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웨이브렛 계수의 텍스쳐 표현에 의한 영상 압축

(Image Compression by Texture Expression Method of Wavelet Coefficients)

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요 약

본 논문에서는 웨이브렛 영역에서 텍스쳐 표현에 기반을 둔 영상 압축 기법을 제시하였다. 웨이브렛 변환 후 고주파 대역의 분산값이 원 영상보다 낮다는 특성을 이용하면, 동질 영역에서의 텍스쳐 표현은 웨이브렛 변환 대역에서 효율적으로 수행될 수 있다. 얻어진 텍스쳐 파라미터는 수신측에 전송되거나 디스크에 저장한 다음 나중에 복원을 위해 사용된다. 대부분의 경우에 있어서 제안한 방식은 기존의 SPIHT 방식과 비교할 때, 압축률이나 복원 영상 화질 측면에서 좋은 결과를 얻을 수 있다.

Abstract

A new scheme for image compression based on texture expression in the wavelet transform domain is presented. After taking wavelet transform, using the fact that the high-pass filtered bands has a lower variance than that of the original, a texture expression for the homogeneous polygonal regions can be more efficiently performed in the wavelet transform domain. The estimated texture parameters are transmitted to the receiver and later used for reconstruction after storing in disk. In most cases, the proposed method has yields good results with respects to the compression ratio and reconstructed image quality when our system has compared to conventional SPIHT scheme.

Keyword : wavelet transform, SPIHT, RMT, ECVQ

I. Introduction

Recently, a number of the image coding schemes based on wavelet transformation is proposed. The advantage of the wavelet transform over more familar transforms such as Fourier or cosine transform lies in the localization of wavelets in both spatial and frequency domains[1] and the multiresolution nature of wavelets[2]. These features can be properly used for image compression.

Current compression algorithms achieve excellent compression performance at transmission rates in the range 0.2 ~ 0.5 bpp, but these systems have their

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interest that usually attempt to minimize an objective image quality, i.e, RMS error.

For many applications, the RMS error fidelity criterion unnecessary limits image compressibility. In order to solve this problem, it is proposed model based image coding, which deals with segmented information like contour, texture. These methods produce fairly high compression ratios, but the reconstructed images often appear artificial; the boundary transitions are too sharp, and the textures are not realistic.

We propose a new image coding scheme by texture analysis in wavelet domain. In wavelet pyramid, medium and high frequency subband regions become more stationary random process and are therefore easier to manipulate in a statistical sense. The simulation results show the high compression ratio and good reconstructed image quality. The results have shown us that our scheme can be used for the very low bit image coding like MPEG-4.

Ⅱ. Characteristics of the Wavelet Transform

The wavelet transform has been successful in improving the quality of reconstructed image and the ratio of compression. It has some characteristics that make it superior to most other traditional transform techniques. Here, we will consider these characteristics of the wavelet transform in details.

A. Energy Concentration

Energy concentration is one of the most important characteristics for digital image compression. Because the wavelet expansions of the image have coefficients that drop off rapidly, the original image can be efficiently represented by a small number of wavelet coefficients. So we can use a large number of small or zero wavelet coefficients for compression. The wavelet transform is near optimal for digital image compression.

B. Efficient Calculation

The wavelet transform has good orthogonal bases, and its lower resolution coefficients can be calculated from the higher resolution coefficients using a filter bank. These characteristics allow a very simple and efficient calculation of wavelet coefficients, perhaps one of the few really useful linear transforms with a complexity that is O(N).

C. Utilization of the Human Visual System

The human visual system has different sensitivity along variant spatial frequencies and directions. It is more accurate at low frequencies than at high frequencies, and more accurate in horizontal and vertical directions than in diagonal directions. At the same time, the wavelet transform decomposes the original image into bands that vary in spatial frequencies and directions. This decomposition matches the human visual system well. It is a good match to the human eye with no visible degradation. It can achieve better image quality than other traditional transform techniques at the same bit rate, or achieve the same image quality at lower bit rate.

