A comparative study of medical image applications: compression and transmission†

조 규 철, 김 재 준*
(Kyu-Cheol Cho, Jae-Joon Kim)

Abstract PACS is an integrated communication network system which is consists of image acquisition devices, storage archiving units, display stations, computer processors, and database management systems. In medical industry, they have been introduced the medical equipments through PACS systems based on the DICOM standard. In this paper, we have reviewed the visual quality performance of various JPEG and JPEG2000 compression options for medical images. Through the realized the transmission mode on DICOM standard, the developed DICOM viewer has been shown in medical applications.

Key Words : PACS, DICOM, JPEG, JPEG2000, transmission mode.

1. Introduction

Picture Archiving and Communication Systems (PACS) has been developed in achieving high functions such as remote diagnosis, 3D stereopsis, and functions of moving picture. Historically, PACS is a concept perceived in the early 1980s by the radiology community as a future method of practicing radiology.

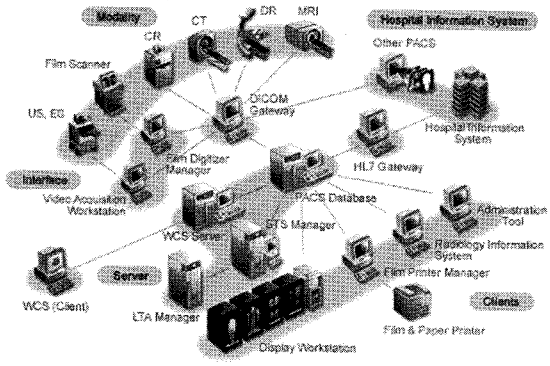
In the image compression, JPEG and JPEG2000 have been adopted in international standard for lossy, lossless, and nearly lossless compression of still images. The DICOM (Digital Imaging and Communications in Medicine) subcommittee also gives an impetus to develop the compression technology supported in DICOM. In addition, the image transmission is one of the major parts for the physicians. To explore the transmission performance, the transmitted images were decoded and evaluated in terms of peak signal-to-noise ratio (PSNR) on a sequential and progressive transmission mode.

Interest of latest PACS trend is focusing on remote image diagnostic (teleradiology). Patients usually wait for hours before hearing physician's results from an MRI, CT or ultrasound test because radiologists are not always in residence to view the data. In order to avoid the inconvenience, the new web-based teleradiography system has been adopted network access and allows images from an MRI, CT or ultrasound test to be viewed by a radiologist from another location as long as there is Internet access [1].

Figure 1 shows the overall full PACS system. It describes that PACS captures X-ray, MR, CT and ultrasound images in a digital format and allows these images to be accessed by physicians via computer for the immediate diagnosis. PACS

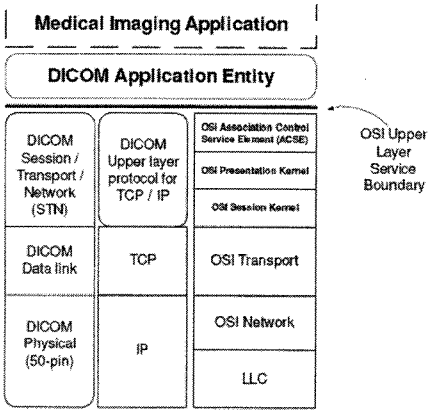
† This research was supported (in part) by the Daegu University Research Grant, 2007.
* 대구대학교 정보통신공학부 조교수

consists of image acquisition devices, storage archiving units, display stations, computer processors, and database management system [2]. These components are integrated by a communication network system based on medical image standard.



<Fig. 1> A schematic for full PACS.

DICOM is not just a file format for medical images but a communications protocol that has been adapted world-wide [3][4][5]. In general, DICOM specifies that image information represents an Information Object which is defined in Information Object Definition (IOD). A Composite IOD is an Information Object Definition which represents parts of several entities included in the DICOM model of the real-world such as a patient's name, an examination type, a date and etc. With specific values, when an instance of a composite IOD is communicated, this entire context is exchanged between application entities. The commanding words are relating to Service Classes which are defined in DICOM Message ServiceElement (DIMSE) [6]. In this paper, we have used some standard (Part 3) among current DICOM standards. Figure 2 describes the general DICOM mode.



