Journal of the Korea Industrial Information Systems Research Vol. 20 No.5, Oct. 2015 :53-60
http://dx.doi.org./10.9723/jksiis.2015.20.5.053 ISSN:1229-3741

선택적인 DCT 상수의 사용과 이미지압축 품질에 관한 연구

(Research on Image Compression Quality and Limited Inclusion of DCT Coefficient)

문 병 현[1)*]
(Byung-Hyun Moon)

요 약 본 논문에서는 DCT 상수를 선택적으로 사용하는 무손실 이미지 압축시스템을 Lenna, Cameraman 및 제안하였다. 복원된 영상의 적정한 화질에 필요한 DCT 상수를 구하기 위하여 컴퓨터 시뮬레이션을 실시하였다. 실험에 사용된 영상의 크기는 256x256 이다. 제한적으로 선택된 DCT 상수를 사용하여 복원된 영상의 PSNR값을 도출하였다. 복원된 Lenna, Cameraman 및 Baboon 영상의 PSNR값이 최소 30이 되기 위한 상수의 개수는 각 각 $N=16,32,,37,55$로 주어졌다. 본 논문에서 구해진 결과는 Lenna, Cameraman, Baboon 영상 복원영상과 선택적 DCT 상수의 중요도를 결정하는 기준을 제공한다.

핵심주제어 : DCT계수, 이미지압축, PSNR

Abstract In this paper, the DCT based lossless image compression system which selects a limited number of DCT coefficients is proposed for the Lenna, Camerman, and Baboon image. The number of DCT coefficients to obtain a suitable image quality for the reconstructed image is computed by simulation. The image size of 256X256 are used in the experiment. The PSNR values for the reconstructed image by selecting limited number of DCT coefficients are found. It is shown that the minimun number of the coefficients for Lenna, Cameramen Baby and Babbo image to obtain PSNR=30 are $N=16, 32, 37, 55$, respectively. The result can provide the guideline of the importance of the DCT coefficient toward the compression for the tested image of the Lena, Cameraman, and Baboon.

Key Words : DCTcoefficient, Image Compression, PSNR,

1. Introduction

JPEG is the most frequently used image compression algorithm. Visual signals such as compressed still images suffers various channel noise. Reliable transmission of high quality images through noisy communication channel requires some kind of techniques to overcome the errors introduced by the channel. Numerous papers have been researched on UEP(Unequal Error Protection) on the transmission of the DCT compressed images

* Corresponding Author : bhmoon@daegu.ac.kr
† 이 논문은 2013학년도 대구대학교 학술 연구비 지원에 의하여 연구되었음.
Manuscript receivrd September 16, 2015 / revised October 23, 2015 / accepted October 29, 2015
1) 대구대학교 정보통신공학부, 제1저자, 교신저자

[1-4]. In [1], a scheme to improve the quality of the DCT compressed image transmission by the Turbo UEP(Unequal Error Protection) code is proposed. High error protection region where a DC component and low frequency AC components included is defined to use unequal error protection. It is shown that the PSNR values for the Lenna image with UEP scheme obtained 37.5 while EEP scheme obtained 37.411 with SNR=2.5dB. A family of pre/post-filters is designed to provide desired tradeoffs between coding efficiency and robustness to transmission[5-6]. In order to understand the characteristics of the DCT coefficients with the quality of the image, numberous researches have been performed. In [7], the characteristics of different DCT coefficients are studied. Experimental results showed that the robustness of all the low frequency coefficients is inferior to the single DC coefficient when watermarking is embedded.

In this paper, a DCT based image compressed system with a selected number of DCT coefficients is proposed. By increasing the number of included DCT coefficients from 1 to 60, the PSNR value for the reconstructed images for the Lenna, Cameraman, Baby and Baboon are obtained by simulations. The rest of the paper is organized as follows. In section 2, the proposed system, the 2-dimensional DCT, a DCT coefficient selector, and an example of a DCT coefficient of an 8x8 image block are explained. The simulation results for the reconstructed images with different number of selected DCT coefficient for Lenna, Cameraman, Baby and Baboon are described in Section 3. Finally, conclusion is made in Section 4.

