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Ultrasonic Echo Image Adaptive Watermarking using the Just-noticeable difference estimation

Amnach Khawne, Kazuhiko Hamamoto, and Orachat Chitsobhuk

Abstract—Most of the image watermarking methods, using the properties of the human visual system (HVS), have been proposed in literature. The component of the visual threshold is usually related to either the spatial contrast sensitivity function (CSF) or the visual masking. Especially on the contrast masking, most methods have not mention to the effect near to the edge region. Since the HVS is sensitive what happens on the edge area. This paper proposes ultrasound image watermarking using the visual threshold corresponding to the HVS in which the coefficients in a DCT-block have been classified based on the texture, edge, and plain area. This classification method enables not only useful for imperceptibility when the watermark is insert into an image but also achievable a robustness of watermark detection. A comparison of the proposed method with other methods has been carried out which shown that the proposed method robusts to blockwise memoryless manipulations, and also robust against noise addition.

Keywords—Medical image watermarking, Human Visual System, Image Adaptive Watermark

I. Introduction

AT the present, multimedia technology has been rapidly growth up with a widely use on the internet. It almost performed in a variety of digital formats. Most clinical picture archive and communication systems (PACS) use the digital imaging and communications in medicine (DICOM) [3] standard image format for medical images. The advantages of internet technology emerge to be useful of an access into the own medical file by the patient [1]. This leads to how the patient information can be protected from unauthorized person. Ultrasound imaging is one of the images that handle and store in PACSs system and is also used in the diagnosis and the assessment of imaging organs and soft tissue structures. The images of the human body are derived from the interaction of energy with human tissue. With the propertied improvement, ultrasound imaging has been used in the assessment and characterization of cardiac imaging. In this paper, we mention to protect ultrasound imaging with focusing on embedding electronic patient records (ERP) [4], [6], [7]. For protecting of the medical image, it needs such kinds of security characteristics such as confidentiality, availability, and reliability. Both of the confidentiality and the reliability are important objectives [2]. Medical image watermarking is the most widely used, and thus those of requirements are achieved with both of tamper detection and authentication [5]. Furthermore, it has been generally implemented not only on the spatial domain but also on the frequency domain [8]. In order to make the robustness watermarking, the frequency domain is prominent than the spatial domain because it can be facilitated directly on each component. For privacy protection of medical images, the watermark method should make to ensure that patient's medical records are secured in such a way that: confidentiality, integrity, and authentication. On the other hand, imperceptibility, the image quality point of view [1], is the one of the most factors that should be considered and most of the medical images should not destructive in case of diagnosis ways. Fortunately, the medical watermark methods, using the visual threshold with slight modifying on images, have been proposed [3], [9], [11], [12]. In addition, the coefficients, in adaptive case, are selected from less sensitive area to the human eyes using Watson's model proposed in [12]. In the spread spectrum scheme, the watermark, generated from pseudo-random sequences, is embedded into a host document with ultradistant adding or subtracting, which called spread-spectrum-like method [3]. A comparison of perceptual-shaping has been proposed in [12], and the experimental results have obviously shown that the well-known Watson perceptual model outperforms the pixel-wise masking (PWM) on a tested set of images. With this motivation, our method conducts by using the Zhang's human visual perception model [10] on the ultrasound image watermarking. With this visual threshold, it is shown that imperceptibility and robustness of the proposed method has more efficient than the watermark method which uses Watson's model even we compare our method, DCT-based, with wavelet-based Watson's model. In this paper, we propose a method of ultrasound image watermarking by using the human perception threshold with resulting in the best performance of tracing, integrity control issue [8]. We also demonstrate the results of our experiment in comparison with other methods proposed in literature [11], [12]. The rest of this paper is organized as follows: In the next section, the visual threshold using in image watermarking is described, and the embedding and the extracting method together with watermark evaluation is shown in Section III. The experimental results with various attacks are shown in Section IV; Section V gives the conclusions of this work.

