

SAR 디스플레이 영상을 위한 무손실 압축

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LOSSLESS DATA COMPRESSION ON SAR DISPLAY IMAGES

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ABSTRACT

Synthetic aperture radar (SAR) is a promising active remote sensing technique to obtain large terrain information of the earth in all-weather conditions. SAR is useful in many applications, including terrain mapping and geographic information system (GIS), which use SAR display images. Usually, these applications need the enormous data storage because they deal with wide terrain images with high resolution. So, compression technique is a useful approach to deal with SAR display images with limited storage. Because there is some indispensable data loss through the conversion of a complex SAR image to a display image, some applications, which need high-resolution images, cannot tolerate more data loss during compression. Therefore, lossless compression is appropriate to these applications. In this paper, we propose a novel lossless compression technique for a SAR display image using one-step predictor and block arithmetic coding.

1. INTRODUCTION

Synthetic aperture radar (SAR) is a microwave imaging system capable of producing high-resolution imagery from data collected by a relatively small antenna, and SAR is becoming important in various applications such as terrain mapping, auto target recognition (ART), and geographic information system (GIS); specially, some applications like GIS use SAR display images. In general, these applications need enormous data storage because they deal with wide terrain images with high resolution. So, compression is considerable to these applications that process SAR display images with limited storage.

There exist many readily available, effective techniques for general image compression such as JPEG. However, these techniques are not appropriate to the SAR display image compression for several reasons. One

of these reasons is that most of them are lossy compression technique. Because the procedure of making a SAR display image from a SAR complex image results in some information loss unavoidably, more loss by compression is undesirable to the applications that require high-resolution images. So, lossless compression is preferable in the compression of SAR display images. Another reasons are caused by the fact that the existing techniques don't show the good performance in the compression of SAR display images because they are developed for continuous images of which the characteristics are different from those of the SAR display images. Therefore, developing a new lossless data compression method on SAR display images is valuable.

SAR display images have very different characteristics from general images in several aspects [1]. One of the differences is that the SAR display images show less pixel correlation than general images due to speckle. This is the reason why the most existing predictors that reference many previous pixels don't works well with SAR display images. Another reason is that SAR display images consist of various terrains that have different histograms respectively, because SAR display images generally represent very wide area. Under the consideration of these characteristics, we propose a new lossless compression method that uses one-step predictor and block arithmetic coding and is appropriate to the SAR display images.

This paper is organized as follows. Section 2 reviews SAR image characteristics for the explanation of the proposed method. In Section 3, we introduce the new method using one-step predictor and block arithmetic coding. Section 4 presents experimental results with real SAR display images; one of them is shown in Figure 1. Finally, Section 5 presents conclusions.

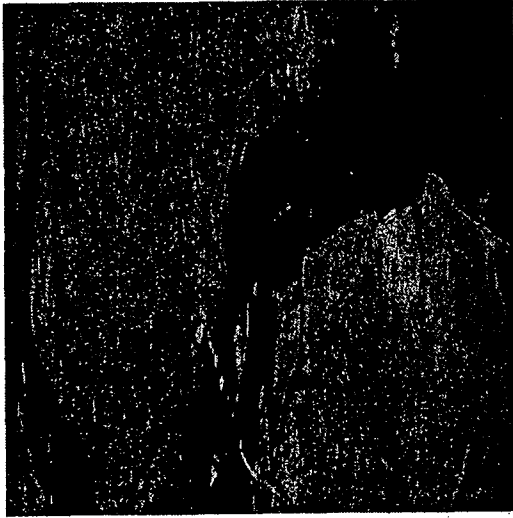


Figure 1. The gulf of Asan SAR image.

2. SAR IMAGE CHARACTERISTICS

SAR systems generate images by coherent processing of the scattered signals. Each resolution cell of the system contains a very large number of randomly distributed scattering elements. Through complex addition the magnitude of terrain reflectivity varies randomly. Sometimes the magnitude is assigned a large value or small value that is inappropriate to the actual terrain. This phenomenon is called speckle that gives the image a grainy appearance. Speckle seems to be a noise and decreases the correlation between neighboring pixels in SAR display images.

In SAR display images, especially spaceborne SAR, many artificial models such as buildings and ports are represented by a few pixels. That causes the less pixel correlation unlike general images.

SAR image is a complex image and its pixel value is a random variable, whose real and imaginary parts are randomly distributed. Considering the very large number of the back-scattered radiation, we can assume that each real and imaginary part has Gaussian distribution by the central limit theorem. Generally, SAR display images are made by mapping the magnitude of the complex image, which is the mean square of two Gaussian random variables. Therefore, SAR display images have Rayleigh distribution.