2. DCT-Based Compression

2.1 The Proposed System

Fig. 1 shows the key processing steps which are key steps of the proposed image compression system. The proposed DCT based lossless image compression system which consists of a FDCT(Fast Discrete Cosine Transform) and DCT coefficient selector. The reconstructed image is obtained by performing IFDCT(Inverse Fast Discrete Cosine Transform) on the compressed image with selected DCT coefficients by the DCT coefficient selector. The size of source images used in this paper is 256X256.

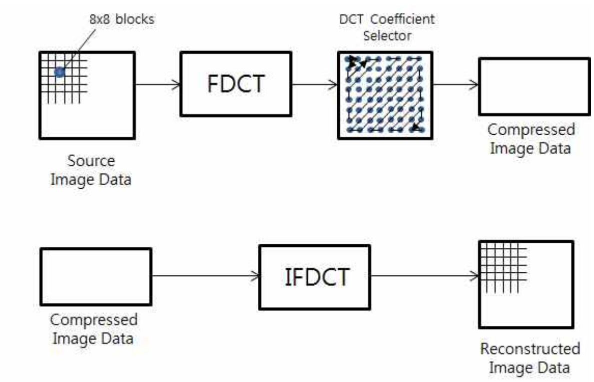

Fig. 1 DCT based Image Compression

2.2 2-Dimensional DCT

At the input to the DCT based image compression, source image samples are grouped into 8x8 block and input to the Forward DCT(FDCT). At the output from the system, the Inverse DCT(IDCT) outputs 8x8 sample blocks to form the reconstructed image. Fig. 1 shows the key processing steps which are key steps of the proposed image compression system. The proposed DCT based lossless image compression system which consists of a FDCT(Fast Discrete Cosine Transform) and DCT coefficient selector. The reconstructed image is obtained by performing

IFDCT(Inverse Fast Discrete Cosine Transform) on the compressed image with reduced DCT coefficients. The following DCT equations (1) computes the i,j^{th} entry of the DCT of an image

$$D(i,j) = \frac{1}{\sqrt{2N}} C(i)C(j)f(x,y)\cos\left[\frac{(2x+1)i\pi}{16}\right] * \cos\left[\frac{(2y+1)j\pi}{16}\right] \quad (1)$$

$$f(x,y) = \sum_{i=0}^{7}\sum_{j=0}^{7} C(i)C(j)F(i,j)\cos\left[\frac{(2x+1)i\pi}{16}\right] * \cos\left[\frac{(2y+1)j\pi}{16}\right] \quad (2)$$

where $C(i), C(j) = 1/\sqrt{2}$, for $i,j = 0$
$C(i), C(j) = 1$, $otherwise.$

The variables $x \& y$ are the indexes in the spatial domain, and $i \& j$ are the indexes in the frequency domain.

2.3 DCT Matrix

To get the matrix form of Equation (1), we will use the following equation

$$T_{i,j} = \begin{bmatrix} \frac{1}{\sqrt{N}} & \text{if}, i=0 \\ \sqrt{\frac{2}{N}} cos\left[\frac{(2j+1)i\pi}{2N}\right] & \text{if}, i>0 \end{bmatrix} \quad (3)$$

For an 8x8 block, it results in matrix T as shown in equation (4).

$$T = \begin{bmatrix} 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 \\ 0.4904 & 0.4157 & 0.2778 & 0.0975 & -0.0975 & -0.2778 & -0.4157 & -0.4904 \\ 0.4619 & 0.1913 & -0.1913 & -0.4619 & -0.4619 & -0.1913 & 0.1913 & 0.4619 \\ 0.4157 & -0.0975 & -0.4904 & -0.2778 & 0.2778 & 0.4904 & 0.0975 & -0.4157 \\ 0.3536 & -0.3536 & -0.3536 & 0.3536 & 0.3536 & -0.3536 & -0.3536 & 0.3536 \\ 0.2778 & -0.4904 & 0.0975 & 0.4157 & -0.4157 & -0.0975 & 0.4904 & -0.2778 \\ 0.1913 & -0.4619 & 0.4619 & -0.1913 & -0.1913 & 0.4619 & -0.4619 & 0.1913 \\ 0.0975 & -0.2778 & 0.4157 & -0.4904 & 0.4904 & -0.4157 & 0.2778 & -0.0975 \end{bmatrix} \quad (4)$$

2.4 DCT Coefficient Selector

As shown in Fig. 3, the DCT coefficient are selected according to the order of the zig-zag sequence as shown in Fig. 2. For example, 3 coefficients are selected according to the zig-zag sequence order as shown in the first example of the Fig. 3. Similar example of $N = 20$ is shown in Fig 3 that includes 20 coefficients of the FDCT out of 64 coefficients.

