2의 지수형식에 기초한 디지털 이미지 워터 마킹

Digital Image Watermarking Based on Exponential Form with Base of 2

아리운자야*, 김한길*, 추형석**, 안종구*

Ariunzaya Batgerel*, Han-Kil Kim*, Hyung-Suk Chu**, Chong-Koo An*

요약

본 논문에서는 새로운 디지털 워터마킹 기법을 제안하였다. 제안한 알고리즘은 임의의 실수가 2의 지수형식의 합으로 될 수 있고, 몇 개의 수로써 표현될 수 있음을 이용하였다. 여기서, 임의의 실수가 일부분 변하더라도 2의 지수형식으로 표현하였을 경우에 큰 자리 수는 변하지 않음을 알 수 있다. 제안한 알고리즘은 입력 영상을 웨이블렛 변환하였고, 2의 지수형식으로 표현된 웨이블렛의 중요계수에 다중 바코드 워터마크를 삽입하였다. 제안한 알고리즘은 세미 블라인드이고, 객관적이면서 주관적인 워터마크 검출을 할 수 있다. 또한 병합기법을 이용함으로써 좀 더 정확한 워터마크를 추출할 수 있었다. 실험결과에서 제안한 알고리즘은 잡음 및 영상압축 공격에 대하여 향상된 결과를 보였다.

Abstract

In this paper, we propose a new digital watermarking technique. The main idea of the proposed algorithm relies on the assumption that any real number can be expressed as a summation of the exponential form with base of 2 and if only consider the first few summations some numbers can be expressed in the same form. Therefore, we can be sure that some amount of changes does not affect the first few summations. The algorithm decomposes a host image in wavelet domain and intensity of the significant wavelet coefficient is expressed in exponential form with base of 2. Multiple barcode watermarks are then embedded by modifying the parity of the exponent. The proposed scheme is semi-blind and also offers either objective or subjective deteew su as well. From extracted watermarks, more accurate watermark is obtained by merging technique as a final watermark. As a simulation result, the proposed algorithm could resist most cases of salt and pepper noise, Gaussian noise and JPEG compression.

Keywords : copyright protection, digital image watermarking, robust watermarking

I. Introduction

Computer technology and the internet are rapidly developing and are becoming more and more widely used. Unfortunately, the advance of the internet and processing technology has led to a rapid increase in infringement of copyright by digital means. In other words, most of data is distributed and modified without the permission of its owner. If data is illegally accessed or stolen, it becomes necessary to prove ownership of the data.

One of the most sophisticated methods to prove ownership of digital contents is digital watermarking technique. Digital watermarking is a technique by which some form of extraneous information is hidden within the digital contents which can prove ownership. If such proof is needed, the embedded data can be retrieved and prove ownership.

In recent years, an overwhelmingly large amount of research works has been done in digital watermarking for copyright protection. Digital watermarking schemes can be placed under three categories: non-blind watermarking scheme, semi-blind watermarking, and blind watermarking. If the original host image and or a secret key are required to extract the embedded watermark, the scheme is non-blind. [1, 2] The practicality of the non-blind watermarking scheme is limited, since it needs extra storage to maintain the host image and also the host image may not be available for detection. Semi-blind watermarking scheme uses the embedded watermark or side information instead of the host image to extract the

* 울산대학교 ** 파웰테크윈(주)

투고 일자 : 2009. 10. 9 수정완료일자 : 2010. 4. 14
게재확정일자 : 2010. 4. 29

embedded watermark. [3, 4] In contrast, the blind watermark scheme does need neither the host image nor the embedded watermark. [5]

The proposed digital watermarking algorithm based on exponential form with base of 2. Any real number can be expressed as a summation of the exponential form with base of 2 and if only consider the first few summations some numbers can be expressed in same form. Therefore, we can be sure that some amount of changes may due to noise do not affect the first few summations. Based on above assumption, the proposed algorithm considers the only first 2 summations and then the watermark is embedded by modifying the parity of the exponent. In watermark detection, original host image is not used, and objective and subjective detection are provided.

The rest of this paper is organized as follows. Section 2 refers to related theories. In section 3, the proposed algorithm is introduced. Section 4 represents experimental results and analysis. The paper is concluded in section 5.

