A Hybrid Encoded and Adapted-tuned Neural Network for Asset Medical Image Watermarking Technique

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Abstract

Digital image watermarking techniques are used to authenticate identity of owners and copyright protection of asset images. Asset medical images (AMI) specially require extreme care when embed a watermark message because additional information should affect the AMI quality and the changes in AMI gray levels may interfere with its interpretation. This paper introduces a hybrid encoded and adapted-tuned neural network (TNN) for AMI watermarking technique to cover almost essential watermarking requirements. To attain robustness, security and invisibility, uses human visual system (HVS) and TNN to tune the AMI and to find the maximum amount of adaptive watermark message before the watermark message becomes visible. To achieve transparency, enhance AMI using histogram equalization. Embedding is performed into the middle frequency coefficients of discrete cosine transform of the AMI, to avoid visual parts in the low frequency coefficient and the noise and attacks in high frequency to improve image robustness and increase capacity comparing to spatial domain.

1. Introduction

The rapid development in digital communication systems and the increase of transmission speed have created urgent needs to protect digital images from manipulations and illegal copying. Today, a large amount of AMI exists in digital electronic format for easy storage and transmission. So, data should be protected and secured using information hiding techniques such as cryptography, steganography and watermarking [1-3]. Cryptography is that to convert an asset image into an encrypted image using an encryption key. Steganography means hiding of a message inside an asset image that cannot be detected. While watermarking is the process of embedding a message into an asset image, that must have a relationship with the message. Now, artificial intelligent and neural network help in development of watermarking techniques [4-6]. Yu [4] proposed a new watermarking technique based on the neural network (NN) for digital images. However, using NN for watermark extraction in the time domain and the image compression watermark can be easily erased. Zhang [5] proposed an algorithm using the Hopfield neural network and discussed its watermark capacity. But the NN in this algorithm needs a very large number of neurons. Chang [6] proposed another watermark algorithm based on a full counter-propagation neural network (FCNN), while the watermark is embedded in the NN.

2. Methodology

A proposed concept hybrid encoded and adapted-tuned neural network for AMI watermarking technique, is introduced to adapt the watermark message with maximum strength before it becomes visible by human visual system (HVS) and then embed into the middle frequency coefficients of the discrete cosine transform (DCT).

3. Paper Organization

This paper is classified into nine sections; Section 2 shows the methodology. Section 3 demonstrates the paper organization. Section 4 shows the proposed watermarking technique. Section 5 presents the technique procedures. Section 6 describes the embedding and extraction of a watermark message in to the middle frequency coefficient of the DCT. Section 7 presents the quality measurements Section 8 shows the experiments and results of applying different compressions and geometric attacks. Section 9 gives the conclusion of paper.

4. The Proposed Watermarking Technique

Figure 1 introduces the concept of the proposed hybrid watermarking technique. It consists of two channels: a watermark encoding channel and AMI tuning channel. These two channels are embedded together to get the watermarked image. First, the watermark is to be encoding before embedding into AMI for robustness and security. Second, enhance the AMI using histogram equalization to achieve transparency. Third, use human visual system (HVS) and TNN as a tuning process to find the maximum amount of adaptive watermark message. Use luminance sensitivity, frequency sensitivity and texture sensitivity as tuned input parameters to control the watermark message strength as an output of the TNN. Forth, embed into the middle frequency coefficients of the discrete cosine transform (DCT) of the asset image, to avoid visual parts in the low frequency coefficient and the noise and attacks in the high frequency.

5. The Technique Procedures

A. Encoding the watermark message process

The watermark message is to be encoded for security and robustness using the following steps:

- First, convert the watermark to a binary code matrix using code of Walsh [7].

Binary watermark code matrix = $[0 \ 1 \ 0 \ 1]$.

- Second, the binary watermark code is to be multiplied by a key binary code matrix with length 4, to form a key binary code matrix as:

$$\text{Key binary code matrix} = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \\ +1 & -1 & +1 & -1 \end{bmatrix}$$

- Third, get the resultant coded weight matrix, as:

$$\text{Encoded weight matrix} = [2 \ 0 \ 0 \ -2].$$

- Forth, elevate to positive numbers, e.g. elevate by 2 to get:

$$\text{Elevated coded weight matrix} = [4 \ 2 \ 2 \ 0].$$

- Fifth, convert to binary code, as:

A binary code = [100 010 010 000].

Figure 2 shows the introduced block diagram of the encoding watermark message.

B. Asset medical images enhancement

Image enhancement is to sharpen the contrast of the AMI as happen in ultrasound and X-ray. Histogram equalization (HE) of an image is the best solution to improve pixels distribution of dark and low contrast image. The greater the histogram stretch, the greater is the contrast of the AMI. This method enhances the contrast of the AMI, especially when the usable data of the AMI is represented by close contrast values [8]. So, the applying of histogram equalization (HE) of the MAI is used to obtain high contrast and attain transparency for watermarking [9]. Suppose image (a) as in figure 3.

