Compression of Satellite Image Data using the Wavelet Transform
Wavelet Transform을 이용한 인공위성 영상의 압축

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개 요 : 본 연구에서는 고해상도 위성 영상에 관한 압축을 연구하였다. 위성영상은 많은 픽셀 정보와 이루어져 있기 때문에 빠른 영상처리와 데이터 보관을 위해서 압축이 필수적이다. 특히 영상압축시 도로 정보와 건물, 산림, 지형 등의 특징을 왜곡을 최소화하여 압축하여야 한다. 따라서는 본 연구에서는 함수공간에서 영상 압축이 가능한 웨이브렛을 기반하여 위성 영상의 압축기법을 제안하였으며, 일반적인 정지영상 압축 기법인 JPEG과의 압축성능을 분석하였다. 그 결과 웨이브렛 압축기법이 JPEG보다 1/10 이상의 압축 성능을 보였다.

Key words : wavelet, compression, satellite image

1. Introduction

Recently, GIS (Geographic Information System) is aggressively used in various areas such as land use planning, traffic information, location selection for large-sized facilities and environmental variation forecasts(Lillesand, T.M., and Kiefer, R.W., 1994). For the GIS, the concept of remote sensing has been introduced. Remote sensing allows for the creation of a numerical map, through a variety of geographic points of data, by using various image data collected from diverse sensors built into earth resource exploration satellites with the corresponding resolutions varying according to type. The size of high-resolution satellite data is large, and the image should be saved per process and in each step; therefore, effective image compression/decompression is required(1, 2). Accordingly, image compression /decompression methods maintaining both high-resolution and spectrum reflection features should be studied. In this paper, a method to compress/decompress image data effectively while also maintaining high-resolution and spectrum reflection features was studied, and compression performance was analyzed by comparing it with the compression of map images using the Wavelet transform for JPEGs, a standard method.

2. Image Compression

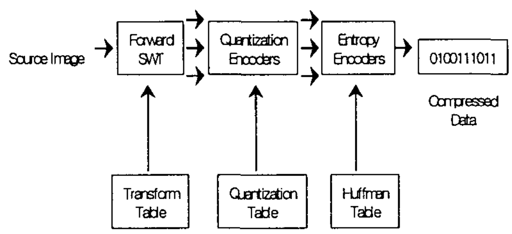
Image compression solves the problem by decreasing the data size required to express a digital image. The compression of the map image should extract redundant or unimportant data to decrease the data size while still maintaining information on roads, buildings, forests, construction sites, etc. Three fundamental redundancies such as coding redundancy, inter-pixel redundancy and psycho-visual redundancy should be removed for compression to be completed.

2.1 Still Image Compression Standard JPEG

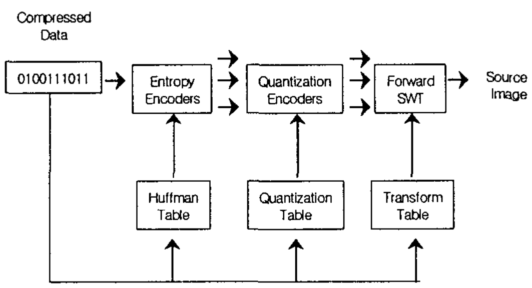
JPEG is a standard compression method and digital compression technology for almost all still images including grayscale and color images(Gonzalez, 1993). JPEG compression utilizes limitations in the human visual system and also uses the same number of operations for compressing and decompressing images, so the time for compressing image data is the same as that for decompressing as it is for the symmetry algorithm.

2.2 Wavelet Image Compression

Generally, the WSQ (Wavelet Scalar Quantization) algorithm is a typical example for the image compression algorithm based on the wavelet transform(Gilbert Strang and Truong Nguyen, 1996). In quantization, wavelet image compression, scalar quantization, vector quantization or trellis quantization is used. In scalar quantization, the data value is scalar. During this type of quantization, actual data loss occurs, and overall, lossy coding is employed. The WSQ compression method is mostly applied and its algorithm structure is shown in Figure 1.