D. Progressive Transmission

The wavelet transform decomposes a digital image into a coarse approximation (LL) plus added details (LH, HL, and HH). This decomposition can be recursively applied on the coarse version, and continued to any level to create the desired decomposition. It provides a hierarchical data decomposition for image representation. This decomposition separates components of an image in a way that is superior to most other methods. An important feature of this technique is its successive approximation property : As more details are added, higher resolution image can be obtained. This is very suitable for progressive transmission of digital image.

Ⅲ. Image Compression by Texture Expression

Figure 1 shows a entire system block diagram proposed in this paper. First of all, given image is decomposed into layer 3, the lowest frequency band is entropy coded without quantization, and other bands except LL band in layer 3 and bands with the variance over a given threshold in layer 1 and 2 is coded after quantization. Texture analysis is applied for only bands except above situation. The reason why is that layer 3 have lower resolution and bigger variance than other layer. Because the layer 1 and 2 have high resolution and small variance relatively, the number of region generated by segmentation is small. So we can do simple texture analysis, and expect the image codec with good performance.

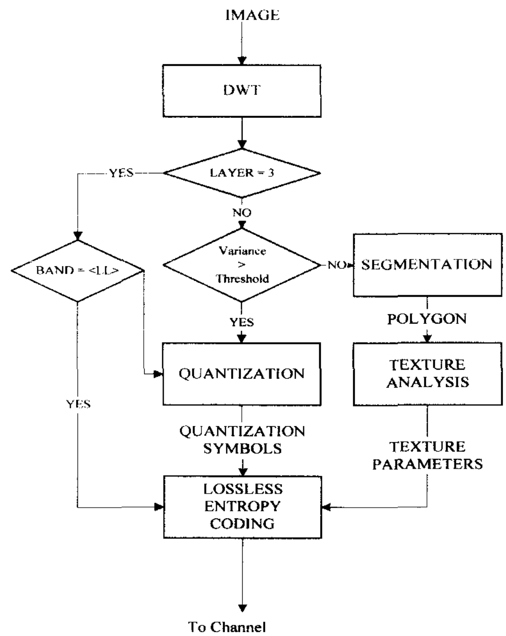


그림 1. 제안한 시스템의 블록도
Fig. 1. Block Diagram of Proposed System.

A. Segmentation

There are numerous viable methods for approaching segmentation, and different methods may be appropriate for different image data types[4]. For the purpose of texture based image coding, it is important to achieve a segmentation that prevents mixing of disparate textures. But, here we do not propose a new method for a segmentation because the purpose of our paper is to show that image coding by texture analysis is very efficient and to prove the possibility that our algorithms can be applied to the next generation image codec. We just use the conventional algorithm for a segmentation, region growing, and confirm the possibility.

After segmentation, the small region is removed, or merged into a large region containing the region. In this time, some wavelet coefficients being included the small region are greater than a given threshold, is called the significant coefficients, are coded and transmitted without removal and merge. These coefficients have heavily influence on image reconstruction.

B. Texture Analysis

In general, the wavelet decomposed bands have the wide homogeneous area. The objective of texture analysis is to produce a small set of parameters that adequately describes the statistics of each polygonal region. Because the subband texture data is zero-mean, it helps our system to get the good results.

For the texture expression, we consider a simple variance model that achieve local correlation by expressing the value of a sample as a only variance of the polygonal region. This model is written as

$$WC_{x,y,k} = M_k + \sigma_k^2 \qquad (1)$$

Where

$WC_{x,y,k}$ Sample at (x,y) position of the kth region

M_k The mean of the kth region

σ_k^2 The variance of the kth region.

In this model, the texture parameters that must be transmitted to the receiver are the mean and the variance σ_n^2. By our experiment, we confirm that this simple model is adequate to poduce realistic homogeneous textures.

C. Quantization and Entropy Coding

This paper apply the ECVQ(Entropy Constrained Vector Quantization) algorithm[5] to quantization of wavelet coefficients. This algorithm begins with a Lagrangian formulation, but in implementation is quite similar to the generalized Lloyd algorithm developed for the constrained number of indexes vector quantizer design problem.