II. Related Theories

2.1 Discrete Wavelet Transform

Discrete Wavelet Transform (DWT) has been heavily studied and developed in signal processing. [6, 7] The 2D-DWT decomposes an image into four sub-bands, marked by LL, LH, HL and HH, shown in Fig. 1(a). The sub-band LL shows the coefficients of the image consisting of the low frequency component. In addition, the remainder LH, HL, HH sub-bands can show the feature which expresses the boundary of the image in the horizontal, the vertical, and the diagonal direction.

The reason why DWT is widely used for image analysis is that an image can be well differntiated into a smooth region and edges in the wavelet domain, shown in Fig. 1(b).

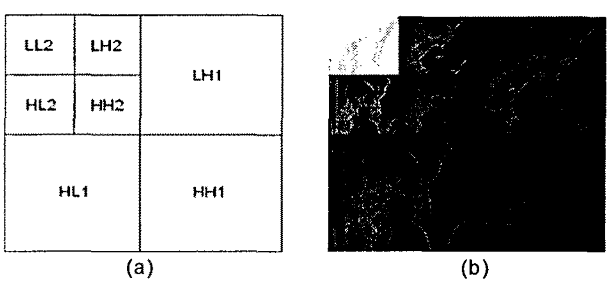


Fig. 1. Representation of the 2D-DWT

Since the location information of image edge, DWT is most widely used for image compression. Since the assumption that the signal magnitudes dominate the magnitudes of the noise in a wavelet representation, DWT is used for image denoising. The knowledge of the significant coefficient as well as insignificant coefficient of an image in wavelet domain can be the reason of usage of the DWT for image watermarking.

2.2 A simple watermark embedding technique

The Cox's function is the most common method to insert a watermark and can be done either in a spatial domain or in a transform domain. [8, 9] The Cox's watermark embedding algorithm can be expressed as below [1][4][5].

$$C' = C + \alpha \times W \tag{1}$$

$$C' = C(1 + \alpha \times W) \tag{2}$$

C is the coefficient of the input image and α is the weight factor used for inserting the watermark and C' is the coefficient into which a watermark bit is inserted. As the size of the weighted factor α is enlarged, the intensity of a watermark embedded coefficient correspondingly increases and then the watermark bit which is embedded the coefficient becomes strong against a noise. However, as the resiliency of the watermark increases, the quality of the image degrades. Equation (1) inserts the watermark without reference to the size of the coefficient whereas equation (2) inserts the watermark proportionally to the size of the coefficient.

2.3 The Quadtree Decomposition

The Quadtree decomposition divides a square images into four equal-sized square blocks (sub-images) and then testing each block to see if it meets some criterion of homogeneity (e.g., if all of the pixels in the block are within a specific dynamic range of gray levels). If a block meets the criterion, it is not divided any further, otherwise, it is subdivided again into four blocks, and the test criterion is applied to the smaller blocks. This process is repeated iteratively until either each block meets the criterion or we reach a block of size 1 pixel. The result may have blocks of several different sizes. [10, 11]

Fig. 2(b) shows a typical Quadtree representation for Fig. 2(a) which is Lena image in the wavelet domain. In Fig. 2(b), black regions mean larger blocks or similar homogenous regions and white regions (like edges) represent more decomposition and un-homogenous regions. Large regions represent mainly the background are or less valuable information and absence of edges. Small regions represent the presence of critical information of the image and hence are the good place for the watermark insertion.

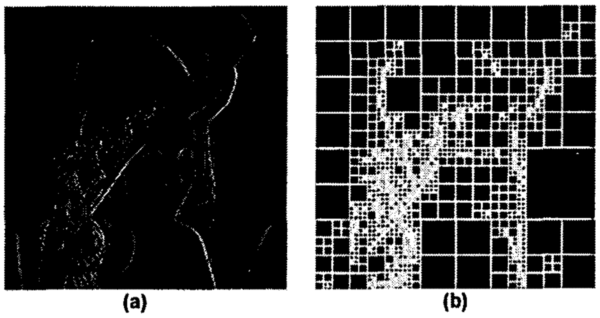


Fig. 2. Quadtree representation of an image

III. Proposed Algorithm

In this section, we explain the main idea of the proposed algorithm and its embedding and extraction steps in detail.

Any real number can be expressed as a summation of the exponential form with base of 2. For example, $115 = 2^6 + 2^5 + 2^4 + 2^1 + 2^0$. If we only consider the first 2 summations 115 will become $115 = 2^6 + 2^5 + p$ $(115 = 2^6 + 2^5 + 19)$, where p is parity of the exponent (residual) and we do not care what it is. Here, let us take other real numbers such as 99 and 127 as an example. These numbers are also expressed in the same form with 115 $99 = 2^6 + 2^5 + p$ $(99 = 2^6 + 2^5 + 3)$ and $127 = 2^6 + 2^5 + p 127 = 2^6 + 2^5 + 31$

Therefore, we can tell that some amount of changes do not affect the first few summations.