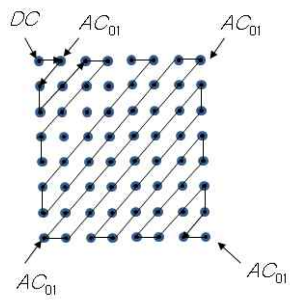

Fig. 2 Zig Zag Sequence

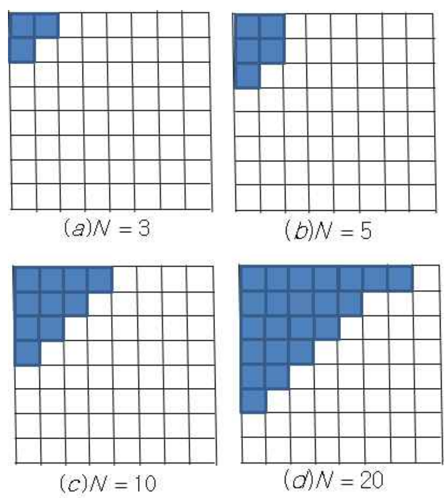

Fig. 3 Coefficient Selection Example

3. Example of a DCT Coefficient Selector for an 8x8 image block

In this section, a DCT coefficient selector for an 8x8 Lenna image block is explained. A DCT coefficient selector of $N=3$ as shown in, Fig. 2 (a)> is explained. As shown in (5), an 8x8 Lenna image block is represented in matrix B.

$$B=\begin{bmatrix} 137 & 135 & 133 & 136 & 138 & 133 & 135 & 132 \\ 137 & 137 & 133 & 136 & 137 & 135 & 134 & 132 \\ 138 & 133 & 134 & 135 & 136 & 131 & 130 & 130 \\ 133 & 133 & 132 & 130 & 134 & 133 & 128 & 125 \\ 129 & 132 & 131 & 130 & 134 & 131 & 132 & 128 \\ 131 & 134 & 130 & 122 & 132 & 130 & 130 & 130 \\ 131 & 130 & 130 & 130 & 132 & 132 & 127 & 130 \\ 131 & 132 & 130 & 130 & 131 & 131 & 131 & 128 \end{bmatrix} \quad (5)$$

In order to perform the Discrete Cosine Transform, the following matrix multiplication as shown in equation(6) is accomplished. In equation (6) matrix M is first multiplied on the left by the DCT matrix T in equation (4); this transforms the row. The columns are then transformed by multiplying on the rignt by the transpose of the DCT matrix. This will make the matrix D as shown in equation (7).

$$D=TMT' \quad (6)$$

$$D=\begin{bmatrix} 4.1407 & 0.0282 & -0.0124 & 0.0275 & 0.0015 & -0.0154 & -0.0081 & 0.0123 \\ 0.0572 & 0.0119 & -0.0082 & 0.0037 & 0.0147 & 0.0107 & -0.0078 & -0.0003 \\ 0.0224 & -0.0053 & 0.0041 & -0.0025 & 0.0090 & 0.0085 & -0.0045 & -0.0077 \\ -0.0045 & -0.0144 & 0.0101 & -0.0007 & -0.0075 & -0.0112 & -0.0057 & 0.0078 \\ -0.0054 & -0.0027 & -0.0111 & 0.0016 & -0.0074 & 0.0071 & -0.0076 & 0.0004 \\ -0.0087 & 0.0072 & -0.0047 & 0.0025 & 0.0082 & -0.0007 & 0.0117 & -0.0010 \\ -0.0035 & 0.0043 & 0.0121 & -0.0012 & -0.0000 & -0.0013 & -0.0021 & 0.0113 \\ 0.0052 & -0.0043 & -0.0086 & -0.0084 & 0.0127 & 0.0103 & -0.0002 & -0.0008 \end{bmatrix} \quad (7)$$