A. Khawne, and K. Hamamoto are with Department of Information Media Technology, School of Information and Communication Engineering, Tokai University. 1117 Kitakaname Hiratsuka-shi Kanagawa, 259-1292 Japan Tel+81-463-58-1211 ext.4083 Fax +81-463-50-2412 e-mail: kkamnach@kmitl.ac.th, hama@keyaki.cc.u-tokai.ac.jp

A. Khawne, and O. Chitsobhuk is with Department of Computer Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang. 3 M 2, Chalongkrung, Ladkrabang, Bangkok,Thailand 10520. Tel +66-2-739-2400 Fax +66-2-739-2404 Email: kcoracha@kmitl.ac.th

II. Visual Threshold in Image Watermarking

Image watermarking with the IA-DCT method [11], [12] has been proposed by taking into account the human visual properties coincided with the IA-W method with using the

Watson's model. The visual gauge of the IA-DCT, made use of three properties, are the frequency sensitivity, the luminance masking, and the contrast masking. These properties are assigned to each of block-DCT coefficients. The luminance sensitivity, $J_{lum}(\mathbf{k}, i, j)$, measures the effect of the delectability threshold of noise on a contrast background in the block $\mathbf{k}^{th}$ at the location (i, j). It is a non-linear function adjusted by the weighted parameter, ξ , which controls the degree of luminance sensitivity. This function can be defined as follows:

$$J_{lum}(\mathbf{k}, i, j) = J_{feq}(i, j)(\frac{C_{\mathbf{k},0,0}}{\bar{C}, 0, 0})^{\xi} \quad (1)$$

where $C_{\mathbf{k},0,0}$ is the DC component of the $\mathbf{k}^{th}$block-DCT coefficients and $\bar{C}_{0,0}$ is the average of DC components. $J_{feq}\left(i, j\right)$ is a frequency sensitivity table being shown in [11]. The contrast masking, $J_{cont}(\mathbf{k}, i, j)$, referring to the reduction in visibility of one image component due to the present of another, is expressed as

$$J_{cont}\left(\mathbf{k}, i, j\right) = \max\left[J_{lum}\left(\mathbf{k}, i, j\right), \left\{\begin{array}{l} \left|C\left(\mathbf{k}, i, j\right)\right|^{0.7} \\ \times J_{lum}\left(\mathbf{k}, i, j\right)^{0.3} \end{array}\right\}\right] \quad (2)$$

where $C(\mathbf{k}, i, j)$ is the DCT coefficient at the $\mathbf{k}^{th}$ block-DCT at the location (i, j). In the contrast masking equation (2), the contrast masking derived from the maximum value between the luminance masking and the multiplication of the luminance masking by coefficients which both are control by the weight.

For the IA-W scheme, the method exploited the Watson's model as a threshold for evaluating of the wavelet coefficients, see [12] for more details. The IA-DCT and the IA-W masking model of ultrasound imaging are shown in Fig. 1 (a), Fig.1 (b), respectively. The proposed method embeds a watermark into the original image by using the same IA-DCT paradigm in [11], [12] which the coefficient value is selected to embed when its value is higher than the visual threshold. In this case, the visual threshold is constructed by using the Just-noticeable difference (JND) proposed by X. Zhang et al [10]. We then called this method DCT-JND, and the model takes into account three components of spatial contrast sensitivity function (CSF), luminance masking, and adaptive inter-and intra-band contrast masking. The prominent difference between these three methods is that the contrast masking of in [10] deal with edge structure because the HVS is sensitive for changing on edges in an image. Each DCT block is assigned into three of them according to the energy in low frequency (LF), medium frequency (MF), and high frequency (HF), shown in Fig. 1 (d). With this reason, the classification of frequency components in each DCT block has been proposed by dividing into three parts: plain, edge, and texture. The final DCT-JND model is estimated from the DCT domain, which can be expressed as follows:

$$t_{JND}(\mathbf{k}, i, j) = T\left(\mathbf{k}, i, j\right) \cdot J_L(\mathbf{k}, i, j) \times J_C(\mathbf{k}, i, j) \quad (3)$$