Fig. 3 illustrates a safe region in case of form $2^a + 2^{a-1} + p$. The safe region showed by red line and guarantees that any number in this region cannot affect to the main form $2^6 + 2^5 + p$, maybe just only p parameter is changed.

The proposed algorithm relied on this assumption.

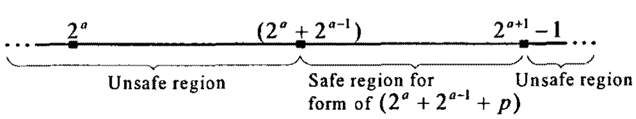


Fig. 3. Illustration of the safe region

In the watermarking technology, the assumption can be explained as below. Let us assume 115 is watermarked coefficient of image and it is expressed in the form of $115 = 2^6 + 2^5 + 19$ $(115 = 2^6 + 2^5 + p)$. We believe that the first two summations $2^6 + 2^5$ keep a watermark bit in a way. After some noise attack the watermarked coefficient 115 might become either 127 or 112. The value 127 is expressed as $127 = 2^6 + 2^5 + 31$ $(127 = 2^6 + 2^5 + p)$ and the value 112 is expressed as $112 = 2^6 + 2^5 + 16$ $(112 = 2^6 + 2^5 + p)$. Since both numbers are expressed in the same form with 115 whose first two summations keep the watermark bit, we can be sure that exact watermark bit would be extracted. This example is shown by figure in Fig. 4.

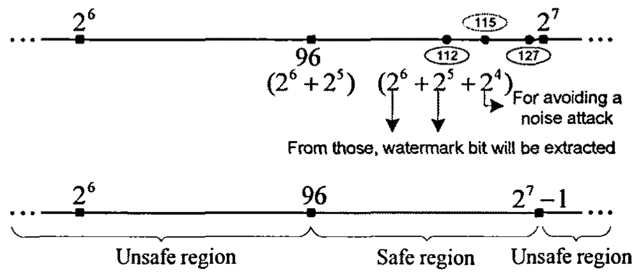


Fig. 4. Illustration of the example

In the proposed algorithm, the significant coefficients are tracked down by Quadtree decomposition algorithm which was applied into each band except low-pass band of an image in wavelet domain. Magnitude of each significant coefficient is expressed in the exponential form with base of 2 and identical barcode watermarks are then embedded by modifying the parity of the exponent. The exact locations where watermark bits were embedded are recorded into a location table which will be used for watermark detection.

The proposed watermarking scheme is semi-blind, and so an original host image is not required for watermark detection. Because the barcode watermark is visually recognizable, besides objective detection using correlation value, the proposed algorithm provides subjective detection too.

The proposed watermarking scheme offers subjective detection as well as objective detection. Since the barcode watermark is visually recognizable, the proposed scheme can have subjective detection without original watermark. Objective detection is done by using correlation.

In extraction part, the numbers of watermarks are extracted referring to the location table. In order to obtain final one watermark which should be appropriate for ownership verification, the proposed algorithm used a merging technique which makes algorithm more effective and makes watermark more robust.

The main scheme of the proposed watermarking algorithm is shown in Fig. 5.

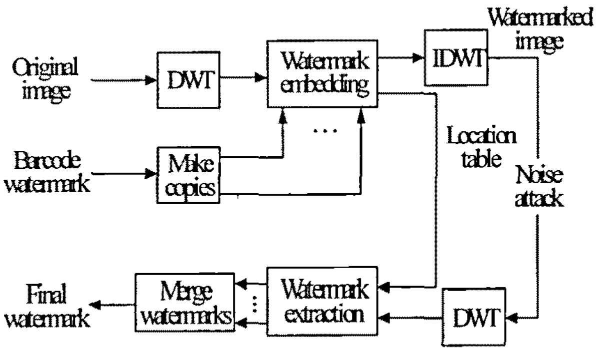


Fig. 5. The skeleton of the proposed watermarking algorithm

3.1 Embedding process

The barcode watermark $W_{n\times n}$ with size of $n\times n$, which contains values of 0 or 1, will be embedded into the host image $I_{m\times m}$ where m is image size. The embedding technique is comprised of the following stages:

