   if the bit = 1
    then set the validity state of this coefficient to 1
   endif
  endif
endfor

2.2 Adaptive Golomb_Rice coding

We used the adaptive Golomb_Rice coding as described in [6]. But the computing of the parameter k ($m = 2^k$) is easier and has low complexity.

Initially: $k = 0$;

After coding $0^m : k = k + 1$;

After coding $0^l 1 (l < m) : k = k - 1$

2.3 Uniform scalar quantization with dead-zone and adjustable parameter

The uniform scalar quantization with dead-zone is used in the quantization step. For each sub-band, the selected uniform quantization step size has some connection with the energy weight of the sub-band. In JPEG2000 algorithm, the quantization step size Δ_b is described as the equation (1) [7].

$$\Delta_b = \frac{2^{1-R_I+R_b}}{\gamma_b} \qquad (1)$$

R_I is the bit that the original image component needs. R_b is the nominal dynamic range of sub-band *b*. γ_b is the energy weight of sub-band *b*.

In the proposed new algorithm, in order to loss compress the remote sensing image more efficiently and flexibly, an adjustable parameter s is used. The quantization step size is described as the equation (2):

$$\Delta_b = \frac{2^{1-R_I+R_b}}{\gamma_b} * 2^s \quad (s = 0,1,2,......n) \qquad (2)$$

The parameter s is adjusted according to the needs. The last s bit-planes are discarded after the quantization with the quantization step size (1).

3. EXPERIMENTAL RESULTS

Some experiments were carried out to compare the loss compression time and performance between the new algorithm and the other algorithms, such as the JPEG2000 and the JPEG. The experiment data were 6 remote sensing images with different sizes and different resolutions.

Then the coding time, decoding time and the compression performance were compared with JPEG2000 which also has several progressive characteristics. The parameter s was set to 0, which can obtain the same PSNR with JPEG2000 after compression. The average PSNR of the six test image is 52.815db. The average coding and decoding times of the new algorithm decrease 25.83% and 27.78% respectively compared with JPEG2000. Fortunately, the compression performance of the new algorithm decreases only 4.50% compared to JPEG2000.

Table 1. Loss compression performance compare.

Data	Bit/pixel	New algorithm PSNR (db)	JPEG PSNR (db)
Abudhabi	2.49 (s=1)	47.52	42.15
	0.95 (s=3)	36.00	33.58
	0.44 (s=4)	31.38	29.62
Beijing	3.77(s=1)	46.45	41.44
	1.57(s=3)	34.08	31.44
	0.76(s=4)	29.10	27.47
Bevhills	3.44(s=2)	40.10	35.83
	2.18(s=3)	33.31	29.97
	1.00(s=4)	27.43	25.89
Cairo_c	4.81(s=0)	52.36	50.87
	2.56(s=2)	40.09	37.90
	0.83(s=4)	29.44	27.30
DC_1M	4.64(s=1)	46.76	41.80
	3.43(s=2)	40.02	35.58
	1.22(s=4)	28.32	26.36
Nevada	4.53(s=1)	46.57	41.83
	2.16(s=3)	33.84	30.99
	1.21(s=4)	28.46	26.95

The PSNR values of different bit rates were compared between the new algorithm and the JPEG loss compression. The different bit rates were obtained by setting different s values. The compare results are shown in table 1. The last two columns are the PSNR value (db). Comparing all the data in different bit-rate in this table, the PSNR of the new algorithm is higher obviously than the JPEG loss compression at the same bit rate. Therefore, the new algorithm has a favorable loss compression performance.

4. CONCLUSION

Based on the characteristics of the remote image data, a new progressive wavelet coding algorithm for the remote sensing image was proposed. This algorithm has three progressive characters. The experiments showed that the new algorithm could decrease the coding and decoding time evidently compared with the JPEG2000, while maintains favorable loss compression performance.

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