<Fig. 2> A general DICOM model [6].

In this paper, in what follows we will first introduce the concept of the realization for image compression and transmission on medical application are presented. In section 3, experimental results are presented and we conclude in Section 4 with discussions and future works.

2. Principles of image compression and transmission

A medical image requires very high quality and high volume. For example, an acquired chest image in CR amounts one image size to 7 ~ 8 MB. When an image from various equipments is deciphered by interpretation doctor or stores for conservation to long term storage device etc., it should be compressed without the influence on next interpretation. Therefore, compression and transmission technology should be highly considered in PACS.

In DICOM standard, the compression technology specify in lossy or lossless methods such as JPEG, run-length encoding, or JPEG-LS. Currently, JPEG2000 in [7] is added in new standard of DICOM image compression. Another considerable point of PACS could be a transmission of scanned image. Unlike the high-transmission environment, it is necessary to

consider the transmission component such as bit rate or number of scans. In the following subsection, we review the basic technology in terms of bit-rate compression performance and transmission schemes.

2.1 Image compression

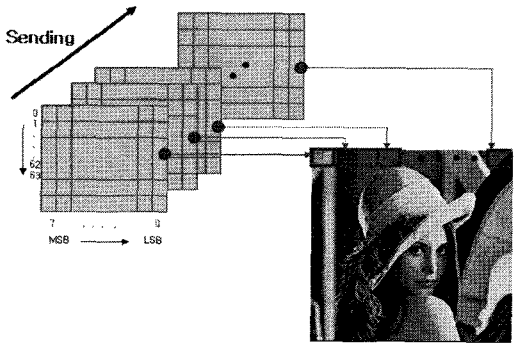
The JPEG [8][9] standard for the image compression is comprised of a toolkit that has three distinct components: baseline lossy, extended lossy, and lossless. A baseline lossy JPEG - the most widely implemented of the three schemes, utilizes the discrete cosine transform (DCT) to decompose an image into sets of spatial frequency coefficients. The characteristics of JPEG2000 [10][11] can embody the lossy and lossless compression at the same time in one encoded bit stream, and has shown more excellent quality than the existent JPEG with the high compressibility. In addition, JPEG2000 in a sense of ROI (region of interest) coding [12] has some advantages to apply to the techniques such as watermarking or labeling. Also, it has a various bit-depth in compression and supports the compression of motion image. The strength of JPEG2000 has the capability of tiling. Since JPEG processes 8x8 subimage tiling and DCT, it is tended to the block-shape artifact in a high compression ratio. On the other hand, JPEG2000 has an advantage enhancing the quality of image or reducing a usage of memory by tiling the image. Also, DCT in JPEG changes an image to characteristic of frequency, but JPEG2000 has the scalability by scale or resolution based on DWT (discrete wavelet transform) [13].

The moving picture compression of the medical image was discussed at MPEG in 2002 but that issue was not decided yet as DICOM base standard in 2003. Moving picture in PACS means that multi-frame DICOM images were generated followed by animated with the captured still images.

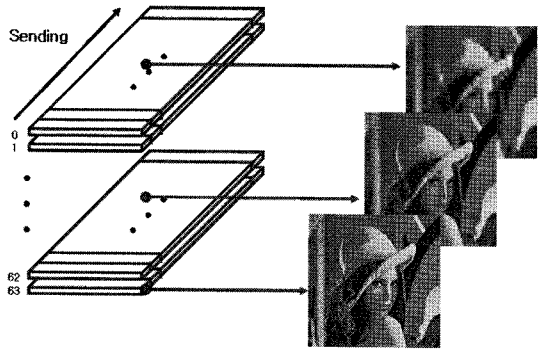
2.2 Image transmission

The aim of this section is to realize the visual data transmission under the medical environment with JPEG transmission schemes. The physicians still requested the lossless data to ensure the detection of the patient's disease. The compression methods in the case of the incremental transmission enable the progressive transmission of the whole image starting with low-resolution, and then gradually increasing the resolution. In many practical situations (i.e., large images transmitted over low-speed connections), it is not feasible to transmit the whole image at the high resolution. In this paper, we reviewed the sequential and progressive transmission schemes.