1. Transform the host image $I_{m\times m}$ into the wavelet domain using DWT
2. Apply the Quadtree decomposition algorithm into each band except LL band to find significant wavelet coefficients
3. FOR all watermarks

   FOR all significant coefficients

   - Express a significant coefficient as first summations of the exponential form with base of 2 as $x=2^a+p$
   - IF watermark bit = mod (a/2)

     $x' = 2^a + 2^{even} + 2^{even-1}$

     ELSE

     $x' = 2^a + 2^{odd} + 2^{odd-1}$

     (Where even (odd) means an even (odd) value just before "a")
   - Record a location table in where exact locations of the embedded coefficients are kept.
4. Compute an inverse DWT to create a watermarked image **I** in the watermarked bands.

3.2 Extraction process

The proposed algorithm has semi-blind detection and so only requires the location table which is created during embedding process. We assume that the watermarked image has been attacked by some interference, denoted by **I** . The extraction stages are shown as below:

1. Transform the distorted image **I** into the wavelet domain using DWT
2. By referring to the location table we can determine the location in which the watermark was embedded.
3. FOR all coefficient in which the watermark was embedded
   - Express a coefficient as first two summations of the exponential form with base of 2 as
   - IF mod(b/2) = 0

     $W(k) = \mathrm{mod}(a/2)$

     ELSE

     $W(k) = inverse(\mathrm{mod}(a/2))$
4. FOR all extracted watermark
   - Obtain final watermark by merging extracted watermarks as following rule

$$W'(i,j) = \begin{cases} 1, \sum_{i=1}^{n} W(k,l) \geq \frac{n+1}{2} \\ 0, \sum_{i=1}^{n} W(k,l) < \frac{n+1}{2} \end{cases} \quad (3)$$

   - Convert extracted watermark series into a 2D barcode watermark

IV. Experiment

The proposed watermarking algorithm was tested on two gray-scale images of Lena (as a picture with low spatial frequency) and Barbara (as a picture with high spatial frequency) which were 512 by 512 in size. As a watermark, binary barcode watermark with size of 20 by 20 was used, shown in Fig. 6(a). Each test repeated 10 times and final result was obtained by averaging those.

For analyzing the results, PSNR and statistic correlation were computed. In the image watermarking, the PSNR (Peak Signal to Noise Ratio) is used to evaluate the quality of the watermarked image. For a $N_1\times N_2$ pixels image with pixels' luminance values ranging from zero (black) to $L_{\max}$ (white), the PSNR is defined as:

$$PSNR = 10\log_{10}\frac{L_{\max}\times L_{\max}}{MSE} \quad (4)$$

where MSE is mean square error defined as:

$$MSE = \frac{\sum_{i=1}^{N_1}\sum_{j=1}^{N_2}[I(i,j) - I_W(i,j)]^2}{N_1 \times N_2} \quad (5)$$

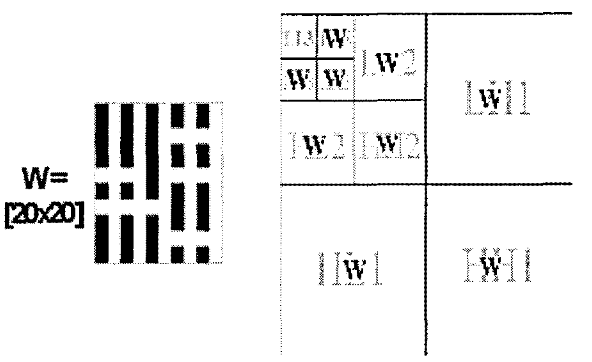
Higher PSNR tells us that the watermarked image is suffered a little from the embedding process.

In case of the barcode watermark, we can analyze the extracted watermark subjectively. In other words, there is no need to compare extracted barcode watermark with the original barcode watermark for proving the presence of watermark because it is visually recognizable. However, we used normalized correlation to measure the similarity of the extracted watermark objectively as a following equation.

$$NC = \frac{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2}[W(i,j)\,W'(i,j)]}{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2}[W(i,j)]^2} \quad (6)$$

Where $W(i,j)$ and $W'(i,j)$ are respectively original and extracted watermarks with size of $M_1 \times M_2$ pixels. Higher correlation value tells us that the extracted watermark is more similar to the original watermark.