3. THE COMPRESSION METHOD

Generally, lossless compression follows two stages; the first is a prediction stage and the second is an entropy coding stage. The proposed compression method has the same two stages, one-step predictor as a prediction stage and block arithmetic coding as an entropy coder stage.

There are many prediction schemes for lossless compression [2]. However, most of them are not proper

for the compression of SAR display images because they were developed for general continuous images that have many different properties such as the correlation between neighboring pixels from SAR display images. In SAR display image, little correlation exists with other pixels except adjacent one pixel, so one-step prediction is expected to be appropriate. Actually, one-step predictor shows the better performance in SAR display images than other prediction schemes. To explain one-step predictor, assume that the 8-bits scaled pixel x_n , which belongs to the range $0 \leq x_n \leq 255$, is given as input. Then the predictive value \hat{x}_n is evaluated as

$$\hat{x}_n = \alpha \times x_{n-1}, \quad (1)$$

where x_{n-1} is a previous pixel value and α is a fixed coefficient, which is determined by the correlation between x_{n-1} and x_n experimentally. For the given predictive value \hat{x}_n , the residual error is shown as

$$\varepsilon = x_n - \lfloor \hat{x}_n \rfloor = x_n - \lfloor \alpha \times x_{n-1} \rfloor, \quad (2)$$

where the predictive value is limited to integer by rounding down in order to remain ε as integer for the coding efficiency. In this case, the residual errors from predictor take on values in the range $-\lfloor 255 \times \alpha \rfloor \leq \varepsilon \leq 255$, unlike the range of x_n . So, more bits than 8 are needed to represent a residual error. That degrades the compression efficiency. But, since the decoder can evaluate \hat{x}_n in the same procedure of the encoder, we assume that \hat{x}_n is given, then the residual error is in the range $-\lfloor \hat{x}_n \rfloor \leq \varepsilon \leq 255 - \lfloor \hat{x}_n \rfloor$. So, the residual error can be converted to a value between 0 and 255 by shifting negative residual errors to the backside of maximal residual. As a result, the residual error can also be represented with the same 8-bits.

The second stage is an entropy coding of which the main aim is to reduce the size of the input data sequence to its overall entropy. Huffman coding and arithmetic coding are the most popular entropy coding techniques in the lossless compression area because of their simplicity and good performance. Huffman coding needs the Huffman table that maps the input symbol into a variable-length output codeword depending on the probability of input symbols [3]. So, if the probability of input symbols changes case by case like the SAR display images, it is inevitable to use the side information that holds the Huffman table that is accordant with the characteristic of the input. Because the side information results in the degradation of compression performance, Huffman coding is not so good to the compression of the SAR image. On the other hands, arithmetic coding represents input symbols as an interval of real numbers between 0 and 1 in accordance with the input symbol probabilities generated by the distribution model [4]. In

arithmetic coding, the distribution model can be fixed or updated adaptively. In the case of an adaptive distribution model that represents the changing symbol frequencies seen so far in an input image, initial model state of the encoder is identical to that of the decoder. The encoder receives the next symbol, encodes it, and updates its model. The decoder identifies it according to its current model and then updates its model. Therefore, the distribution model when a certain symbol is encoded is reproduced in the model as decoding the symbol. It means that no side information of the distribution model is need in decoding process, so an adaptive model outperforms a fixed model in terms of compression efficiency where the symbol frequencies vary block by block like SAR display images. Consequently, the proposed method is based on arithmetic coding with an adaptive distribution model for the entropy coding stage.

Generally, because a SAR display image represents very wide area, it includes many various terrains and each terrain image has a different histogram as shown in Figure 2 and Figure 3; Figure 2 is a sample of sea and its histogram, and Figure 3 is for mountains. And residual errors produced by prediction also have different histograms corresponding to each terrain content. Because arithmetic coding uses a histogram in encoding a image, it is appropriate to encode each terrain image separately for improving compression performance. Therefore, we develop a block arithmetic coding that divides SAR display images into uniform blocks with proper size, and processes each block separately.

