THE COMPARISON OF THE WAVELET- BASED IMAGE COMPRESSORS

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ABSTRACT:

The paper made a comparison test concerning wavelet-based image compressors- ECW 2.0, MrSID 1.4 and EYACODER. The 12 kinds of test data were built according to the given target compression rates, which are 2, 3, 5, 6, 8, 10, 15, 20, 25, 30, 50 , to compare above mentioned three wavelet compressors in term of compression speed, compression rate, and reconstructed image quality. The method of PSNR (peak signal noise rate) in the paper was taken to evaluate the compressors by comparing the difference between the reconstructed and original pixel value. The test result shows EYACODER and MrSID1.4 are better than ECW 2.0 in doing image compression when the target compression rate is less than 3, and the tendency in viewing is getting neutral when the given compression rate is getting larger.

1. INTRODUCTION

Wavelets are mathematical functions that cut up data into different frequency components, and then study each component with a resolution matched to its scale. Pyramid Coding, Filter Bank Theory and Sub-band Coding develop and support the theory of Wavelet. Recently, wavelet applications in the field of image compression have advantages over traditional Fourier methods both in analyzing physical situations where the signal contains discontinuities and sharp spikes and in shortening computation time which the signal will be proceeded by computer. Most researchers put their interests in studying image compression based on wavelets either in the field of still or in dynastic images. The study shows that the application of Wavelets in the field of image compression has a bright future and is changing the way we work with large images.

Today, the main tendency in the whole world concerning the wavelet compression is to use the discrete wavelet transform (DWT) technology to compress images file. The process can be described simply as follows:

1. The DWT analyzes the signal at different frequency bands with different resolutions by decomposing the signal into a coarse approximation and detail information.

2. The DWT employs scaling functions and wavelet functions, which are associated with low pass and high pass filters respectively, to decompose the signal into different frequency bands.

3. At the first decomposition level, the output original signal which is passed through the high pass half the time resolution and double the frequency resolution and constitute the first level of DWT coefficients.

4. At the second decomposition level, only the signal which is the output of the low pass filter at the first decomposition level will pass through the same high pass and low pass filters for decomposition. The high pass filter’s output of the signal will constitute this level’s DWT coefficients. The low pass filter ’s output at this level will be the coming level’s input for further decomposition.

5. The process continues until the number of the decomposition level stops at n.

This constitutes one level of decomposition and can mathematically be expressed as follows:

$$y_{high}[k] = \sum_n x[n] \cdot g[2k-n]$$
$$y_{low}[k] = \sum_n x[n] \cdot h[2k-n] \qquad (1)$$

Where, x[n] is original signal; g[n] and h[n] are the high pass and low pass filters respectively; $y_{high}[k]$ and $y_{low}[k]$ are the outputs of the high pass and low pass filters respectively.

The DWT of the original signal is then obtained in reverse order of the above procedure by concatenating all coefficients starting from the last level of decomposition. The reconstructed signal at every level are upsampled by two, passed through the synthesis filters g[n], and h[n] (high pass and low pass, respectively), and then added. So, the reconstruction formula becomes simply :

$$x[n] = \sum_{k=-\infty}^{\infty} \left(y_{high}[k] \cdot g[-n+2k]\right) + \left(y_{low}[k] \cdot h[-n+2k]\right) \qquad (2)$$

where x[n] is the reconstruction signal by the reconstruction formula.

Interpreting the DWT coefficients sometimes can be rather difficult because the way DWT coefficients being presented is rather peculiar. Different compressors have their own technology to analyze the image at different frequency bands, to find the filters, to quantize and encode the information in order to provide perfect reconstruction image.

The purpose of this paper is to find the difference among selected compressors based on wavelets through the test and to provide some valuable information on how to select compressors for doing the image's compression.

2. TEST

2.1 Conditions

The image used in the test is the 9312×9284 grayscale (256) Fujian Black and White aerial digital image, scanned by the Ultra5000 in the resolution of 25U and stored in tiff format. The file size is about 85M.