The HE of the image (a) is computing as the following:

1. Count the number of pixels of the image.
2. Calculate the probability of pixel = intensity number of pixel / total number of pixels.
3. Calculate the cumulative probability of pixel.
4. Change intensity in the range (1-20) (multiply by 20).
5. Rounding the values to lower (floor rounding).

Table 1 shows the results of the mentioned above five steps of histogram equalization of the AMI (a).

Table 1: The five step of histogram equalization of AMI (a).

Pixel intensity	1	2	3	4	5	6	7	8
Number of pixels	1	3	3	2	2	1	3	1
Probability	0.0625	0.1875	0.1875	0.125	0.125	0.0625	0.1875	0.0625
Cumulative probability	0.0625	0.25	0.4375	0.5625	0.6875	0.75	0.9375	1
Cumulative probability x 20	1.25	5	8.75	11.25	13.75	15	18.75	20
Floor rounding	1	5	8	11	13	15	18	20

Fig. 4 represents the AMI and the enhancement matrix.

C. Human Visual System Model (HVS)

There are several important requirements for digital watermarking algorithms. Integrating a HVS and a NN together into watermarking technique as a tuning process to find the maximum amount of adaptive watermark message before being visible, could assist in satisfying these watermarking requirements. HVS results from that, every pixel value of an image can change by a certain amount without making any perceptible difference in image quality. Several models studied based on HVS watermarking [10-14]. The present proposed technique utilizes the proposed TNN and the HVS for producing an adaptive watermark message to be embedded into enhanced AMI to attain invisibility and watermark robustness. There are three basic tuning properties for human vision: luminance sensitivity (L_k), frequency sensitivity (F_k) and texture sensitivity (T_k) are to be used as inputs of the introduced TNN.

- *Luminance sensitivity (L_k)*

Brightness masking improves the effect of a detectable noise threshold on a constant background. When the background is brighter the embedded signal increased [15].

- *Frequency sensitivity (F_k)*

Divide an asset image into (8x8) blocks and apply DCT to each block, there will be (8x8) matrixes of DCT coefficients. Each matrix consists of three areas of high frequency (HF), low frequency (LF), and middle frequency (MF). The energy content of an image is concentrated in LF coefficients (top left). So, the watermark cannot be embedded in the LF that places the watermark in the image. On the other hand, the embedding in HF (bottom right) coefficients causes the watermark to be removed from the image after any image compression. So, the best place to embed the watermark is into its MF [16].

- *Texture sensitivity (T_k)*

An image can be classified into three blocks: smooth, textured and edge block. HVS research shows that distortion sensitivity of the human eye decreases from the edge block, smooth block and texture block respectively [17]. Dissimilar sensitivity degrees mean different significance of these three blocks.

A. The tuned neural network method

A neural network is an important field of artificial intelligence; it has many advantages on the aspect of artificial simulation. Also, it has self-teaching, self-organizing, association of ideas. Moreover, it has great comparability with the HVS [18]. In this paper, the proposed TNN is a feed-forward TNN (FFTNN). Figure 5 introduces the architecture of this TNN; the output aims to produce the strength of the watermark message. The TNN is composed of three layers, namely: a tuned input layer, hidden layer and an output layer. In this study, each HVS feature vector has three input elements. The feature components form the feature vectors (L_k, F_k, T_k) represent the sensitivity values of luminance, frequency, and texture

respectively. Each feature vector is one of the input components of sensitivity values in the TNN. Feed these tuned three inputs (L_k, F_k, T_k) to the hidden layer; and then feed the response to the output layer. During training, information is propagated again through the TNN and used to update connection weights. The learning for each sample in the training set is repeated many times until the error is smallest. This proposed TNN is important as well as the watermark technique to generate the maximum watermark strength.

6. Embedding And Extraction Of The Watermark

The proposed method is based on using the MF of the DCT domain, to authenticate and protect the medical image from different types of noise attacks: compression and geometrical attacks, like median filter, cropping and other noise and attacks. The method is useful for watermarking extracting [19].

7. Quality Mesurments

In order to evaluate the quality performance of the watermarking technique [20], Peek Signal-to-Noise Ratio (PSNR) is used to measure the difference between the original image and the watermarked image.

$$PSNR = 10 \log_{10} \left(\frac{255^2}{MSE} \right) \quad \dots\dots\dots(1).$$

The mean-square error (MSE) is computed as:

$$MSE = \frac{1}{m \ n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i, j) - K(i, j)]^2 \quad \dots\dots\dots(2)$$

Where m, n is the size of the image and I is the asset image and K is the watermarked image.

Also, a normalized correlation coefficient (NC):

$$NC = \frac{\sum_{i=1}^m \sum_{j=1}^n W_{i,j} \oplus W^*_{i,j}}{m \times n} \quad \dots\dots\dots(3)$$

It measures the difference between the original watermark message and the extracted watermark message.