Figure 3 depicts the image block of the sequential encoding process. As shown in this Figure 3, the sequential mode is transmitting the generated blocks based on block by block encoding procedure. On the other hand, the progressive scheme shows the multiple scans through the image as depicted in Figure 4.



<Fig. 3> JPEG sequential encoding process [9].



<Fig. 4> JPEG progressive mode [9].

2.3 Related work

[14] and [15] described the compression program for the observation with different modalities. [16] showed the integration with DICOM standard. In this paper, however, we reviewed the characteristics of JPEG and JPEG2000 based on the compression and transmission point of view. In addition, the DICOM viewer is designed with a DICOM file and data format. Table 1 shows the comparison of the related study.

3. Experimental Results and Discussions

In a transmission application, the compression has always to be performed prior to the data transmission. In this experiment, we tested the performance of data compression point of view and realized the image transmission. In the transmission, the physicians have been waited the study film to diagnose the patient. In order to avoid the waiting time, they can diagnose the data by transmitting study image sequentially or progressively.

3.1 Data compression

The tested images of knee, wrist, abdominal, coronal MRI for the compression performance analysis and brain for the compression and transmission analysis are utilized in the work (Figure 5). Table 2 shows the image comparison based on JPEG and JPEG2000 as described in previous section. In this research, the experimental data were used as DICOM standard image. In particular, Figure 6 shows the lossless

<Table 1> The comparison of related works

	Experimental data Type	Property	Note
Ref. [14]	CR	- Develop the comparison program between original and compressed images - Propose two monitors for the observation	JPEG2000 compression
Ref. [15]	CT MRI	- Clinical experiment for the Image compression - Propose the suitable image compression rate 1/10 in CT, 1/5 in MR clinically	JPEG2000 compression
Ref. [16]	Infrared image	- Establish a full integration of the infrared modality into the standard - Involve manufacturers of thermal cameras into the process.	IOD

<Table 2> The compression result for experimental data (dB)

Compression ratio	5 : 1		15:1		30 : 1		65 :1	
	JPEG	JPEG2000	JPEG	JPEG2000	JPEG	JPEG2000	JPEG	JPEG2000
Sample 1	51.0574	54.4541	39.5381	43.035	34.0784	38.0387	28.3906	34.494
Sample 2	46.6995	50.9639	35.9453	39.0654	31.3309	34.1674	27.4482	29.9453
Sample 3	37.1763	42.0786	27.5097	29.5065	24.1487	25.952	21.6765	23.4709
Sample 4	39.6107	44.7122	32.1323	34.1234	27.5814	30.8129	25.5501	27.7418
Sample 5	46.7478	51.7169	35.8099	38.0613	29.3816	33.6265	27.024	29.8038

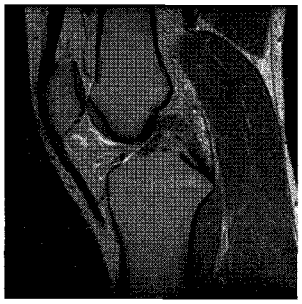
operation with ratio 2:1. As shown in Figure 6, we can expect the no difference for the case of lossless operation. For the better understanding, the high compressed image shows the blocking effect as we expected in Figure 7.

On the purpose of comparison of an image quality, a general evaluation tool, PSNR (Peak Signal to Noise Ratio), has been adopted. The PSNR can be written by following.

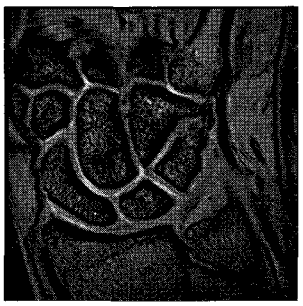
$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right)[dB] \quad (1)$$

Where, MSE is a mean square error between the original and reconstructed images. Figure 8 shows the comparison results based on compression ratios with JPEG and JPEG2000 using the PSNR.

