IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-6, Issue-5, May 2018 E-ISSN: 2347-2693

An Arnold DCT based Non-Blind Watermarking Technique for Medical Images

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Available online at: www.ijcseonline.org

Accepted: 22/May/2018, Published: 31/May/2018

Abstract— Telemedicine is a blend of medical information system and information technology that incorporates the transmission of medical data over the internet. The potential difficulties involved in implementation are confidentiality, robustness against attacks and integrity. In this paper, a dual-transform domain watermarking model has been proposed based on Arnold transform used for spatial de-correlation of the host image applied after Discrete Cosine Transform domain-based watermark insertion. The salient feature of this method is to accomplish improved robustness while safeguarding the originality of the image. This paper attempts to substantiate the guaranteed features by simulating the quality metrics on the benchmark images (MRI, X-Ray and US-Scan). The consequences of examinations have been exhibited through quality measures such as Structural Similarity Index (SSIM), Normal Cross Correlation (NCC) and Peak Signal-to-Noise Ratio (PSNR).

Keywords- Arnold, DCT, Integrity, Medical Imaging, Watermarking.

I. INTRODUCTION

Exchange of medical diagnostic images and multimedia data among networked hospitals or doctor's facilities put in different topographical areas is a typical practice keeping in mind the end goal to arrive at a collective determination of confounded sickness [1]. Medical imaging is the area that deals with making images of the human body for the clinical purpose. In the medical domain, human anatomy is analyzed using various methods, for example, Radiology, Medical Resonance Imaging, Nuclear Medicine, Medical Ultra Sonography, Endoscopy etc. Medical imaging gives a high quality of radiological services with the improvement of health care service delivery. It is an essential part of enhancing general welfare in a wide range of population groups by comprising different image modalities. It is a process of the imaging human body for diagnostic and treatment. Medical imaging trails the course of an ailment previously cured and additionally treated.

The fundamental motivation behind correspondence in medical image handling is to reduce the physical effort of exchanging information or patient record and to improve the reliability of information. To improve the medical services the medical images are exchanged through private or public networks, which help the time management in such communication. Medical images are transmitted through the internet for diagnostic purpose among networked hospitals, which will enhance the convenience of such correspondences. To safeguard the confidentiality, integrity and authentication while transmitting information to the remote location, watermarking a technique for hiding information inside digitized multi-media content is utilized. These days watermarking has turned out to be more popular and imperceptible [2]. Watermarking has an additionally preferred standpoint of medicinal images for security, trustworthiness and privacy. An essential prerequisite of watermarking is that the medical image should not vary perceptually from the original host image, as any wrong output acquired because of mismatch or loss of significance features may prompt faulty conclusions. The images ought not to experience any sort of corruption over the correspondence channel that influences the correctness of images. Patient-Id as the watermark helps in keeping up the information integrity of the patient avoiding any mismatch between data and patient.

The work on digital watermarking for the past six decades.

The very first electronic watermarking refers to the patent filed in 1954 by Emil Hembrooke of Muzac Corporation entitled "Identification of sound like signals" (Hembrooke E. F., 1961), the purpose of which was to safeguard the ownership of audio work. Since then a lot of work has been done in the digital watermarking field in all these six decades. While the main purpose was the protection of copyrights on multimedia contents, the attention was also drawn towards Medical Information Systems in which the main objective was security that centered around the three factors: availability, confidentiality and reliability. The inter and intrahospital communication for the healthcare of patients in telemedicine lead to a significant work in medical image watermarking since 2006. Papers published in almost all reputed journals, international conferences held and research projects on watermarking proved beyond doubt that the subject has been thoroughly researched in these six decades.

While the initial work concentrated on simple methods like Least Significant Bit (LSB) manipulation in spatial domain that was not robust, the directions moved towards methods in the frequency domain. The basis was so strong that the watermarking techniques based on mathematical transformations gained importance. SVD, DCT, DFT based watermarking insertion and extraction are mainly proved to be robust. However, they stabilized on the DWT based methods as proved by the good and a lot of papers published including a few doctorate thesis reports as evidenced in references available on the internet. Watermarking can be classified mainly into three categories. Robust, Fragile and Semi-Fragile watermarking (Xinshan Zhu et al., 2014; Venkateswarlu L. et al., 2018; Zhang X. et al., 2007). All these categories can be utilized for Medical images.