(a) WSQ Encoder



(b) WSQ Decoder

Fig. 1 Structure of WSQ Compression

As shown in Figure 1, the WSQ encoding algorithm consists in three main processes for compression: Wavelet transform for the original image, scalar quantization of the wavelet coefficients and entropy coding of the quantized value. In order to decompress the image, decoding is processed in the opposite direction of the encoding sequence as shown in Figure 1. Additional information on the transform table, quantization table and Huffman table for decoding is required. This information is created during compression. In this study, a high-resolution map image was compressed based on information of the image data file, the demanded compression rate and image data size (width and height) in JPEG compression and WSQ compression methods, and each methods performance was compared.

3. Experiment and Results

In this study, an IKONOS 4m multi-spectral image was compressed and the JPEG and WSQ method were compared in order to verify image compression performance. In procedure for WSQ image compression, first, the image data is transformed from a 16 bit map image at 65536 level gray-scale (16 bit/pixel, grayscale) input data (0 ~ 65535) into real data (-32768.0 ~ +32767.0), maintaining overall scale and shift in order for use again for re-configuring the data when decompressing it.

$$L_d = Min - S, \quad Hd = Max - S \tag{1}$$

$$S = \frac{I_{Max} - I_{Min}}{2} + I_{Min},$$

$$\cdots\cdots \begin{cases} if(Ld > Hd), & S_c = \frac{Ld}{128.0} \\ else & Sc = \frac{H_d}{128.0} \end{cases}$$

$$f_i = \frac{(I-S)}{S_c}$$

, where I is the input data; S is the shift; I_{max} and I_{min} are the maximum and the minimum value of the input data respectively; Sc is the scale; *Max* and *Min* is the maximum and minimum gray-scale level of the image; f_i is the transformed image data. In order to process the wavelet, the overall image data was divided into 20 sub-bands. If 1/2 down sampling is done for one wavelet sub-band, and LPF (Low Pass Filter) and HPF (High Pass Filter) are obtained from Equation (2) and (3), then four sub-bands divided by the frequency per direction are created. The image data was filtered until it had 20 sub-bands. The filter coefficients used are shown in Table 1.

$$a_0 = \sum_{n=0}^{N-1} x(n) h_0(2k-n) \qquad \text{LPF} \tag{2}$$

$$a_1 = \sum_{n=0}^{N-1} x(n) h_1(2k-n) \qquad \text{HPF} \tag{3}$$

Table. 1 coefficients of wavelet filter

Tap	계 수 값
$h_0(0)$	0.85269867900940
$h_0(\pm 1)$	0.37740285561265
$h_0(\pm 2)$	-0.11062440441842
$h_0(\pm 3)$	-0.023849465019380
$h_0(\pm 4)$	0.037828455506995
$h_1(-1)$	0.78848561640566
$h_1(-2,0)$	-0.41809227322221
$h_1(-3,1)$	-0.040689417609558
$h_1(-4,2)$	0.0645388826282938

Quantization was done after distribution for each quantization sub-band. The quantized data was coding-compressed through run length coding and Hoffman coding, and coding was processed by dividing it by two. Decompressing the image was done as in Figure 1(b), absolutely reverse to the compression procedure. After compressing the image at each compression rate and decompressing it, the wavelet method showed less error than the JPEG method, and the results are shown in Figure 3. Here, distortions of roads, buildings, etc. in the map image were found after compressing it into 1/14. Especially, Figures 4, 5 and 6 show serious blocking in the JPEG method after compressing the image into 1/45, showing that high compression in the JPEG method is unsuitable for map image processing. WSQ, however, showed little visually apparent blocking, and can be utilized for land use classification which does not require high resolutions. For roads, there is quite a bit of pixel loss, showing that road vector extraction generates many errors. Therefore, image compression with WSQ shows better performance than compression with the JPEG method.