The coefficient selector choose the first 3 DCT coefficients of the D to make the selected matrix of S as shown in equation (8).

$$S=\begin{bmatrix} 4.1407 & 0.0282 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0572 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (8)$$

The reconstruced image is obtained as shown in equation (9) by performing IFDCT by using the selected coefficients of the matrix S.

$$R=\begin{bmatrix} 0.5324 & 0.5316 & 0.5303 & 0.5285 & 0.5265 & 0.5247 & 0.5234 & 0.5226 \\ 0.5309 & 0.5301 & 0.5288 & 0.5270 & 0.5250 & 0.5232 & 0.5219 & 0.5211 \\ 0.5281 & 0.5273 & 0.5260 & 0.5242 & 0.5222 & 0.5204 & 0.5191 & 0.5183 \\ 0.5244 & 0.5237 & 0.5223 & 0.5205 & 0.5186 & 0.5168 & 0.5154 & 0.5147 \\ 0.5205 & 0.5198 & 0.5184 & 0.5166 & 0.5146 & 0.5128 & 0.5115 & 0.5107 \\ 0.5169 & 0.5161 & 0.5147 & 0.5129 & 0.5110 & 0.5092 & 0.5078 & 0.5071 \\ 0.5141 & 0.5133 & 0.5119 & 0.5102 & 0.5082 & 0.5064 & 0.5050 & 0.5043 \\ 0.5126 & 0.5118 & 0.5104 & 0.5086 & 0.5067 & 0.5049 & 0.5035 & 0.5028 \end{bmatrix} \quad (9)$$

4. Simulation Results

The original 256x256 images of Lena, Cameramam, Baby and the Baboon are compressed with the selected DCT coefficients and reconstructed in the simulation. The experiments are done in turn selection from $N=1$ to $N=60$ coefficients to use to reconstruct the original images. In order to observe the reconstruced image quality, the PSNR(Peak Signal and Noise Ratio) is measured from the reconstructed image. The expression for the PSNR is given by the equation (10).

$$PSNR=10\log\left(\frac{f_{P-P}^2}{MSE}\right)=10\log\left(\frac{255^2}{MSE}\right) \quad (10)$$

where

$$MSE=\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}[D(i,j)-R(i,j)]^2. \quad (11)$$

$D(i,j)$ represents the original image and $R(i,j)$ represents the reconstructed image.

The PSNR values for the reconstructed images for the Lenna, Cameraman, Baboon and Baby are summarized in Table 1 to Table 4.

Table 1 PSNR Value for the Reconstructed Lenna Image

N	PSNR	N	PSNR	N	PSNR
1	20.1025	10	28.0154	26	32.4198
2	22.4792	12	28.3380	30	33.4895
3	23.8620	14	29.7619	35	35.1100
4	24.4772	16	30.0263	40	35.9833
5	24.7191	18	30.8831	45	37.9845
6	26.4878	20	31.4615	50	39.7396
7	27.0211	22	31.5829	55	42.6653
8	27.5407	24	31.8634	60	46.8048

Table 2 PSNR Value for the Reconstructed Cameraman Image

N	PSNR	N	PSNR	N	PSNR
1	19.1642	10	24.4207	26	27.0631
2	20.4560	12	24.8405	30	28.4352
3	21.4915	14	25.2712	35	31.2494
4	21.7221	16	25.7689	40	34.5379
5	22.1820	18	26.1693	45	37.6070
6	23.4547	20	26.4994	50	39.6055
7	23.7749	22	26.6938	55	44.4164
8	23.8926	24	26.7660	60	49.0584

Table 3 PSNR Value for the Reconstructed Baboon Image

N	PSNR	N	PSNR	N	PSNR
1	18.5700	10	20.4792	26	22.5754
2	18.9890	12	20.6636	30	22.9554
3	19.3538	14	21.0012	35	23.8418
4	19.5132	16	21.1583	40	25.0202
5	19.7244	18	21.3790	45	25.9566
6	19.9174	20	21.6561	50	27.7150
7	20.0254	22	21.9928	55	29.6974
8	20.1808	24	22.3180	60	33.7376