ECVQ is generalized. ECVQ is the coder minimizing the following Lagrangian function.

$$J = E[\rho_n(X^n, \beta(\alpha(X^n))) + \lambda|\gamma(\alpha(X^n))|] \qquad (2)$$

In equation (2), α, maps a source vector X^n into an index, γ, maps the index into a channel codeword, the mapping β outputs a reproduction vector for an index. ρ is the measure of distortion, and n is the dimension of vector. λ is the slope of rate-distortion curved line on convex hull.

For entropy coding we use BPRLC(Bit Plane Run Length Coding)[6], which is adapted to code subband that have the different resolution and the various statistical property.

Ⅳ. Simulation Results

In this paper, we prepare real world images for simulation. Cronkite and Lenna. They have 8 bit gray level with the size 256×256.

The segmentation process have an effect on the simulation result. In first, observe the result of segmentation. Table 1 shows the number of segmented region for each images. In the table, the symbol, Region-Merge-Threshold(RMT), represents the threshold used to merge neighborhood coefficient.

As the RMT increases, the number of region decreases and variance in the region increases. In this state, texture expression for the region have some problems. Observing the table 1, we know that Lenna image have the numerous region over all

표 1. 세그멘트된 영역 수

Table 1. The Number of Segmented Region.

	RMT	Layer 2			Layer 1		
		HL	LH	HH	HL	LH	HH
Lenna	1.0	22	22	14	94	82	56
	2.0	23	17	3	60	26	26
Cronkite	1.0	41	13	7	56	44	16
	2.0	12	8	4	14	27	1

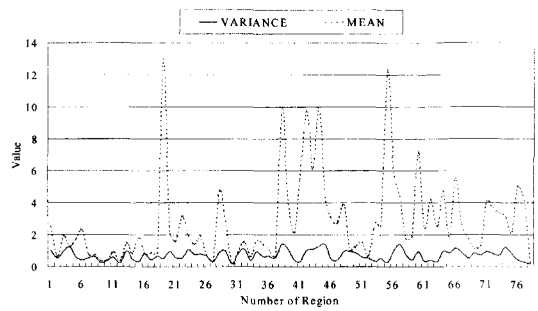


그림 2. 세그멘트 된 영역의 평균과 분산

Fig. 2. The mean and variance of segmented region.

RMT values. The more regions, the more bit rates are required for expressing the region.

In cases of Cronkite image, in HL band of layer 1, the numerous region is generated. The mean and variance of each region after segmentation is showed in Figure 2. This figure exhibits the variance is distributed in the range 0 to 1. So most region can be carefully modeled by the mean and variance.

As shown in Figure 3, original signal and reconstructed signal by texture expression, we can

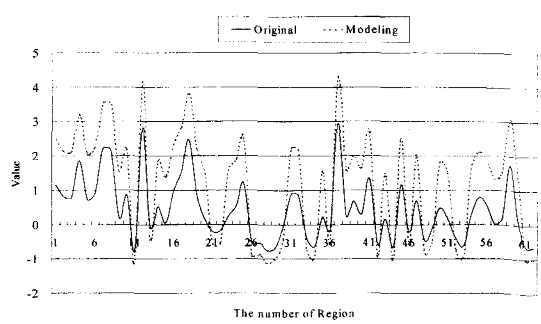


그림 3. 원 텍스춰의 복원

Fig. 3. Reconstruction of Original Texture.

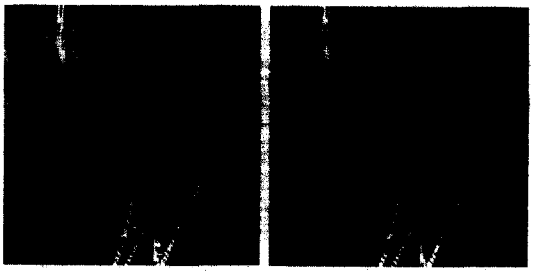


그림 4. Cronkite 영상에 대한 텍스춰 표현 결과 (왼쪽) 원영상 (오른쪽) 복원영상

Fig. 4. The result of Texture Expression for Cronkite image (Left) Original (Right) Reconstructed.