All test were performed on a Hp computer corporation's HP l600 computer with the following key components:

- Intel 933MHZ Pentium III microprocessor
- 512M SDRAM
- ELSA Synergy II-32 video card /32 M RAM
- IBM-DTLA-307030 60GB HARD DISK
- WINDOWS 2000 Professional

The wavelet compressors used in the test are Earth Resource Mapper's Enhanced Compressed Wavelet Compressor V2.0 (ECW), LizardTech's MrSID Workstation Geospatial Encoder V1.4 (MrSID) and EYACODER(EYA).

2.2 Method

In order to compare compressors, we put our interests in three key facets: compression speed, compression rate, and reconstructed image quality. The method we take in the test is: firstly, we use the above mentioned compressors to compress the same digital black and white aerial image according the given target compression rates; secondly, we decompress all of the compressed image using their own decompressors and plug-ins and store the decompressed images in tiff, respectively; thirdly, we compare the difference of the each pixel value between the original image and the reconstructed image; finally, we evaluate the compressors through the change of the pixel value.

we use the PSNR(Peak Signal Noise Rate) to compare the processed image quality between the original and the reconstructed image, and the formula can be described as follows:

$$\mathrm{PSNR} = 20\log_{10}\left(\frac{255}{\mathrm{RMSE}}\right) \quad (3)$$

$$\mathrm{MSE} = \frac{\sum[f(i,j) - F(i,j)]^2}{N^2} \quad (4)$$

Where, RMSE (root mean squared error) is the square root of the MSE (mean squared error); f(i,j) is pixel value located in the i(row) and j(column) in the original raster image; F(i,j) is pixel value located in the i(row) and j(column) in the reconstructed raster image; N^2 is the number which is equal to I multiples j.

The work chart of the test can be described in Figure 1.

2.3 Test Data

The table 1 below listed the test data according to the above work chart.

Rate	Actual Rate			Compressed Time			PSNR			RMSE		
	eya	ecw	sid	eya	ecw	sid	eya	ecw	sid	eya	ecw	sid
2	2.23	3.00	2.11	1.57	1.03	2.35	48.4205	41.8586	48.10647	0.9672	2.0588	1.0028
3	3.10	3.60	3.05	1.54	1.03	2.30	41.3593	39.1577	41.39581	2.1806	2.8097	2.1714
5	5.02	5.10	4.82	1.41	1.14	2.15	36.8286	33.0567	35.9741	3.6737	5.6716	4.0535
6	6.02	5.94	5.80	1.37	1.12	2.00	35.1108	32.4207	34.6157	4.4771	6.1025	4.7397
8	8.04	7.90	7.29	1.32	1.08	1.57	33.7138	31.3018	32.9444	5.2583	6.9414	5.7453
10	10.02	10.20	9.04	1.27	1.00	2.00	32.6247	30.4872	32.2708	6.8008	7.6239	6.2086
15	15.01	16.60	14.70	1.21	0.53	1.57	31.4796	29.2395	31.3323	5.9607	8.8017	6.9171
20	20.01	22.80	18.60	1.18	1.13	1.35	30.4411	28.5329	29.9800	7.6645	9.5476	8.0823
25	25.02	30.00	22.27	1.23	1.33	1.47	30.4411	27.8899	29.0786	7.6645	10.2812	8.9662
30	30.01	36.20	27.57	1.22	1.32	1.35	28.8783	27.4549	28.5377	9.1753	10.8093	9.5423
50	50.02	57.90	44.42	1.23	1.24	1.27	27.6508	26.5622	27.3341	10.5681	11.9793	10.9606

Table1. Test data table obtained from the test. The rate stands for the target compression rate and the actual rate stands for the program's actual compression rate corresponding to the given target compression rate.