where $J_L(\mathbf{k}, i, j)$ is the adaptive luminance at the location $\mathbf{k}$; $\mathbf{k} = m, n$, where m and n are the block indices. $J_C(\mathbf{k}, i, j)$ is the contrast masking. $T(\mathbf{k}, i, j)$ is the spatial contrast sensitivity function (CSF) for more detail illustrated in [10]. Furthermore, the contrast masking is constructed with both inter- and intra-band and the extent of inter-band masking. The value of $\psi(\mathbf{k}$, can be expressed as in Table 1. where

TABLE I
INTER-BAND MASKING

$\psi(\mathbf{k})$	Assigned for
$1 + [(T_E\ (k) - 290)/1510] * 1.25$	Texture block
1.25	Edge block and $L + M > 400$
1.125	Edge block and $L + M \leq 400$
1	Plain block

$T_E = M + H$ which H, M,L are the sum of the absolute DCT coefficient values in the high, medium, and low frequency, respectively. The intra-band masking is obtained by

$$J_C(\mathbf{k}, i, j) = \left\{\begin{array}{ll} \psi\left(\mathbf{k}\right) & for\ \ (i, j) \in LF \cup MF\ in\ Edge\ block \\ \psi\left(\mathbf{k}\right) \times \max\left\{1, \left(\frac{C(\mathbf{k}, i, j)}{T(\mathbf{k}, i, j)}\right)^{0.36}\right\} & otherwise \end{array}\right. \quad (4)$$

where LF and MF are the location in the $\mathbf{k}$ block and are shown in the Fig. 1 (d).

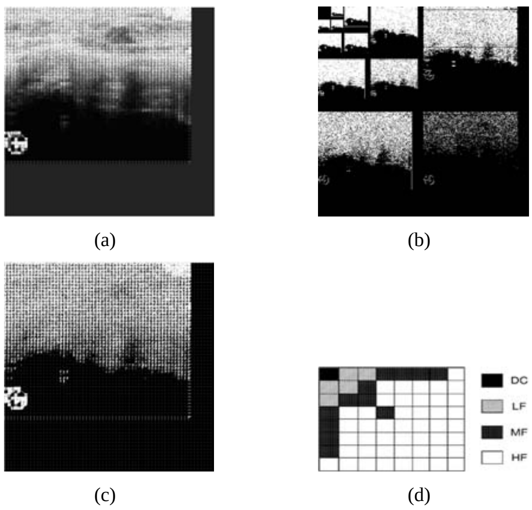

Fig. 1. Visual masking 1(a) IA-DCT masking, 1(b) IA-W masking, 1(c) JND-DCT masking, 1(d) DCT block classification

III. PROPOSED ULTRASOUND IMAGE WATERMARKING

A. Embedding Method

The embedding method modifies of the DCT coefficients straightforwardly. After the visual threshold is constructed, the DCT coefficients are selected to embed if the values are higher than the visual threshold, t_{JND} . The embedding method is directly multiply the selected coefficients to the pseudo random sequences and then added to the DCT coefficients. With regarding to imperceptibility, the proposed method elaborately holds the PSNR up to 50 dB. Let I be an original image of size $M \times N$. Firstly, the original image is divided into 8×8

blocks and each block is transformed by using the discrete cosine transform (DCT). Let $C(i, j)$ be DCT coefficients at the location (i, j) in the block $\mathbf{k}^{th}$. The method of image watermarking can be expressed as follows:

$$C'(\mathbf{k}, i, j) = \begin{cases} C(\mathbf{k}, i, j) + \alpha \cdot \beta(\mathbf{k}, i, j) \cdot \omega(\mathbf{k}, i, j) \\ when\ C(\mathbf{k}, i, j) > t_{JND}(\mathbf{k}, i, j) \\ C(\mathbf{k}, i, j) \quad otherwise \end{cases} \tag{5}$$

where $C'(\mathbf{k}, i, j)$ is the watermarked coefficients. α is the embedding strength in which varied from 0.1 to 1. $\omega(i, j)$ is the watermark and is pseudo random sequence generated form Gaussian distribution with zero mean and unit variance. $\beta(\mathbf{k}, i, j)$ is the DCT coefficients selected from which its value is higher than the threshold. Each block of watermarked coefficients is inversed transform, and then reconstructed as the same size as the original image I.