Table 4 PSNR Value for the Reconstructed Baby Image

N	PSNR	N	PSNR	N	PSNR
1	20.1200	10	24.9624	26	27.9611
2	20.9807	12	25.3881	30	28.6477
3	22.5353	14	25.8157	35	29.4783
4	22.8542	16	26.4887	40	30.5014
5	23.2505	18	26.9086	45	31.9462
6	24.0289	20	27.4013	50	33.3205
7	24.1660	22	27.6940	55	35.2839
8	24.3622	24	27.6415	60	38.5898

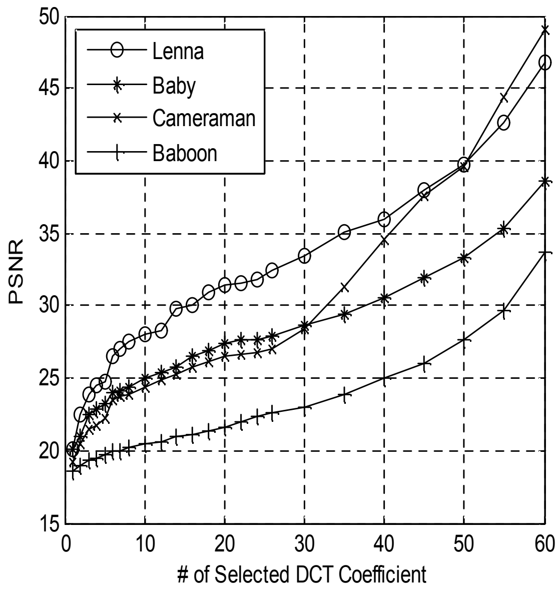

Fig. 4 PSNR value with number of selected DCT Coefficienting

Fig. 4 shows the PSNR value with the selected number of DCT coefficients to reconstruct the images. When the DC coefficient is selected, the PSNR value for the reconstructed image is given by close to 20 for the 4 images. However, as the number of selected AC coefficients are increased, the PSNR values are varied drastically from image to image. For example, the required number of DCT coefficients for PSNR=30 is $N=16$ for the image Lenna. $N=32$ is necessary for the