표 2. 부호화 결과

Table 2. The Coding Results

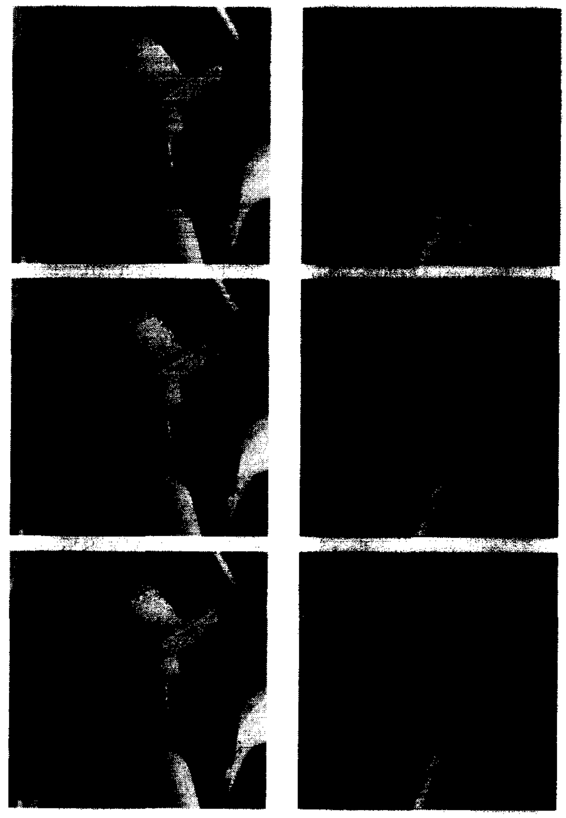
MCT		3		5		7		9		SPIHT	
RMT		1	2	1	2	1	2	1	2		
Cronkite	bpp	0.35	0.18	0.21	0.09	0.1	0.08	0.08	0.07	0.1	0.2
	PSNR	42.2	36.2	37.7	33.5	33.8	29.5	29.6	26.7	32.2	35.2
Lenna	bpp	0.41	0.32	0.23	0.21	0.15	0.1	0.09	0.08	0.1	0.2
	PSNR	36.9	33.5	29.8	28.4	24.5	23.9	20.9	20.4	24.2	28.5

be expect a good reconstructed image quality because the difference original and reconstruction is small.

Figure 4 shows the shape generated by texture expression for the HL band in layer 1 in multi-layered Cronkite image. The edge is well reconstructed with some errors.

Table 2 is the coding result by texture analysis for each image. The symbol, MCT, in the table represent the threshold to determine the significant coefficient. This table shows that the proposed coding method has better performance than SPIHT scheme[7], especially at a image having low complexity like Cronkite.

In table 2, the relationship MCT and bit rates have inverse proportion. Through this table, we select a MCT value, 5, considering rate-distortion. This equals to the fact that coefficients less than 5 have not influence on image reconstruction. From the result shown as in Fig 5, the image having the complexity in the spatial domain does not represent the good performance.



(Top) Original Images (Middle) MCT = 5, RMT = 1 (Bottom) MCT = 3, RMT = 1

그림 5. 복원 영상

Fig. 5. The Reconstructed Images.

V. Conclusion

In this paper, we propose a new scheme for image coding based on texture analysis in the wavelet domain. Texture analysis is performed in the wavelet domain within regions that have been determined to be homogeneous by an spatial frequency-domain texture segmentation algorithm. The quality of the result depends heavily on the quality of the segmentation. The intention of this paper was to prove the effectiveness of image coding based on texture expression in the wavelet domain, and shows the possibility to use our algorithms for image codec in future. We are going to study better scheme for expressing boundary information of segmented region and texture expression.

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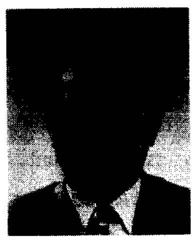

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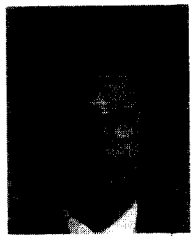

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