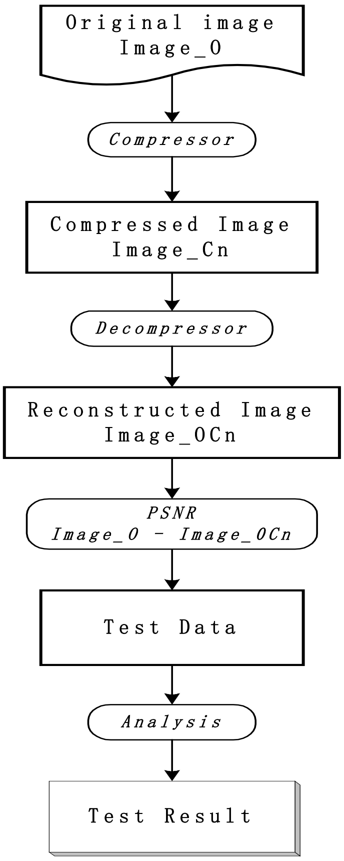

Figure 1. Work chart of the test

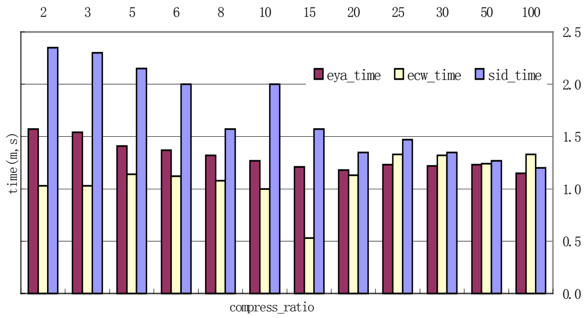

Figure 2. Comparison of compress time

3. ANALYSIS

3.1 Compression Time

The figure2 below shows the compression time according the target compression rate. In the average, the time used by MiSID is about 2 minutes and 16 seconds; EYA is about 1 minute and 32 seconds; ECW is about 1 minute and 8 seconds. The test result shows that ECW compressed twice as fast as MrSID.

3.2 Compression Rate

As we know, different compressors take the different output as their tradeoff, for example, output size or output quality. What the compressors do is to adjust the compression rate to guarantee a quality during compression. This is the reason why the target compression rate is not same as the actual compression rate after the image compression. Figure3 shows that the absolute error of EYA between the target compression rate and the actual compression rate is 0.05. Whatever we try, the actual compression rate is always larger than what the user specified.

Table2 shows that EYA and MrSID is better than ECW in doing compression work when the target compression rate is less than 3.

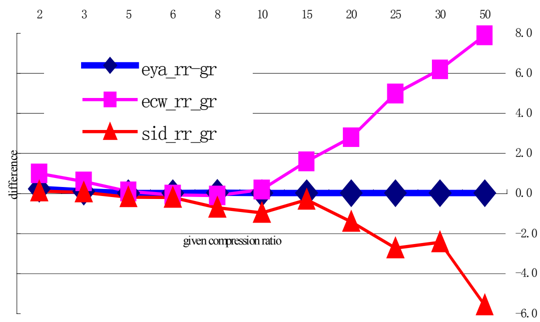

Figure 3. Comparison of compress rate

	The number of changed pixels when the target compression rate is 2			The number of changed pixels when the target compression rate is 3		
value	ECW_pn	EYA_pn	SID_pn	ECW_pn	EYA_pn	SID_pn
0	17187464	37855878	35279294	12922936	21852369	18150880
1	29257077	40760961	40642912	22589995	30925332	27324893
2	20752410	7373864	9726001	18591521	17310397	19876016
3	11741970	389290	782872	13779578	8222950	11905358
Total	78938921	86379993	86431079	67884030	78311048	77257147
Ratio	0.913089	0.99916	0.999751	0.785217	0.905826	0.893636

Table 2. The changed amount of the pixel's gray value in the reconstructed image compared with the original image when the target compression rate is 2 and 3. Ratio can be got from dividing Total of the table by 86452608 (9312×9284) which is the total pixel number of the test image.

Figure 4 clearly compares the relations by the amount of changed pixels in the different reconstructed image by different compressors, corresponding to changed pixel gray value being 0, 1, 2, 3and the rest respectively.