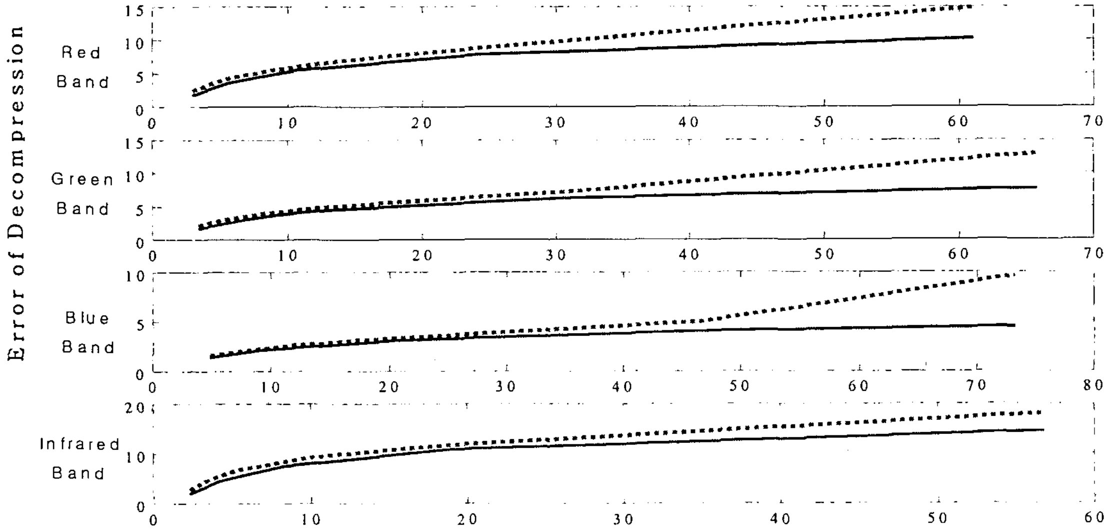


Fig. 3 pixel mean error of compressed multi-spectral image
(JPEG : ···· , WSQ : —)

After decompressing the image compressed at each compression rate, the Wavelet method shows less error than the JPEG method, and the results shows in Figure 3. Here, distortions of roads, buildings, etc. were found in the map image after compressing into 1/14. In the JPEG method, especially, blocking was found in the compressed image; proving that the Wavelet method is a better compression method than the JPEG method.

Fig. 4 IKONOS multi-spectral image with 4m resolution per pixel

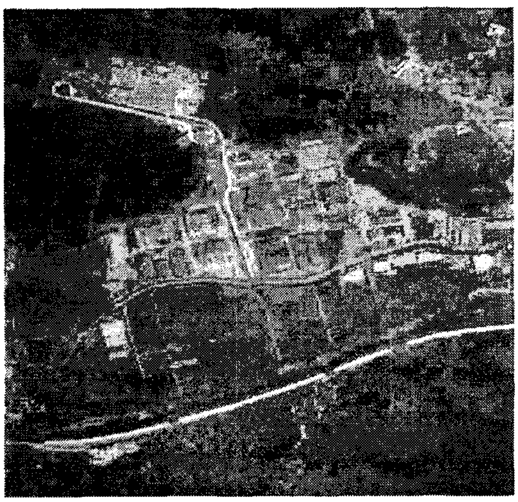


Fig. 5 compressed image as 1/45 using JPEG

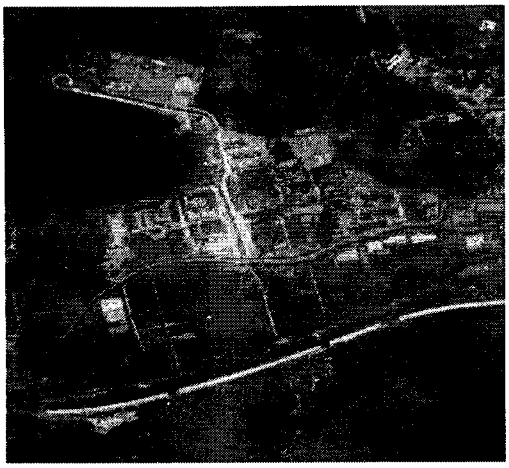


Fig. 6 compressed image as 1/45 using WQS

4. Conclusion

In this paper, the JPEG and WSQ compression methods were compared by compressing high-resolution satellite images with large data. According to the experimental result, roads, building and forests can be visually distinguished at 1/10 in JPEG compression, but show many errors in DEM (Digital Elevation Model) and when extracting contour lines. After compressing it to 1/14 or lower, blocking occurs in forests and land areas, resulting in unsuitability for DEM extraction or land use classification. When comparing the WSQ with JPEG methods when compressing the image to 1/20, roads, buildings and forests provide similar visual results as the JPEG method, but DEM extraction error is lower than when using the JPEG method due to the WSQ algorithms characteristics, which compresses the pixel change for the image functionally. Therefore, the WSQ method is more effective than the JPEG method in compressing/decompressing image data while also maintaining high-resolution and spectral reflection feature .

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