Where $W(i, j)$ is the original message and $W^*(i, j)$ is the extracted message [21] This proposed watermarking technique is tested on several AMI with size (512x512) pixels.

8. Experiments And Results

Applying compression; cropping, filtering, and other image attacks are described in this section, as in Figures 6(a - h).

From figure 6(a- h), the AMI and the watermarked images are nearly identical in visual quality. The ($PSNR \approx 40$) indicates that the watermarked image is almost similar to the MAI, which means that this watermarking technique attains the invisibility. Also, the ($NC \approx 1$) indicates that there is almost no difference between the original watermark message and the extracted watermark message.

A. Robustness against Compression attacks

In early researches it was found that when applied compression to an image for transmission or storing, the quality of image had decreased. Different compression ratios are applied to the proposed watermarking technique and each time decreasing the quality factor (QF) from 90% then 70%, 50%, 30% to 10%. In the previous work [22] it was found that when the QF is larger than 90%, the watermark message can be extracted, while for the QF is 30%, the extracted watermark message identified. Figure 7(a) shows that the watermarked image under compression attack with quality factor 10% and figure 7(b) shows the response with higher value. Thus, this proposed technique can extract watermark under high compression attack with quality factor 10%. Figure 8 shows the NC values (0.7 to 1) due to different compression ratios QF which means that extracted watermark message after the different compression attacks is similar to the original watermark. Also, the proposed technique can resist high compressions with quality factor as low as 10%. This proposed technique enhances the performance against compressions as shown in Figure 9. The ($PSNR \approx 40$) means that AMI and watermarked image that attacked by different rates of compression is imperceptible. Thus, this technique attains high robustness and invisibility against compression.

B. Robust against other attacks (Gaussian, and cropping)

In order to prove the robustness of the proposed watermarking technique, carried out a range of attacks and evaluate the performance of this watermarking technique, Table 2 displays the correlation coefficient's values. The experimental results demonstrate that the correlation coefficient's values are above 0.6 and near to 1. So, the extracted watermark and original are almost identical. Thus, the robustness of the proposed algorithm is evident. Also, the proposed algorithm has better performance, especially for cases that suffering from compression [23].

Table 2: the values of the correlation coefficient (NC).

Image	The values of the correlation coefficient (NC)			
Attack	image1	Image2	Image3	Image4
Gaussian	0.9352	0.9178	0.9423	0.9543
Salt and pepper	0.9980	0.9943	0.9872	0.9756
Speckle	0.9674	0.9710	0.9541	0.9642
Rotation	0.7225	0.7019	0.7134	0.7345
blurring	0.6743	0.6501	0.6872	0.6798
Median filtering	0.8283	0.8747	0.8354	0.8623
Mean filtering	0.7421	0.6985	0.7231	0.7129
Cropping	0.9023	0.9548	0.9372	0.9123

9. Conclusion

This paper introduces an encoded-adapted hybrid tuned neural network for medical asset image watermarking technique to attain security, capacity, transparency, invisibility and robustness and face almost all types of attacks. This hybrid technique combines enhancement, decomposition and conversion of a AMI. Also, the tuned process that using the HVS and TNN techniques to find the maximum amount of adaptive watermark embedded into the middle frequency coefficients of the discrete cosine transform of AMI to attain all watermarking requirements. Simulation results demonstrated the ($PSNR \approx 40$) indicate that the watermarked image is very similar to the AMI. Also, the ($NC \approx 1$) indicate that there is almost no difference between original watermark message and extracted watermark message. Moreover, this technique can extract watermark under compression attack with quality factor down to ($QF=10\%$).

Declarations

Conflict of Interest

The authors declare that they have no conflict of interest.

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Figures

Figure 1

The concept of the proposed hybrid watermarking technique.

Figure 2

The introduced block diagram of the encoding watermark message.

Figure 3

The image (a).

The tuned neural network.

Figure 6

(a) medical asset image1, (b) watermarked image1 (PSNR= 40.34), (c) medical asset image2, (d) watermarked image2 (PSNR=39.81). (e) medical asset image3, (f) watermarked image3 (PSNR= 43.62),

(g) medical asset image4, (h) watermarked image4 (PSNR=42.74).

Figure 7

watermarked image under compression with quality factor 10%

(a): compression (10%) (b): response of attacked by (10%)

Figure 8

Results of compression attack experiment.

Figure 9

Mean values of PSNR between the original and watermarked image attacked by different rate of compression.

Figure 10

The watermarked images1,2,3,4 exposed to various attacks:

(a) Watermarked image1 after Gaussian noise, (b) Watermarked image1 after Salt and pepper noise, (c) Watermarked image1 after Speckle noise, (d) Watermarked image1 after Rotation noise, (e) Watermarked image1 after blurring noise, (f) Watermarked image1 after Median filtering noise, (g) Watermarked image1 after Mean filtering noise, (h) Watermarked image1 after cropping attack.