Robust Watermarking: This watermarking framework is intended for opposing the attacks for expelling or pulverizing the watermarks. It is utilized for copyright protection.

Fragile Watermarking: The watermark cannot be retrieved even if a small change occurs in the image. Because of its sensitivity, it is used to check the image is tampered or not.

Semi-Fragile Watermarking: The property of the semi-delicate watermark is mid-route amongst Robust and fragile watermark. It could tolerate up to a couple of degrees of progress to watermark image as because of the robust watermarking strategy. Unlike fragile watermarking, this kind of watermarking can hold its strength for slight changes.

A significant work on medical image watermarking

A. G. Bors [1996] has proposed a DCT based watermarking technique[3]. Subsequently, B. Tao [1997] proposed an adaptive DCT based watermarking technique [4]. In recent years also, many researchers have proposed DCT based watermarking techniques. S. Liu proposed a DCT and fractal encoding based watermarking model [5]. S. Tyagi proposed a DCT and genetic algorithm-based technique [6]. Similarly, researchers have proposed DCT based SLT, DWT, PCI, SVD and ICA transformation techniques for watermarking[7-15]. The methods applied for digital watermarking are equally applied in medical information systems also. However, in the recent years, many researchers proposed DCT based watermarking for medical images[16-18].

The focus of this paper is to represent the medical image in a transformed domain such as Discrete Cosine Transformation. The cosine coefficients sparsely represent the inter-pixel dependencies. In other words, if the image is smooth then the Cosine coefficients of the transformed image assume smaller values. The reaction of this circumstance is, the expansion of watermark will have the extreme bearing on the nature of the host image, which is undesired. To limit the symptom of the inadequate portrayal of the image we propose a dual domain transform procedure that subjects the host image to Arnold transformation which will scramble the spatial coordinates of pixels prompting a reduces the inter-pixel dependencies between pixel. This component is highlighted in the proposed work which encourages us to have expansive cosine coefficients of the host image close by and the little cosine coefficients of the watermark can be embedded straightforwardly. Because the watermark is inserted on scrambled host image, the basic issue relating to Region of Interest (ROI) and Region of Non-Interest(RONI) is irrelevant.

II. THE FUNDAMENTAL THEORY OF TRANSFORMS

A. Arnold Transform

V J Arnold in his exploration took a shot at Ergodic Theory and established a change. It is a playing hooky change known as Arnold Transform or Cat mapping [19-21]. Consider an image N X N. Let x, y represents original pixel coordinates and X Y be the transformed coordinates. x, y belongs to {0,1, 2, …, N-1}. Presently Arnold change is depicted as

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \; MOD(N)$$

In 2-D it can be expressed as:

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \; MOD(2)$$

Arnold transformation when applied to any computerized image, the conveyance of the image brightness may be changed by moving the pixel coordination. Reestablishing the first state is possible by applying the inverse Arnold transform. This strategy depends on periodicity. The change in period is the fundamental parameter that influences the decryption. The adjustment in period relies upon the size of the image. This Arnold change offers a surprisingly positive turn of events while making Region of Interest (ROI) and Region of Non-Interest (RONI) viewpoints insignificant.

B. Discrete Cosine Transform

DCT is a system to change over a flag into its principal recurrence segments. It speaks to an image to be a whole of sinusoids of differing extent and recurrence. With input image X, the DCT coefficients of the changed yield image Y are computed utilizing the beneath condition. If I is the information image which has M X N pixels, I (x, y) is the intensity of a pixel in rows x and columns y of the image, and f(p, q) is the DCT coefficient represented in p rows and q columns of the DCT grid, then

$$f(p,q) = \sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}} \propto_p \propto_q \sum_{p=0}^{M-1}\sum_{q=0}^{N-1} I(x,y)\cos\frac{(2x+1)p\pi}{2M}\cos\frac{(2y+1)q\pi}{2N}$$

where

$$\propto_{\mathrm{p}} = \begin{cases} -\frac{1}{\sqrt{2}}, & \mathrm{p} = 0 \\ 1, & \mathrm{p} = 1,2,3,..\mathrm{N}-1 \end{cases}$$

$$\propto_{\mathrm{q}} = \begin{cases} -\frac{1}{\sqrt{2}}, & q = 0 \\ 1, & q = 1,2,3,..N-1 \end{cases}$$

The block-based DCT change partitions an image into non-overlapping squares. This division brings about three recurrence sub-groups: Low-Frequency (LF) subband, Mid-Frequency(MF) sub-band, and a High-Frequency(HF) sub-band. The DCT kind of watermarking model considers two issues. The first is that a great part of the signal energy lies at the LF sub-band which contains important visual parts of the host image. In this way, the watermark can't be embedded in LF subband. The second is that the HF sub-band parts of the image are normally dispensed through compression and commotion attacks. The watermark is finally embedded by adjusting the coefficients of MF sub-band with the goal that permeability of the image would not be influenced, and the watermark would not be evacuated totally by attacks.