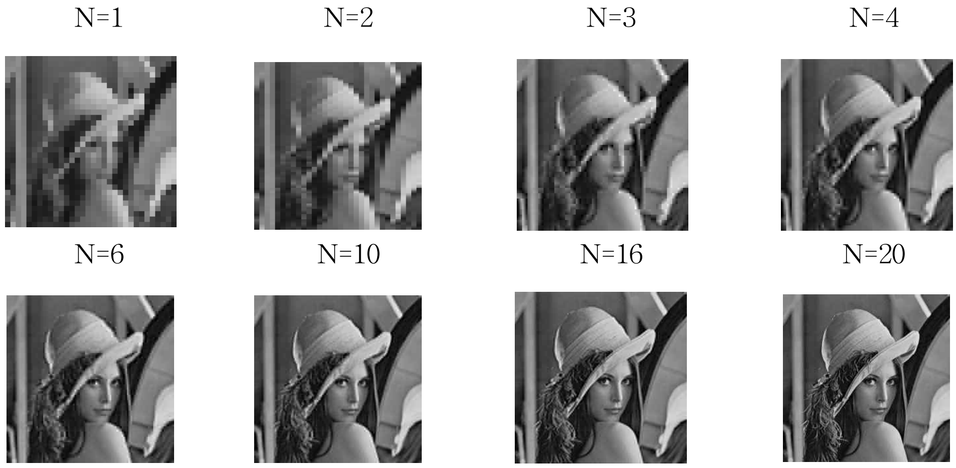

Fig. 5 Restored Lenna image with limited number DCT Coefficient

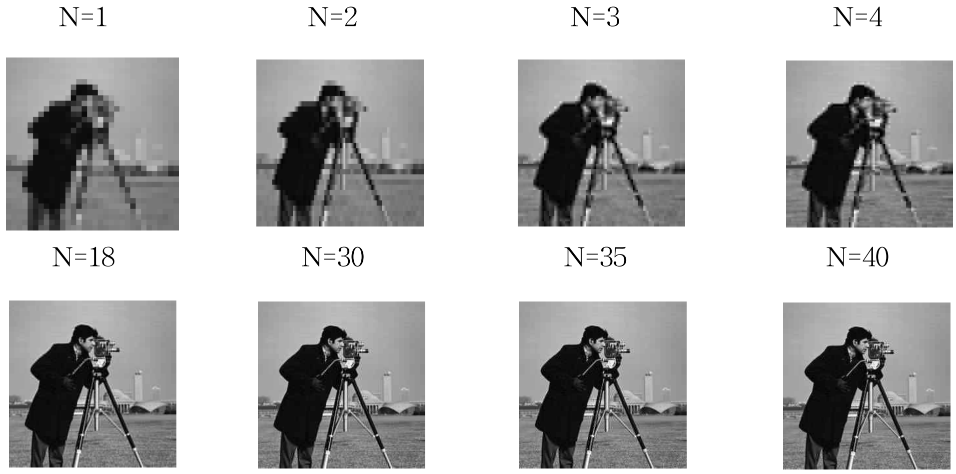

Fig. 6 Restored Cameraman image with limited number DCT Coefficient

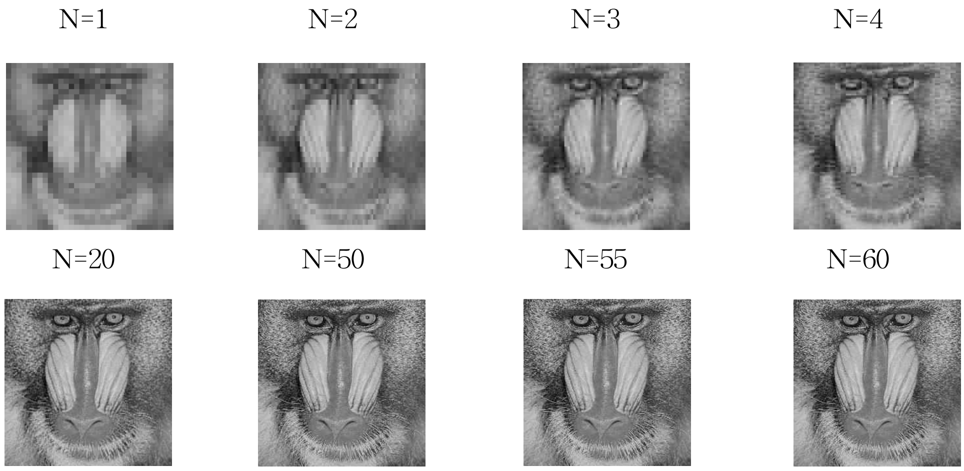

Fig. 7 Restored Baboon Image with limited number DCT Coefficient

image Cameraman to get PSNR=30. For the case of a Baby image, $N=37$ is required to reach PSNR=30. Finally, The number of selected coefficient $N=55$ is obtained for the Baboon image. The reconstructed images with varying inclusion of the DCT coefficients are shown in Fig. 5 to Fig. 8.