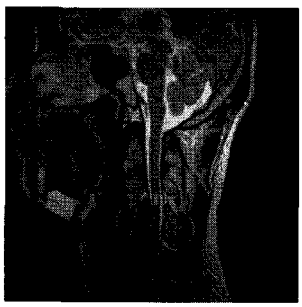
(a) Sample 1 - L KNEE 1



(b) Sample 2 - L KNEE 2



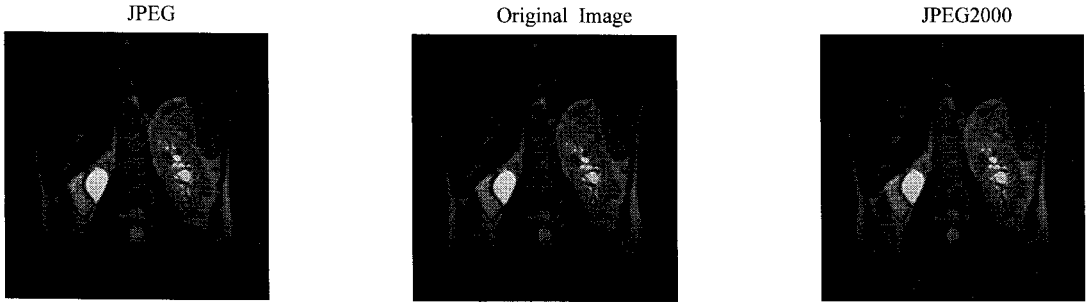
(c) Sample 3 - LEFTWRIST



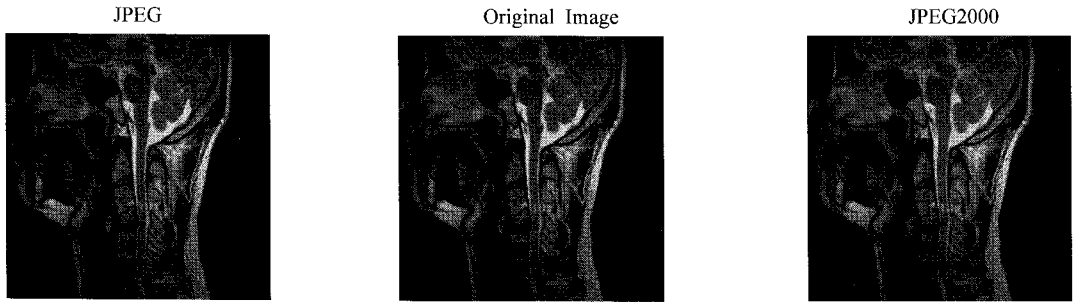
(d) Sample 4 - C_SPINE

(e) Sample 5 - ABDOMEN

<Fig. 5> The experimental data.