III. ARNOLD AND DCT BASED ROBUST WATERMARKING.

In the proposed approach, three watermarks (Patient-ID, Hospital logo and aadhaar card) image has been taken as unique watermark image and Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), X-Ray and DICOM design images as the host images.

A. Watermark Embedding Technique

The below algorithm explains the step by step instructions to insert the watermark in Arnold based DCT domain.

Algorithm 1: Watermark Insertion Using Arnold – DCT

Procedure WAT_INSERTION (H, W)
//H- is host image of size 512X512
//W -is watermark image 128 X 128
BEGIN
//Application of N – cycles AT on the host image H for getting scrambled image SH.
SH← AT (H, N);
//Apply cosine transformation (DCT) on the scrambled SH image for cosine coefficients.
CSH ← DCT(SH);
//Apply Cosine Transform (DCT) on the watermark image W to obtain cosine CW.
CW← DCT(W);
//Scale down the Cosine coefficients of watermark image W by using scaling factor α = 0.14, (0< α <= 1)
CW ← α * CW;
//Add the CW content in CSH and (u, v) coordinates of middle-frequency subband in DCT domain
CSH (u, v) = CSH (u, v) + CW (i, j);
//Apply inverse IDCT on CSH for getting watermarked image WSH.
WSH← IDCT (CSH);
//Application of N – cycles Inverse Arnold Transform (IAT) on the watermarked scrambled host image WSH for getting watermarked image WH.
WH← IAT (WSH, N);
END.

The algorithm can be viewed in Fig-1. First host image (chest X-Ray) is scrambled using Arnold and DCT is applied to scrambled host image and watermark image (HLOGO) to get DCT coefficients in each. In Figure 1 it is clearly observed that the scrambled host image DCT coefficients are brighter than that of the watermark image coefficients. This feature will give more robust and high quality watermarked host image. Insert the watermark in DCT coefficients of the host. Apply the inverse DCT followed by Inverse Arnold. The insertion procedure is presented in the following Figure-1.

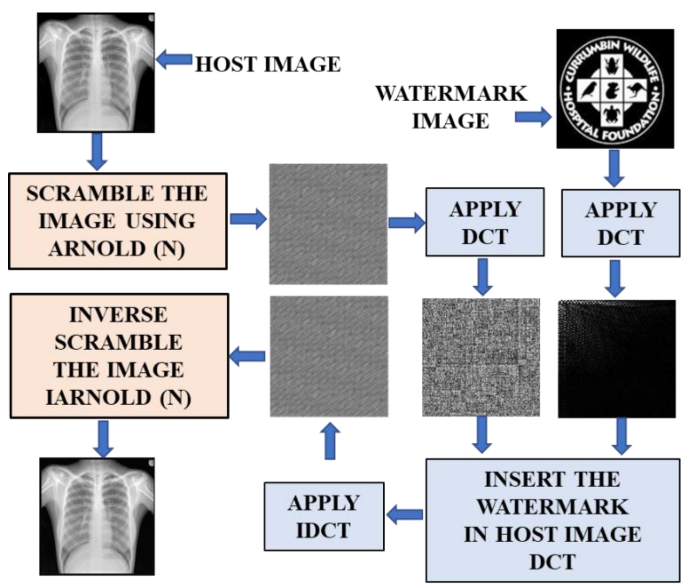


Figure 1. Watermark embedding technique

C. Watermark Extraction Technique

The below algorithm gives the sequence of steps to extract the watermark.