The original host image is decomposed by 3 level discrete wavelet transform. 9 identical barcode watermarks were embedded into each band except LL band as shown in Fig. 6(b). The watermarked image was distorted by three attacks such as Salt and pepper noise, Gaussian noise and JPEG compression. The watermark was then extracted from the distorted image.



(a) Original watermark (b) Watermark embedding places

Fig. 6. Original watermark and its embedding places

Test results are shown in Table 1, and Fig. 7, Fig. 8, Fig. 9 and Fig. 10.

In Table 1, the results of three noise attacks on two images are summarized. By considering the correlation values of both images in the Table 1, we can see that the proposed algorithm works similarly in both high spatial frequency image and low spatial frequency image.

Fig. 7(a) showed the either extracted watermarks or merged watermarks in case of Salt and pepper noise as a detailed view. From this figure, we observed that wavelet coefficients at level 2 and level 3 are more susceptible to Salt and pepper noise.

Fig. 7(b) showed the either extracted watermarks or merged watermarks in case of Gaussian noise. From this result, we could see that wavelet coefficients at lowest level are more susceptible to Gaussian noise.

The results of JPEG compression were shown in Fig. 7(c). From Fig. 7(c), we observed wavelet coefficients at lowest level are more susceptible to JPEG compression.

By referring to Fig. 7, we can say that the proposed algorithm could become essential thanks to merging technique. By considering the visually recognizable property of watermark in Fig. 7, we determined a threshold as 0.75 for analyzing the robustness of watermark objectively.

Further, in order to make sure that the proposed algorithm is practical, we compared the performance of the proposed algorithm with that of the most common method Cox's algorithm. In the Cox's algorithm, we used alpha parameter equal to 0.3. The value of alpha parameter being 0.3 gave a similar PSNR performance to that of the proposed algorithm, shown in tables.

Fig. 8, Fig. 9 and Fig 10 illustrated the result of the proposed algorithm and Cox's algorithm, in case of Salt and pepper noise, Gaussian noise and JPEG compression, respectively. As a final result by referring to there figures, the proposed exponential form based algorithm could achieve higher correlation value than the Cox's algorithm in case of Salt and pepper noise and JPEG compression. Even though the correlation value of the proposed algorithm was less than that of the Cox's algorithm, it was still acceptable for ownership verification. Because the correlation value of the proposed algorithm was higher than the threshold value except case of noise density 0.01.

Table 10. Correlation value of extracted watermarks

Salt and pepper noise			Gaussian noise			JPEG compression		
Noise density	Lena image	Barbara image	Noise density	Lena image	Barbara image	Noise density	Lena image	Barbara image
0.1	0.63	0.65	**0.1**	0.09	0.05	**50**	0.86	0.84
0.05	0.88	0.86	**0.01**	0.16	0.17	**60**	0.94	0.95
0.01	1	0.99	**0.001**	0.79	0.85	**70**	0.97	0.98
0.001	1	1	**0.0005**	0.92	0.97	**80**	0.99	0.99
0.0001	1	1	**0.0001**	1	1	**90**	1	1