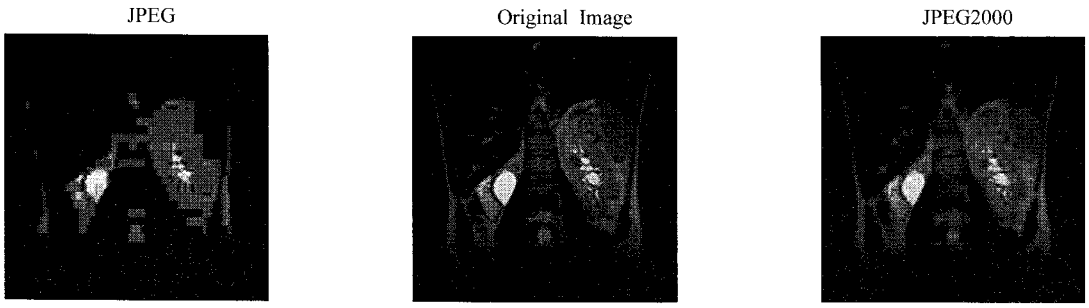


(a) Abdominal

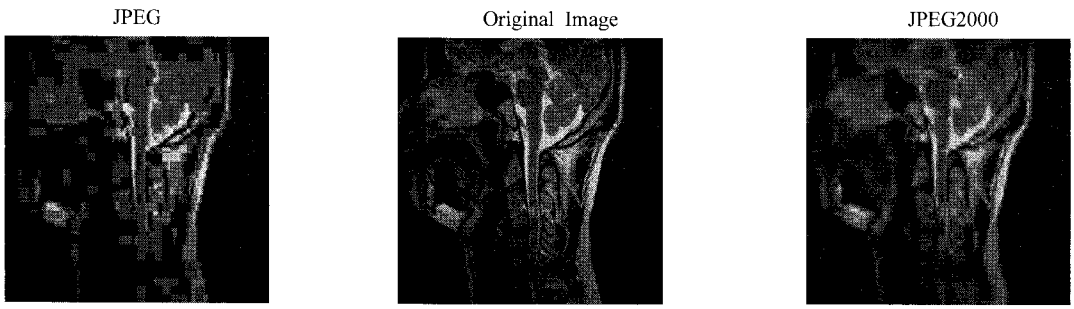


(b) Coronal MRI

<Fig. 6> Example result for JPEG and JPEG2000 image (compression ratio 2:1).

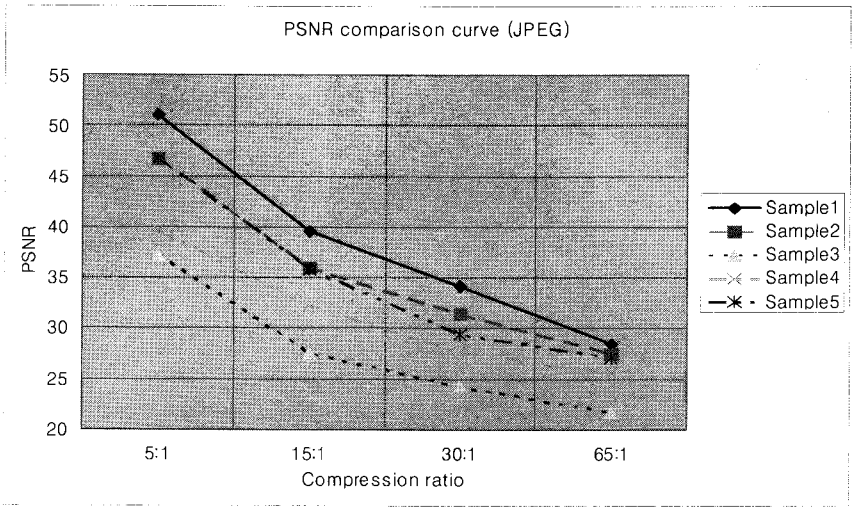


(a) Abdominal

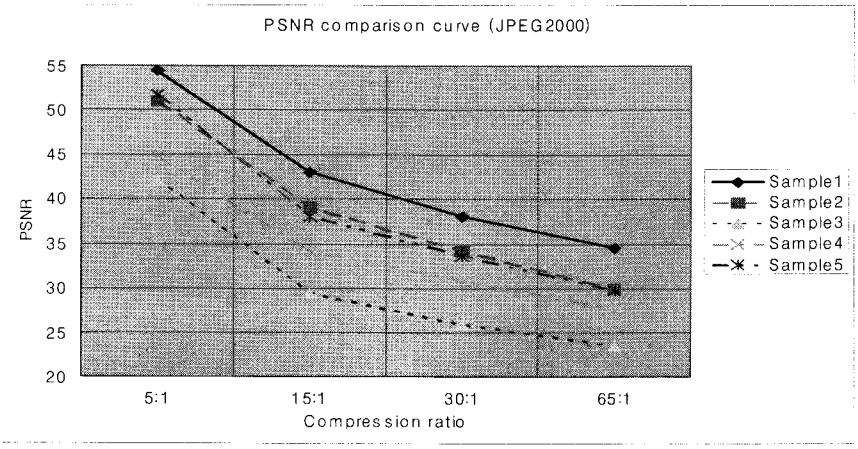


(b) Coronal MRI

<Fig. 7> Example result for JPEG and JPEG2000 image (compression ratio 60:1).