Algorithm 2: Watermark Extraction Using Arnold – DCT

Procedure WAT_EXTRACTION (WH, H)
//WH- is watermarked host image of size 512X512
//H- is host image of size 512X512

BEGIN
//Application of N – cycles AT on the host image H for getting scrambled image SH.
SH← AT (H, N);
//Application of N – cycles AT on the watermarked image WH for getting scrambled image WSH.
WSH← AT (WH, N);
//Apply Cosine Transform (DCT) on the SH and WSH scrambled images getting of Cosine coefficients.
CWSH ← DCT(WSH);
CSH ← DCT(SH);
//subtract the CSH content in CWSH and (u, v) coordinates of middle frequency sub band in DCT domain
CW (i, j) = CWSH (u, v) - CSH (u, v);
//scale up the Cosine coefficients of watermark image by using scaling factor α= 0.14, (0< α <= 1)
CW← CW / α
//Apply inverse DCT on CW for getting retrieved watermark image W.
W← IDCT (CW)
END.

Watermark extraction strategy can be explained in the following steps. First, the host image and watermarked image are scrambled by Arnold transformation. The original and the watermarked images are disintegrated using DCT. The difference of their DCT coefficients subjected to scaling and inverse DCT results in the watermark used. The image comprises positive and negative values considering the noise that gets added because of attacks. To retrieve the watermark, we need the original host image.

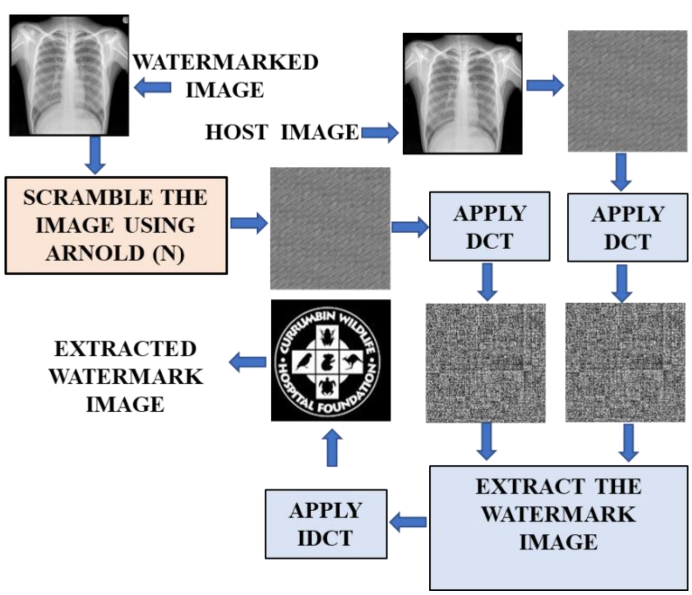


Figure 2. Watermark Extraction Technique

D. Evaluation Measures of Proposed Watermarking Algorithm

The accompanying highlights are extracted to check the similarities between the host and watermarked image.
1. Peak Signal to Noise Ratio (PSNR) is computed to quantify the distortion of the watermarked image.
2. The Structural Similarity Index (SSIM) is used for measuring the auxiliary contortion of the watermarked image.
3. Normalized Cross Correlation (NCC) is computed to measure the Correlation between two images.

IV. EXPERIMENTAL RESULTS

To assess the execution of the proposed technique, simulated experiments have been conducted on a couple of samples of Medical host images (Barre S).

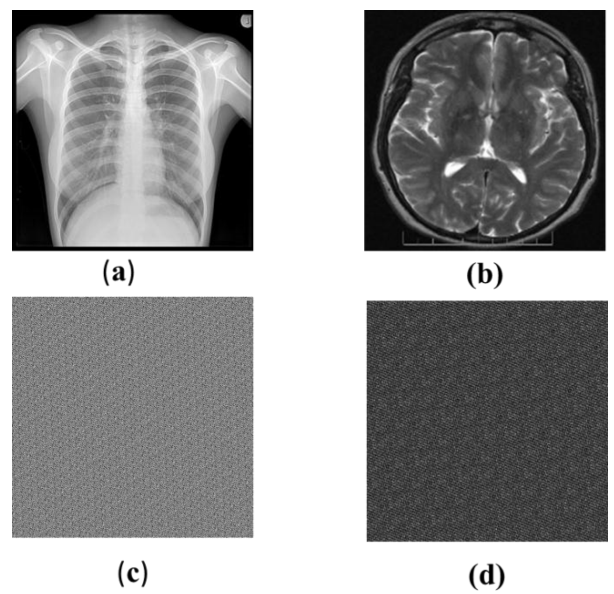


Figure 3: (a) Chest X-Ray, (b) Cross-Sectional Image of a human skull, (c) Arnold Transformed Chest X-Ray and (d) Arnold Transformed Cross-Sectional Image of a human skull.