B. Watermark Extraction

The watermarked extraction method is done by the reverse scheme of the embedded method. The watermarked image , $\hat{I}$ which usually attacked with the general manipulations such as image compression, filtering, noise addition and so on, is firstly divided into block size of 8×8, and each block is then transformed by DCT, Let $C''(\mathbf{k}, i, j)$ be the DCT transformed coefficients of watermarked image at the $\mathbf{k}$) block located at i, j and the extraction method can be calculated as

$$\zeta(\mathbf{k}, i, j) = \frac{C(\mathbf{k},i,j) - C''(\mathbf{k},i,j)}{\alpha\beta(\mathbf{k},i,j)} \quad if\ C''(\mathbf{k}, i, j) > t_{JND}(\mathbf{k}, i, j) \tag{6}$$

where $\varphi(\mathbf{k}, i, j)$ be the normalized coefficients at location (i, j), which expresses as follows:

$$\phi(\mathbf{k}, i, j) = \frac{\zeta(\mathbf{k}, i, j) \cdot w^*(\mathbf{k}, i, j)}{\sqrt{w^*(\mathbf{k}, i, j) \cdot w^*(\mathbf{k}, i, j)}} \tag{7}$$

where $w^*(\mathbf{k}, i, j)$ is a watermark which a thousand number of pseudo-random keys is used in our experiment. The value of normalized correlation is then compared with the threshold. For the threshold calculation, we assume that the original image has the probability density function of a Gaussian distribution. In this case, the watermarked image has also the same distribution as the original image. Thus, the threshold which decided either marked or unmarked is described as follows:

$$T_{\rho_N} = \sqrt{\frac{2}{N}} erfc^{-1}(2P_f) \tag{8}$$

where P_f is the probability of false alarm, and $erfc^{-1}$ is the inverse error function which is $erfc(x) = 2/\sqrt{\pi}\int_x^\infty e^{-t^2}dt$. With giving P_f equal to 10^{-8} and$N = 512 \times 512$, the threshold is calculated from eq. 8 is 0.011 which will be the threshold of evaluation of our experiments.

C. Watermark Evaluation

For perceptibility issue, the PSNR is mostly used in the past decade of quality measurement, but it is not involve with the human visual system. The new measurement gauge used instead of the PSNR is the wPSNR [6], [7], [8], which is more effective with the human visual system. The wPSNR, for evaluation of the watermarked image quality, is described as follows:

$$wPSNR = 10 \log_{10} \frac{255^2}{MSE \cdot NVF^2} \tag{9}$$

where $NVF = 1/1 + \sigma_x^2$. σ_x^2 is the local variance of the image in a window centered on the pixel at the location (i, j) . In addition, SSIM [6, 8] is an image quality assessment, using the SSIM metric, to compare of two images. The metric is derived from luminance, contrast, and strucural functions. In our experiments, SSIM is used to comparison between an original image and the watermarked image. SSIM is calculated from those parameters, which can be expressed as:

$$SSIM(I, \hat{I}) = \frac{2\mu_I\mu_{\hat{I}} + C_1}{2\mu_I^2\mu_{\hat{I}}^2 + C_1} \cdot \frac{2\sigma_I\sigma_{\hat{I}} + C_2}{2\sigma_I^2\sigma_{\hat{I}}^2 + C_2} \tag{10}$$

where $\sigma_I\sigma_{\hat{I}}$ is covariance between an original image and a watermarked image, and μ_I, σ_I^2 and $\mu_{\hat{I}}, \sigma_{\hat{I}}^2$ are the mean and variance of the original image and the watermarked image, respectively. C1 and C2 are appropriate constants.