(a) JPEG compression

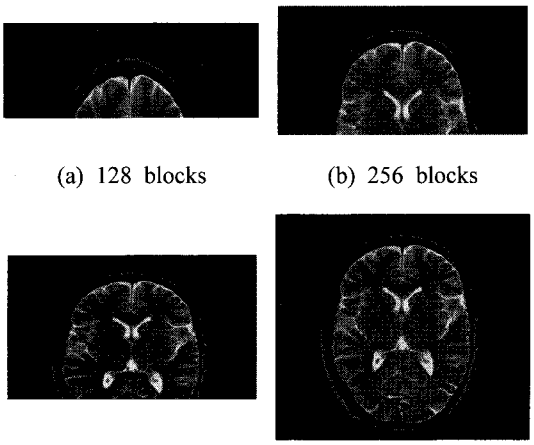


(b) JPEG2000 compression

<Fig. 8> PSNR comparison curves.

3.2 Image transport

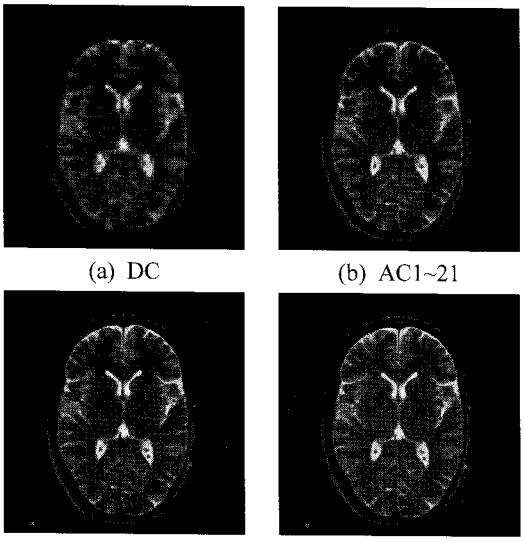
For the transmission of study image, the brain image was utilized. As shown in Figure 9, the brain image was processed by blocks sequentially. Figure 10 described the progressive process using spectral selection of DC and AC components. Sometimes, the diagnosis radiologist might be expected and figured out the fundamental information for the emergency case.



(a) 128 blocks (b) 256 blocks

(c) 384 blocks (d) 512 blocks

<Fig. 9> Sequential mode brain image



(a) DC (b) AC1~21

(c) AC21~42 (d) AC43~63

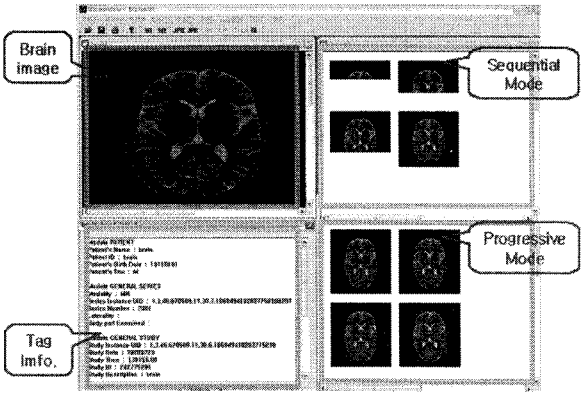
<Fig. 10> Progressive mode brain image

3.3 DICOM viewer

In this paper, we have utilized Intel Pentium 4 (1GHz or higher) with windows XP OS. For the implementation of application development, we used Visual C++ 6.0 and the MFC (Microsoft Foundation Class) library for the UI(User Interface). In the transmission application, JPEG standard has been adopted. The new development of medical image viewer based on standard is an essential and indispensable element. Even though the developed viewer system has very limited properties on comparing the commercial software, the developed medical imaging viewer has the following properties:

1. Read a DICOM standard formatted image
2. Read the patient/study information
3. Provide the JPEG sequential and progressive process of decoding stage
4. Support the JPEG/JPEG2000 encoding and decoding

Figure 11 shows a snapshot of the imaging viewer with above properties. The left side describes the test image and header information. The right side explains the example of JPEG sequential and progressive process.



<Fig. 11> A snapshot of DICOM viewer.

4. Conclusions

In this paper, we reviewed the JPEG and JPEG2000 standard algorithm for utilizing the medical image application. The purpose of this work is to explore the comparison of the compression and the transmission performance. Also, the developed DICOM viewer is naive but it can be applicable to the various network environment. The web-PACS and the mobile PACS are gradually rasied and it requires to consider the patient's private information and security problems.