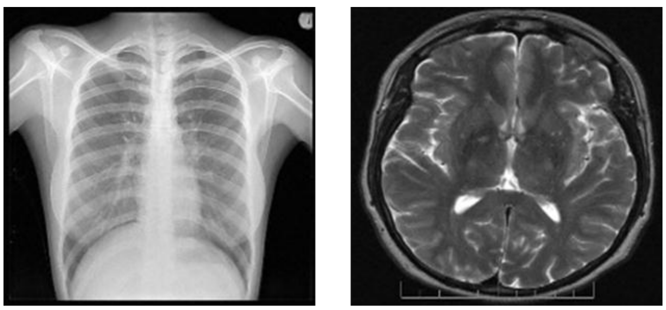
Previews of the two sample host images (Chest X-Ray and CT-SCAN of human Skull) are shown in Figure 3(a) and 3(b) along with Arnold transformed medical host images Figure 3(c) and 3(d) with a number of cycles equal to thirteen.

The below Figure 4 shows three sample watermark images 4(a) hospital logo, 4(b) patient Id and 4(c) Aadhaar card.

(a) (b) (c)

Figure 4 (a), (b) and (c) Original watermarks.

Figure 5 demonstrates the host images after insertion of a single watermark (HLOGO). We can see that there are no visual distortions in the images (Figure 3 and Figure 5) showing the objective quality based on human perception.



(a) (b)

Figure 5 (a) Watermarked Chest X-Ray (b) Watermarked Human Skull Image

A watermark image is inserted into the chest X-Ray to test the limit and power of the calculations. Figure 6 below demonstrates the extracted watermark images (Figure 6(a) HLOGO, 6(b) Patient Id and 6(c) Aadhaar card). From the Figure 6, it is observed that perceptually there is no distortion in watermark images.

(a) (b) (c)

Figure 6 (a), (b) and (c) Extracted watermarks.

The Figure 7 below indicates watermarked host images of the two specimen medical images after applying attacks. However, in medical images, we will consider specifically accidental attacks like transmission errors (Figure 7(a), 7(d)), compression (Figure 7(b), 7(e)) and a small percentage of cropping (Figure 7(c) and 7(f)).

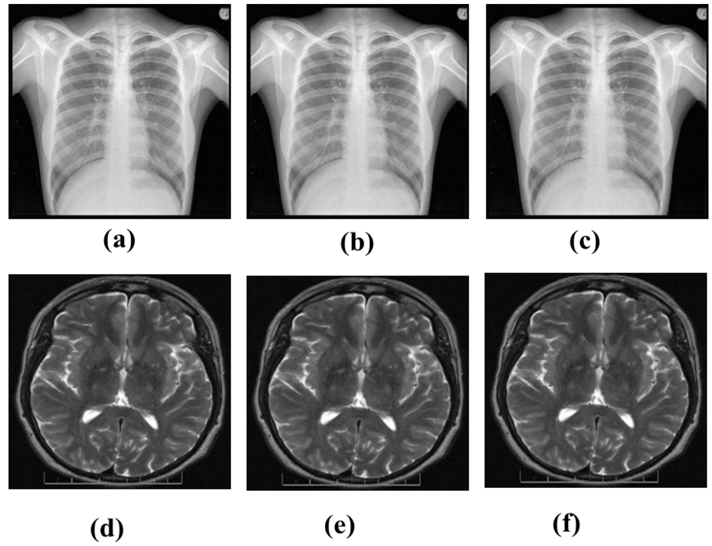


Figure7. Watermarked images after the attack (a) and (d) Gaussian noise attack, (b) and (e) Compression attack (25%), (c) and (f) cropping of the image (4%)

From the images above, it can be observed that the watermarks inserted did not degrade the quality of host medical images and hence serve the objective of integrity when viewed objectively. In the following parts, the quality factor is viewed subjectively based on mathematical features of images.

The deviations of a watermarked image and the extracted watermark are measured by Peak Signal-to-Noise Ratio (PSNR), Normalized Cross Correlation(NCC) and Structural Similarity Index Method (SSIM). These subjective measures are well being used in the field for the judgment of image quality. The results are tabulated in Table I. When subjected to attacks, the nature of the watermarked image is distorted.