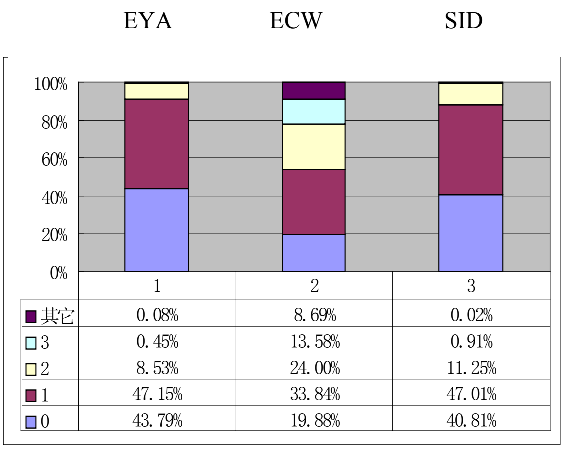

Figure 4. Comparison of the changed pixel' value when the target compress rate is 2.

3.3 Reconstructed Image Quality

The result of the comparison of PSNR is that EYA is 34.268, MrSID is 33.779, and ECW is 31.633, in average. The RMSE corresponding to EYA, MrSID, ECW, is 5.854, 6.217 and 7.512, respectively. Figure 5 and 6 shows the details.

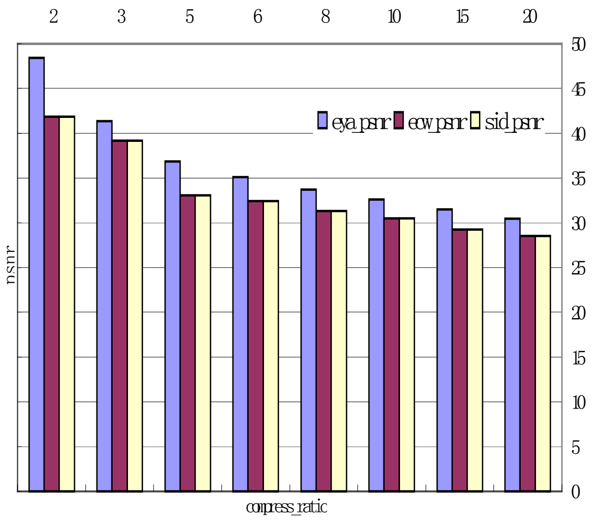

Figure 5. Comparison of the PSNR

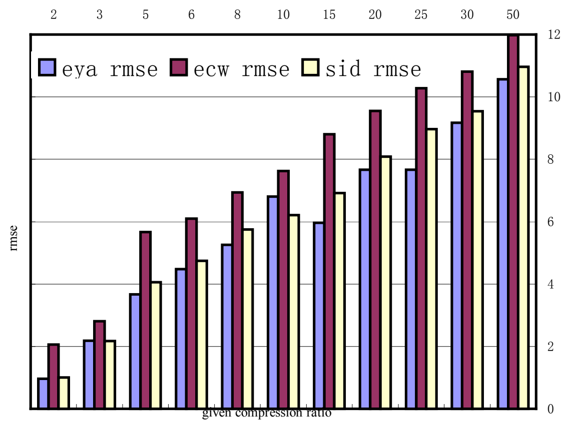

Figure 6. Comparison of the RMSE

4. SUGGESTION

EYA is developed by the private people, and it can only be used independently and can not be embed in other software systems. But the selling price is very cheap.

ECW is an open Standard for both compression and decompression and compression and serving of large imagery opens up exciting capabilities to GIS, CAD, OFFICE, and web users. They have released both decompression and compression ECW software development kits for ECW, as well as free ECW utilities (with 500 MB limit on input image size; $4,995 for the full ERMapper GIS and unlimited image size) and application plug-ins.

MrSID is the industry standard for encoding and viewing massive raster images in the Geospatial community, and most of the mainstream applications have enabled MrSID viewing technology. The MrSID was sold at $1, 500 for the version with a 500 MB file size limit and $5,000 for the version with unlimited image size and free applications plug-ins were also provided.

The table 3 below lists some important factors for selecting the compressors to do the project. We suggest that EYA and MrSID should be selected to do the image compression when the target compression rate is less than 3. When the target compression rate is getting larger, the effect of the compressed image by different compressors does not have the big difference in viewing, one of the compressors can be selected according to the table 3.

	Compression time			Compression rate			Compression quality			Price		
	1	2	3	1	2	3	1	2	3	1	2	3
EYA		2		1			1			1		
MrSID			3		2			2				3
ECW	1					3			3		2	

Table 3. Ordinal number table obtained according to the compressor's function

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