References

[1] O. Herman and Paul T. Gihring, DICOM Basics, 2nd ed., OTech, Inc., Aubrey, TX, 2002.

[2] http://www.dclunie.com

[3] NEMA PS 1 - Digital Imaging and Communications in Medicine, 2004 ed., Global Engineering Documents, Englewood CO, 2004.

[4] Moreno R. and Furuie S, "Integration of heterogeneous systems via DICOM and the clinical image access service", IEEE

Computers in Cardiology, pp.385-388, 2002.
[5] Mei-Yen, Chang. Chien-Tsai Liu, Ying-Chou Sun, Rheun-Chuan. Lee, Chian-Fa Chang, Michael Mu-Huo. Teng, Cheng-Yen Chang, "Design and Evaluation of a DICOM compliant Video-fluoroscopy Imaging System", Proceeding of e-Health Networking, Application and Services, pp. 248-251, 2007.
[6] NEMA PS 3 - Digital Imaging and Communications in Medicine, 2004 ed., Global Engineering Documents, Englewood CO, 2004.
[7] Chai, D. and Bouzerdoum, A. "JPEG2000 image compression: an overview", Intelligent Information Systems Conference, pp. 237 - 242, 2001.
[8] W. B. Pennebaker and J. L. Mitchell, JPEG Still Image Data Compression Standard, Van Nostrand Reinhold, New York, 1992.
[9] ITU-T Recommendation T.81 | ISO/IEC 10918-1, "Information technology - Digital compression and coding of continuous-tone still image", JPEG standard, Part 1 - Requirements and guidelines, 1994.
[10] David H. Foos, Edward Muka, Richard M. Slone, Bradley J. Erickson, Michael J. Flynn, David A. Clunie, Lloyd Hildebrand, Kevin S. Kohm, and Susan S. Young, "JPEG 2000 compression of medical imagery", Proc of SPIE Vol. 3980, pp. 85-96 , 2000.
[11] A. N. Skodras, C. A. Christopoulos and T. Ebrahimi, "JPEG2000: The Upcoming Still Image Compression Standard" , Proceedings of the 11th Portuguese Conference on Pattern Recognition, pp. 359-366, 2000.
[12] Watanabe, O. and Kiya, H., "An extention of roi-based scalability for progressive transmission in JPEG2000 coding", Circuits and Systems, 2003. ISCAS '03. Proceedings of the 2003, pp535-540, 2003.
[13] Martin Boliek, et al., "JPEG 2000 Part I Final Draft International Standard", ISO/IEC JTC1/SC29 WG1, 2000.
[14] Hong Seong-Wan, Jeon Yong-Kyeong, Cha Soon-Joo, Kim Yong-Hoon, Hur Gham, "Comparison of Two Types of JPEG2000 Observation Programs for Clinical Evaluation", Korean Journal of PACS, Vol. 12, pp. 35-40, 2006.
[15] Sung-Woo Choi, Soon Joo Cha, Yong Hoon Kim, Jung Wook, Seo, Gham Hur, "The calculation of compression rate and practicality of JPEG2000 on CT and MR images", Korean Journal of PACS, Vol. 10, pp. 25-30, 2004.
[16] Ying Zhu, Peter Plassmann and Francis Ring, "Adopting the DICOM standard for medical infrared images", Proceedings of the 28th IEEE EMBS Annual International Conference, pp. 236-239, 2006.

조 규 철 (Kyu-Cheol Cho)

- 정회원
- 2003년 대구대학교 정보통신공학부 (공학사)
- 2006년 대구대학교 컴퓨터정보공학과 (공학석사)
- 관심분야 : 의료영상 코덱설계, 인공지능

김 재 준 (Jae-Joon Kim)

- 정회원
- 1991년 한양대학교 전자공학과 (공학사)
- 1995년 Iowa State University (공학석사)
- 2000년 Iowa State University (공학박사)
- 2001년 ~ 2002년 한국전자통신연구원 선임연구원
- 2002년 ~ 현재 대구대학교 정보통신대학 정보통신공학부 조교수
- 관심분야 : 멀티미디어 신호/영상처리, MPEG21, 멀티미디어 코덱설계, 비파괴공학