IV. Experimental Results

In this section, the experimental results of the proposed method have carried on using a number of 10 ultrasound grayscale images. There are four 512×512 images with a gray level named Breast, Thyroid, Bladder Liver, and six 256×256 images with named US1-6, respectively. The quality of watermarked image evaluation, shown in the Section III, is measured by using SSIM, PSNR, and wPSNR. The experiments results shown that the proposed method has a high fidility which averages on PSNR and wPSNR is the 51.86 dB and 52.14 dB, respectively. These results of watermamrked image quality measurement are shown that the proposed method achieves the fidility of medical image watermarking. The sample of original images is shown in Fig. 2. Fig. 3 shows the result of the Breast watermarked image after attacked by JPEG compression with the quality factor 70%. In Fig. 4, a comprarision of the detection responses is illustrated which the proposed method has detection responses higher than IA-DCT and IA-W. The comparison between the proposed method and the other method of all tested images is shown in Fig. 5. The results shows that the proposed method have detection responses higher than the others. This means that the use of JND-DCT mask shows the better performance of robustness.
A compression of JPEG2000 attacks is shown in Fig. 6. It is shown that the proposed method is robust to JPEG2000 compression scheme, which have detection reponses higher than the other methods. In addition, the proposed method with using the HVS properties of inter and intra-band masking resulted in the better watermarked image not only imperceptibility with a high PSNR but also robustness with a high detection response. In experimental results, it is found that the higher the cumulative density probability, the higher detection response of a tested set of ultrasound images. A comparison of noise attacks of Thyroid image is shown in the Fig. 7. The standard deviation has been adjusted with varying from 10 to 100. The results of attacks in are shown that the proposed method could

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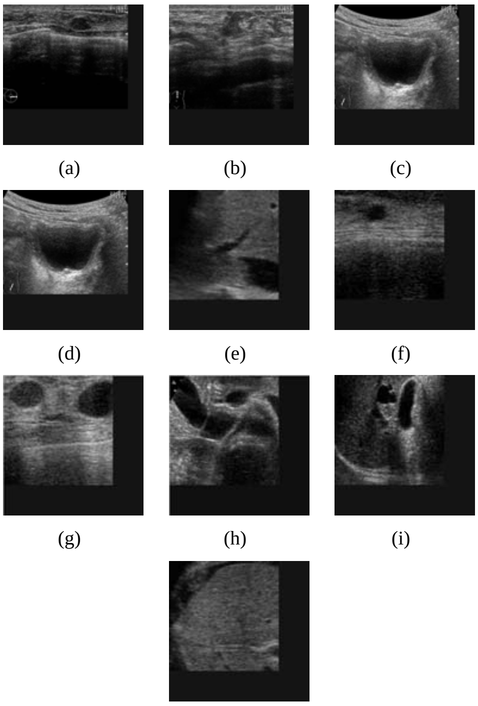

Fig. 2. All tested sets of original images (a) Breast, (b)Thyroid, (c) Bladder, (d) Liver, (e)-(j) US1-6

carry out with a higher detection response than other methods at upper bound of the threshold, 0.1. The proposed method is robust to noise attack when the standard deviation is up to 37 while IA-W is 30 and IA-DCT could not be detected. The result of median filter attack is shown in Fig. 8. The proposed method shown that the detection response can be achieved the threshold whereby the other method cannot meet this requirement.

V. Conclusion

Ultrasound image adaptive watermarking using the visual threshold has been proposed. The embedding coefficients have been selected from which they have less effect of the human vision. The perception threshold has been set up to be a gain of selecting the coefficient on each block, which composed of the contrast sensitivity function, luminance masking, and contrast masking. Especially on contrast masking, the masking model has classified each block of the DCT coefficient. The results are shown that the correlation have been totally detected with the peak value higher than IA-DCT and IA-W with all sizes of image when the watermarked image attacked with block-wise memoryless manipulations. Furthermore, it is found that higher cumulative distribution, the higher detection response, which considers to the original image data. Although, we are not consider the ROI, but the proposed method is border on original from distinguish without making any effect with the human eyes.