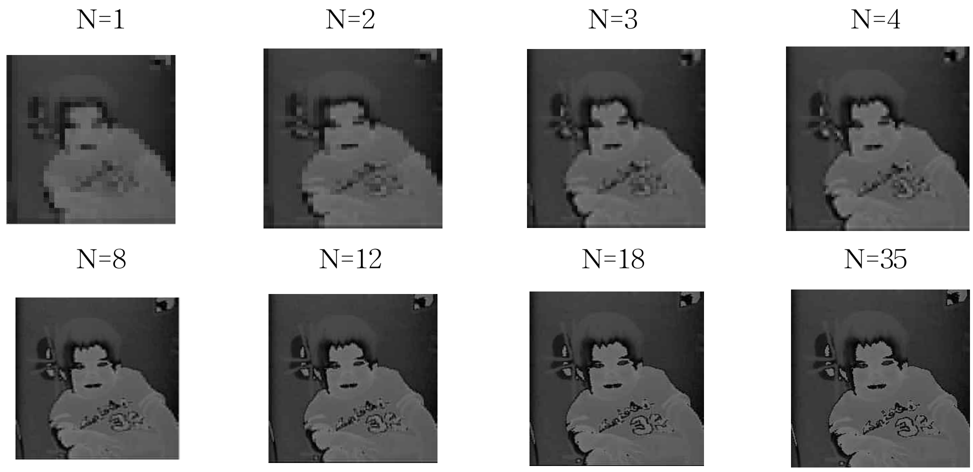

Fig. 8 Restored Baby image with limited number DCT Coefficient

Therefore, the number of selected coefficients can be varied by the required quality of the reconstructed image. As shown in [1]-[5], the UEP(Unequal Error Protection) is used for the DCT coefficient to improve PSNR. The UEP can be replaced by varying number of selected coefficient of the DCT coefficient to meet the required PSNR. The results shown in this paper can give the guideline of the PSNR value with the selected DCT coefficients.

5. Conclusion

In this paper, a lossless DCT based image compression with DCT coefficient selector is proposed. The PSNR value for the reconstructed image with selected number of DCT coefficients are presented by simulation.

Four images of 256x256 Lenna, Cameraman, Baboon and Baby are used in the simulations. It is shown that the required number of DCT coefficients for PSNR=30 is varying drastically depending on the image. The number of DCT coefficients for the reconstructed image with PSNR=30 are given by $N=16$, 32 37 and 55 for the image of Lenna, Cameraman, Baby and Baboon, respectively. The effect of AC component for PSNR of the reconstructed image is different depending on the image. The sharp increase of PSNR is observed for the Lenna image with a few inclusion AC components followed by Baby, Cameraman and Baboon image.

The PSNR values for the reconstructed image of Lenna, Cameraman, Baby and Babbon with selected number of DCT coefficients can be used as the guideline of image quality control.

References

[1] Q. Mao, B. Xu and Y Qin, " A New Scheme to Improve the Quality of

Compressed Image Transmission by Turbo Unequal Error Protection Codes", Seventh International Conference on Intelligent Information Hiding and Multimedia Signal Processing, pp. 226-229, 2011.
[2] P Ma and K. Kwak, "UEP-LDPC Codes with high Spectral Efficiency in Image Transmission", 5th International Conference on Wireless Communications, Networking and Mobile Computing, pp. 1-4, 2009.
[3] Y. Zhang and D. Yuan, "Image Transmission in LDPC Coded Mobile Satellite Communication Systems", ICICIC' 2006, Vol.2, pp.475-461, 2006.
[4] B. Xu et. ei., "Research on Unequal Error Protection with Irregular LDPC and Application on Image Transmission", CISP' 2009, pp.1-5, 2009.
[5] L. Xu et. el., "Unequal Error Protection for Radiography Image transmission Using Protpgraph Double LDPC Codes", Wireless Telecommunications Symposium, pp. 1-5, 2013.
[6] C. Tu, T. Tran and J. Liang, 'Error Resilent Pre/Post-Filtering for DCT-Based Block Coding Systems," IEEE Trans. on Image Processing, Vol. 15, No. 1, Jan. pp. 30-39, 2006.
[7] Y. Wang and Q. Zhu, "Error Control and Concealment for Video Communication: A review," Proc. IEEE, Vol. 86, No. 5, pp. 974-997, May 1998.
[8] J. Xiao and Y. Wang, "Toward a Better Understanding of DCT Coefficients in Watermarking", IEEE Pacific-Asia Workshop on Computational Intellignece and Industrial Application, pp. 206-209, 2008.

문 병 현 (Byung-Hyun Moon)

- 정회원
- 1985년 6월 : Southern of Illinois University 전자공학과 (공학사)
- 1987년 6월 : University of Illinois(Urbara-Campaign) 전자공학과 (공학석사)
- 1990년 12월 : Southern Methodist University 전자공학과 (공학박사)
- 1991년 9월 ~ 현재 : 대구대학교 정보통신공학부 교수
- 관심분야 : RFID, 통신이론, 무선통신