SVD based Watermarking Method for Medical Image Security

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ABSTRACT
Most commonly watermarking is done for authentication purposes. Due to the widespread use of medical images for telemedicine applications the watermarking process gains more attention in the medical field i.e. for secure transmission of medical images from one hospital to another, for presenting the image as court evidence etc. This paper gives a comparative analysis on applying the watermark on the diagonal matrix of the SVD decomposed. The usefulness of SVD in watermarking applications and mathematical models are also given briefly. The performance is verified using PSNR, Pearson Correlation Coefficient and Image Quality Index.

KEYWORDS: - Watermark, Singular Value Decomposition, PSNR, Pearson Correlation Coefficient, Image Quality Index.

1. INTRODUCTION
The Institution of Medicine defines telemedicine as the use of electronic information technologies to provide and support health care when distance separates the participants. The most common application today is in the transmission of high resolution X-rays, CT scan and other medical images. Telemedicine arose originally to serve rural populations or any people who are geographically isolated, where time and cost of travel make access to the best medical care difficult. Now it is increasingly being used in conventional medicine, to permit doctors the world over to share exclusive recourses and valuable experience. Hence, healthcare industry demands secure, robust and more information hiding techniques promising strict secured authentication and communication through internet or mobile phones. So the security aspect of the data hiding is also an important parameter as far as medical field is concerned.

Medical image watermarking requires extreme care when embedding supplementary data within the medical images because the supplementary information must not affect the image quality as this may cause an incorrect diagnosis [1]. This kind of a system requires a high level of security, which can be assured by using digital watermarking techniques. This imposes three obligatory features: robustness, capacity, imperceptibility and capacity [3]. There are several methods that has been using for medical image watermarking. The watermark can directly be embedded in the LSB as described by Mohamed Ali et al. In some applications it is often not allowed to alter the image contents even one bit of information. The requirement of imperceptibility can be fulfilled by two methods (a) by embedding the watermark in the region of non interest (RONI) and keeping the region of interest (ROI) distortion free, and (b) by selecting reversible watermarking method which retrieve the original cover image by undoing the watermark embedding process at the receiving end after the image authentication process is completed. In this paper the performance of embedding the watermark using usual SVD approach is enhanced by simply embedding the watermark in the post and pre diagonal elements, thereby reducing the complexity and still maintaining the quality of the original image.

2. IMPORTANT PARAMETERS IN WATERMARKING SYSTEMS
Digital watermarking systems have a set of parameters. Tradeoff between them is necessary for the robustness and proper working of a watermarking system. The most important ones are listed here [4]:

2.1 Amount of information embedded**:** This important parameter is influenced by the specific application and straightaway influences the potency of the system. The more information introduced, the less robust the watermarking will be. This parameter also depends on the watermark intensity.

2.2 Watermark intensity**:** Also known as the power of the embedded watermark. To increase the robustness, one may increase this parameter, but at the cost of the deprivation of original image. In this paper 'alpha' is used to represent the watermark intensity. As the alpha value increases the image quality decreases, but at the same time robustness increase.

2.3 Size of watermark: Similar to its intensity, the larger the size of watermark is, the robust the system will be. It should be noticed that watermark that is too small tend to have little value in real application.

2.4 Control information**:** Though it has nothing to do with the invisibility or robustness of the watermarking system, the control information, for example, the key used to reorganize the watermark before embedding it, plays an important role in system security.

3. PERFORMANCE VALIDATION PARAMETERS
Basically the performance evaluation parameters can be classified into two types

1. Objective
2. Subjective

Objective parameters are based on human visual system (HVS) they attempts to incorporate human perceptual quality measures e.g. image quality index (IQI), picture quality scale(PQS),mean optimum score etc, whereas subjective measures are based on some mathematical model for e.g. peak signal to noise ratio, mean square error, Pearson Correlation Coefficient (PCC), robustness etc.

3.1 PEAK SIGNAL TO NOISE RATIO (PSNR)

PSNR is one of the most important parameter for the evaluation of image quality.