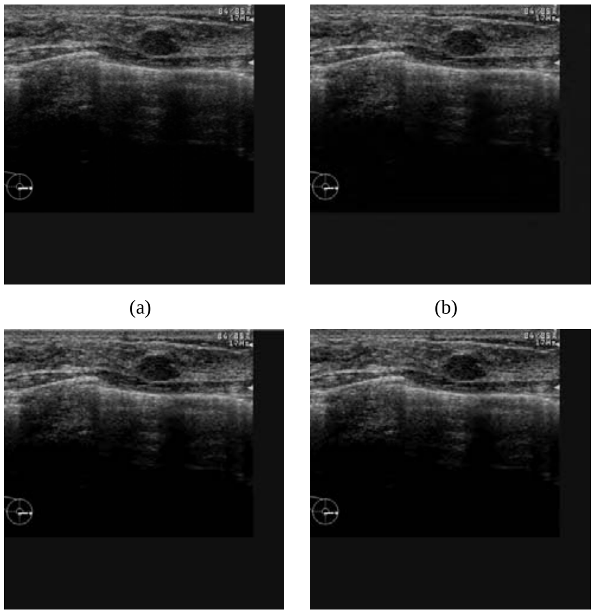

Fig. 3. A comparison of image JPEG compression attacked with quality 70% of each watermarking method, (a) An original of Breast image, (b) Breast watermarked image by JND-DCT, with PSNR= 34.99 dB, wPSNR= 35.74 dB, (c) Breast watermarked image by IA-DCT with PSNR= 35.17 dB, wPSNR = 35.91 dB, (d) Breast watermarked image by IA-W with PSNR= 35.12dB, wPSNR = 35.93 dB

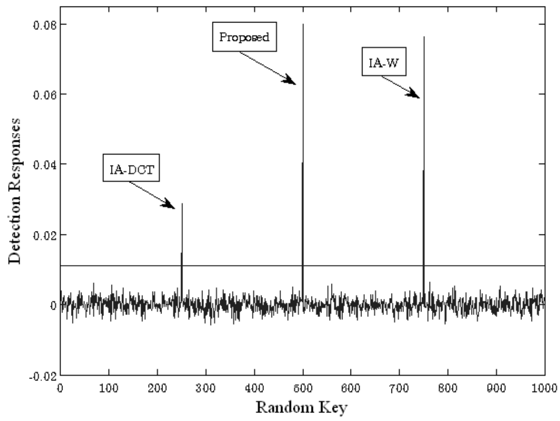

Fig. 4. Comparison of detection responses of Liver image of the proposed method, IA-DCT, and IA-W attacked with JPEG compression with quality factor 70%.

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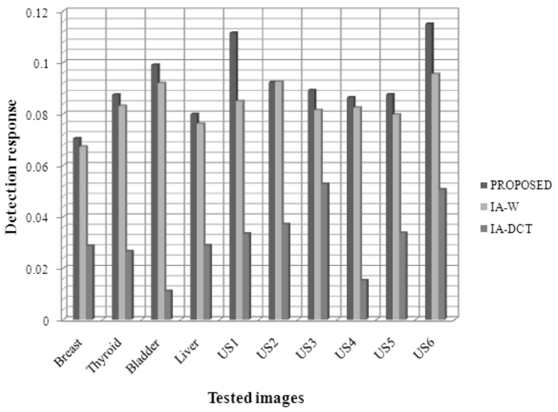

Fig. 5. A comparison of JPEG compression attacked with quality factor 70%

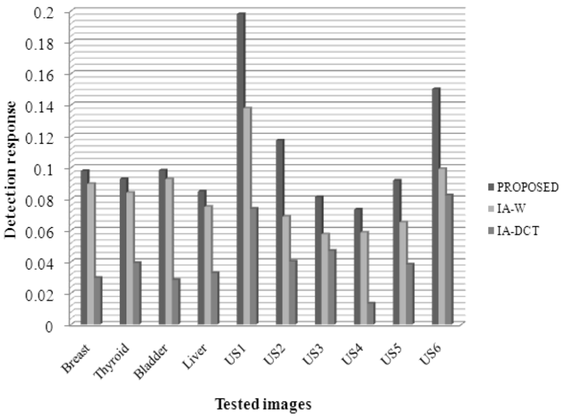

Fig. 6. JPEG2000 compression attacked with all tested images with 0.8 bpp.