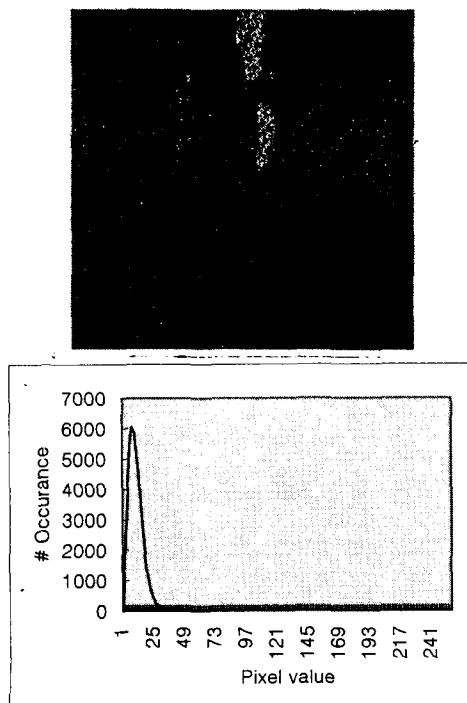


Figure 2. Sea image and its histogram.

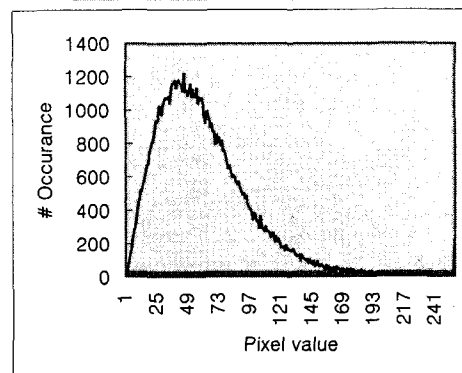
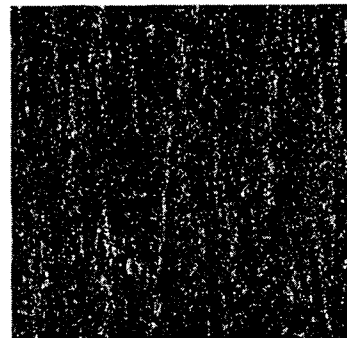


Figure 3. Mountains image and its histogram.

4. EXPERIMENTAL RESULTS

In order to verify the performance of the proposed method, we use 8-bits gray scaled SAR display images of Daejon and the gulf of Asan, which is the ERS-1 SAR SLC images that have 25 meters resolution in range direction and 12 meters resolution in azimuth direction, whose general parameters are given in Table 1.

Table 1. General parameters of ERS-1.

Orbital altitude	785 (km)
Look angle	20.3 (degrees)
Incidence angle	23.0 (degrees)
Azimuth antenna dimension	10 (m)
Range antenna dimension	1 (m)
Frequency	5.3 (GHz)
Chirp bandwidth	15.5 (MHz)
A/D sampling rate	18.96 (Msamples/sec)
Pulse Repetition Frequency (PRF)	1680 (Hz)
Pulse duration	37.1 (μ s)
Azimuth image pixel spacing	3.981 (m)
Range image pixel spacing	7.904 (m)

In one-step predictor of the proposed method, the coefficient α is determined by normalized covariance between x_{n-1} and x_n . The effect of one-step predictor

can be accounted by the entropy of the image content. Table 2 shows the entropy of the test SAR images and the residual error images.

Table 2. Entropy of the test SAR images and residual error images.

	The gulf of Asan 1	The gulf of Asan 2	Daejon
SAR images	6.688	6.540	7.531
Residual error images of after one-step predictor	6.468	6.299	7.461

Table 3 shows the results in compression ratio of several compression methods: arithmetic coding, block arithmetic coding, arithmetic coding with one-step predictor, and the proposed method, block arithmetic coding with one-step predictor. For SAR display image of Daejon, they have high entropy about 7.5, so compression performance is slight. We observe that the block arithmetic coding with one-step predictor gives the best performance among other methods.

Table 3. Compression ratio for various test SAR images.

	The gulf of Asan 1	The gulf of Asan 2	Daejon
Arithmetic coding	1.204	1.228	1.062
Block Arithmetic coding	1.257	1.306	1.066
Arithmetic coding with one-step predictor	1.243	1.274	1.071
Block Arithmetic coding with one-step predictor	1.279	1.331	1.074

5. CONCLUSIONS

In this paper, we have proposed a new lossless data compression method on SAR display images. In the consideration of SAR display image characteristics such as little correlation between neighboring pixels and various histograms depending on the scene, the proposed method is based on one-step predictor and block arithmetic coding. Experimental results confirm the efficiency of our proposed method.

Future work includes the improvement of the predictor in the proposed method for the higher resolution SAR display images obtained by the airborne SAR system.

6. ACKNOWLEDGMENTS

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