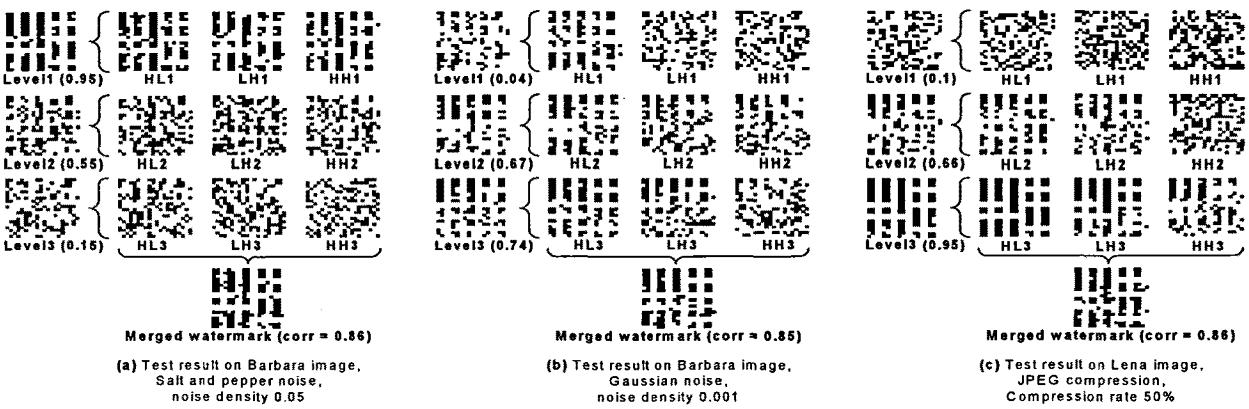


Fig. 7. Extracted watermarks and merged watermarks

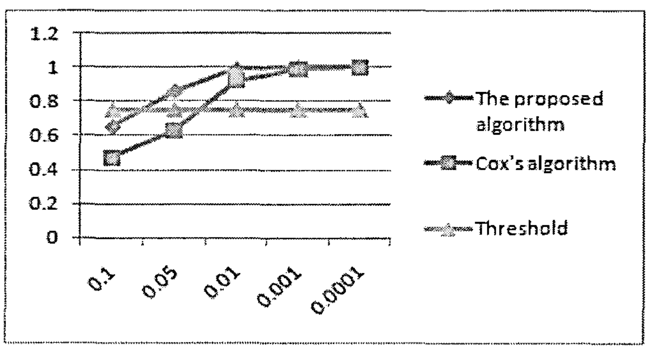


Fig. 8. Comparison of the proposed algorithm and Cox's algorithm (Barbara image, Salt and pepper noise)

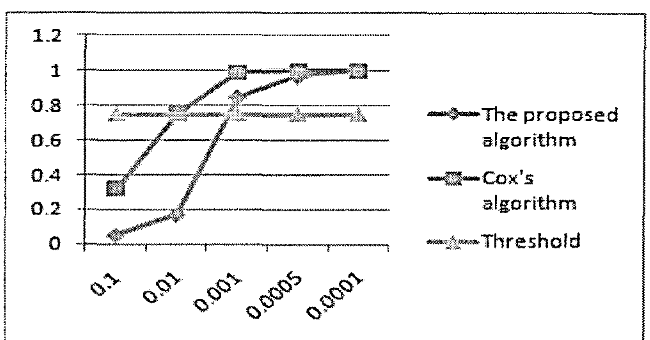


Fig. 9. Comparison of the proposed algorithm and Cox's algorithm (Barbara image, Gaussion noise)

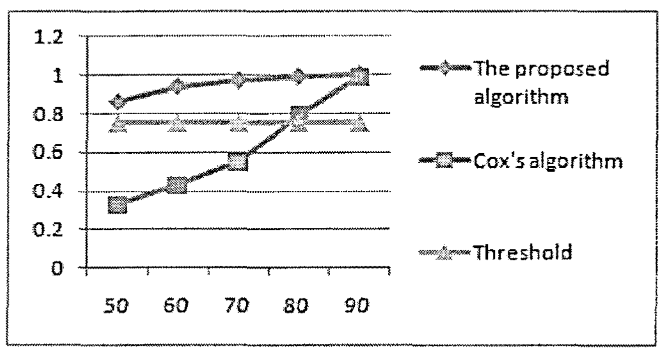


Fig. 10. Comparison of the proposed algorithm and Cox's algorithm (Lena image, JPEG compression)

V. Conclusions

We suggested a simple and new technique for robust digital image watermarking. The algorithm was based on exponential form with base of two. The algorithm decomposed a host image in wavelet domain and intensity of the significant wavelet coefficient was expressed in the exponential form with base of 2. The 9 identical barcode watermarks were then embedded by modifying the parity of the exponent. The final watermark was obtained by merging the extracted watermarks. Since the proposed algorithm used barcode watermark, both objective and subjective detections were available. From simulation result, the proposed algorithm could resist most of noise attacks and could achieve higher performance than the Cox's algorithm in case of Salt and pepper noise and JPEG compression.

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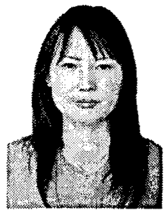

Ariunzaya Batgerel
received her B.S.degree in information technology from the Mongolian University of Science and Technology. Her research interests are digital image watermarking, image denoising, and deblurring.

Han-Kil Kim
received his M.S.degree in mechatronics and IT from the University of Ulsan. His research interests are mechtronics, and digital signal processing.

Hyung-Suk Chu
received his Ph.D.degree in electrical engineering from the University of Ulsan. His research interests are wavelets, images, and signal processing.

Chong-Koo An
received his Ph.D. degree in electrical engineering from the University of Texas at Austin. His research interests are wavelets and Digital signal processing.