Table I. Watermarked Image Before Attacks And After Attacks

Host Image	**Before Attack**	**After Attack**		
		(Gaussian) Variance 0.001	***(Compression)25%***	***Cropping***
MRI	PSNR=41	PSNR=24	PSNR=33	PSNR=31
	NCC=1.003	NCC=1.0013	NCC=1.0013	NCC=1.0013
	SSIM=0.99	SSIM=0.91	SSIM=0.92	SSIM=0.92
X-RAY	PSNR=41	PSNR=25	PSNR=32	PSNR=32
	NCC=1.002	NCC=1.0013	NCC=1.0013	NCC=1.0013
	SSIM=0.99	SSIM=0.91	SSIM=0.93	SSIM=0.93

Figure 7 indicates watermarks extracted after Gaussian noise with variance 0.001, compression (25%) and cropping (4%)

attacks. Analyzing the measures, it can be concluded that ARNOLD-DCT strategy gives perceptually good results. It also demonstrates that the proposed method is sufficiently proficient to deal with such attacks.

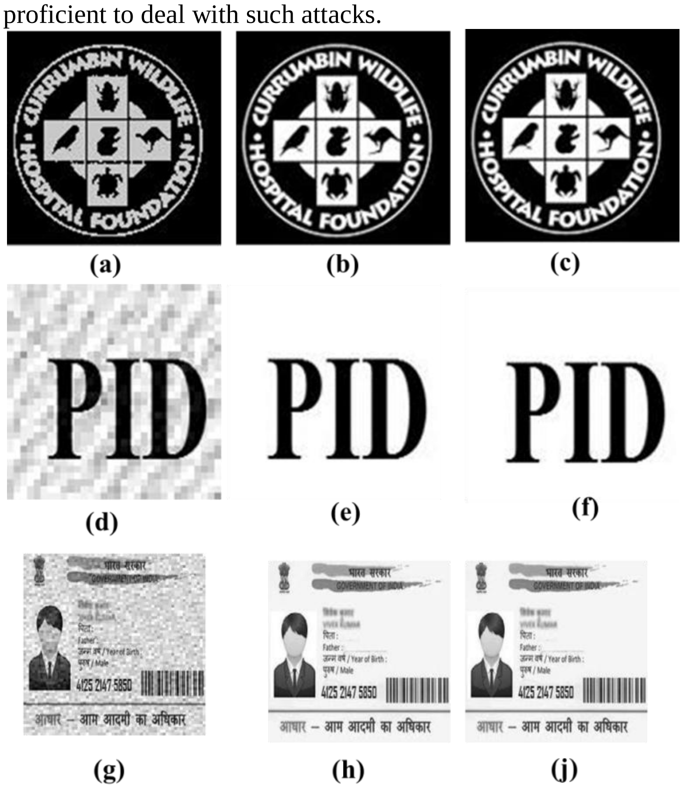


Figure 7 Retrieved watermarks after attacks: (a), (d) and (g) Gaussian attack, (b), (e) and (h) compression attack, (c), (f) and (j) cropping attack.

Table II, given below shows PSNR, NCC and SSIM measures for retrieved watermark image before attacks and after attacks.

Table II. Extracted Watermark Image before Attacks And After Attacks

Host Image	No attack	After attack		
		(Gaussian) Variance 0.001	*(Compression)25%*	*Cropping4%*
MRI	PSNR=H	PSNR=30	PSNR=33	PSNR=34
	NCC=1.0021	NCC=1.0013	NCC=1.0013	NCC=1.0013
	SSIM=1	SSIM=0.87	SSIM=0.84	SSIM=0.84
X-RAY	PSNR=H	PSNR=28	PSNR=26	PSNR=27
	NCC=1.002	NCC=1.0012	NCC=1.0013	NCC=1.0013
	SSIM=1	SSIM=0.84	SSIM=0.81	SSIM=0.82

With no attacks, the extracted and original images should be same in all respects which is confirmed with the high PSNR and correlation coefficient of one. When the watermarked host image is subjected to attacks the original image will be naturally distorted and above resulted measurements followed this observation but PSNR values are above 30db and correlation coefficients are also within the tolerable limits as reported in the literature. In addition, viewing subjectively the watermarks extracted have a good human perception.

V. CONCLUSION

A robust watermarking algorithm for medical images is proposed using a combination of ARNOLD – DCT transformations sustaining image quality. It also satisfies the three significant features of medical information systems cited before in this paper.

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