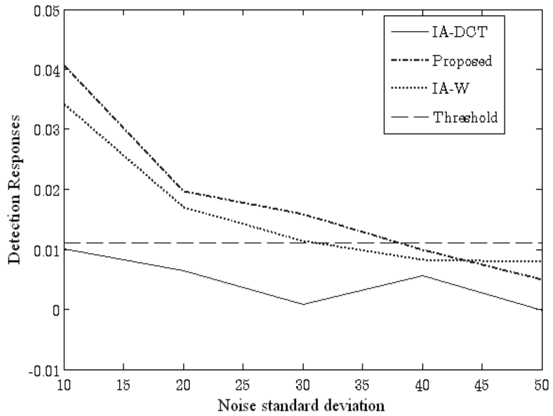

Fig. 7. Gaussian noise addition of Thyroid image with varying the standard deviation from 10 to 50.

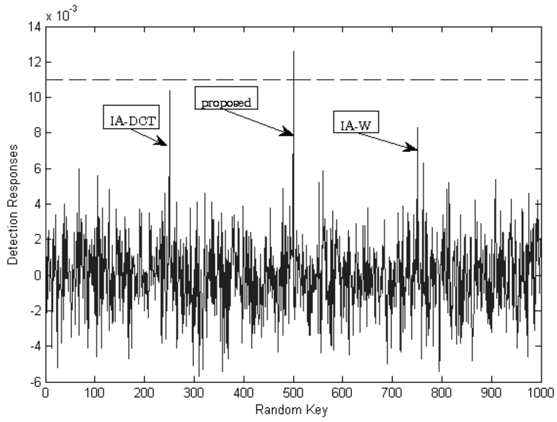

Fig. 8. A comparison of median filter 3x3 attacked of Liver image

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Amnach Khawne received the B.E. degree in telecommunication engineering and the M.E. degree in electrical engineering both from King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand, in 1998 and 2002, respectively. He was an exchange student at the University of Electro-Communication, Japan, in 2000-2001. He is currently a lecturer at faculty of engineering, King Mongkut's Institute of Technology Ladkrabang and is currently pursuing his Ph.D. degree at Tokai University. His researches interests include image watermarking, image compression, and network security.

Kazuhiko Hamamoto received the B.E. degree from department of Electronics Engineering, Tokyo University of Agriculture and Technology, Japan in 1989 and M.E. and Ph.D. from Graduate School of Electronics and Information Technology, Tokyo University of Agriculture and Technology, Japan in 1991 and 1994 respectively. He was an Assistant Professor at School of Engineering, Tokai University in 1994 and became an Associate professor in 1999. He is currently a Professor at Dept. of Information Media Technology, School of Information and Communication Engineering, Tokai University. His research interests are Medical Information Technology, Image Processing, Human Interface and Virtual Reality. He is a member of IEEJ, IEICE, SICE and IEEE, etc.

Orachat Chitsobhuk received the B.E.degree in electronics engineering from King Mongkut's Institute of Technology, Ladkrabang, Thailand, in 1992, the M.S. degree in computer engineering from Arizona State University, AZ, in 1997, and the Ph.D. degree in electrical engineering from University of Texas, Arlington, US, in 2001. She is currently an assistance professor and a lecturer at King Mongkut's Institute of Technology Ladkrabang, Thailand. Her research interests include indexing and retrieval, image and video compression, image registration, visual inspection, pattern recognition, and hardware design for image processing applications.