PSNR is given by the eqn.3.1,

$$PSNR(dB) = 10\ log_{10} \frac{(Max_I)^2}{\frac{1}{M*N}\sum_{j=1}^{M}\sum_{j=1}^{N}[f(i,j) - f'(i,j)]^2} \quad (3.1)$$

where,

$f(i,j) and\ f'(i,j)$ are the original and watermarked images respectively; Max_I is the maximum pixel value.

3.2 PEARSON CORRELATION COEFFICIENT

Defined as the covariance of two variables divided by the product of their standard deviation [5],

$$\rho_{XY} = cov(X,Y)/\sigma_x\sigma_y \quad (3.2)$$

3.3 UNIVERSAL IMAGE QUALITY INDEX

Let x = {x_i |i =1, 2….N} and y = {y_i|i=1, 2…N} be the original and watermarked images respectively, then the image quality index is given by [6],

$$Q = \frac{4\sigma_{xy}\bar{x}\bar{y}}{(\sigma_x^2+\sigma_y^2)[(\bar{x})^2 + (\bar{y})^2]} \quad (3.3)$$

where,

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \quad (3.4)$$

$$\bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i \quad (3.5)$$

$$\sigma_x^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2 \quad (3.6)$$

$$\sigma_y^2 = \frac{1}{N-1}\sum_{i=1}^{N}(y_i - \bar{y})^2 \quad (3.7)$$

$$\sigma_{xy} = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})\,(y_i - \bar{y}) \quad (3.8)$$

The active range of Q is [-1 1]. The value 1 is achieved if $y_i = x_i$ for all values of i= 1, 2…N which is the best value. The value -1 occurs when $y_i = \bar{x} - x_i$ for all values of i =1, 2 … N which is the lowest value. This quality index figures any distortion as a combination of three different distortions: loss of correlation, luminance and contrast. The equation (3.4), (3.5), (3.6), (3.7), (3.8) represents the mean and variance of the respective images. More information about this parameter is not included in this section; further information will be available from the reference paper [6].

4. SINGULAR VALUE DECOMPOSITION AND PROPOSED METHODOLOGY

One of the most important numerical techniques that are used for the diagonalization of the matrices is the singular value decomposition (SVD). It is an algorithm developed for a variety of applications. The main properties of SVD from the viewpoint of image processing applications are: (1) the singular values (SVs) of an image have very good stability, i.e., when a tiny perturbation is added to an image, its SVs do not change considerably; (2) SVs represent inherent algebraic image properties. In this section, we describe a watermark casting and revealing scheme based on the SVD. From the viewpoint of linear algebra we can observe that a digital image is an array of non-negative scalar entries which may be regarded as a matrix. Given the matrix I which represents an input image, singular value decomposition (SVD) can be used to decompose I into I = UDV^T where U and V are orthogonal matrices and D is a singular, diagonal matrix [7]. In applications, SVD method has been applied for image compression, image hiding and image watermarking .Chung et al. [8] presented an SVD and vector quantization-based image hiding algorithm for embedding the secret data into the D component of the SVD. Using a different way, Liu and Tan [9] presented a well-organized SVD-based algorithm to modify the coefficients in D component for embedding watermark into the cover image. Chang et al. [10] presented a block-based watermarking algorithm by partitioning the image into several blocks and changed the coefficients in U component for each block to achieve the watermarking effect. SVD can also used for watermarking by changing the singular values of the input image and replacing the singular values with the watermark.

Mostly the watermark embedding process is done on the entire diagonal elements of the test image; here the embedding is done only on the pre diagonal or post diagonal elements. The results of both are verified using the parameters discussed in section 3. The steps for the watermark embedding and extraction process are given below.

Step1 Take a medical image (CT scan) 512×512

Step2 Apply SVD to the test image so that the image is treated as the product of three matrices

Step3 Apply the watermark (256×256) into the diagonal elements of the test image in such a way that the watermark is embedded on the first half diagonals i.e. pre diagonal elements and the post diagonal elements i.e. bottom half diagonals respectively.

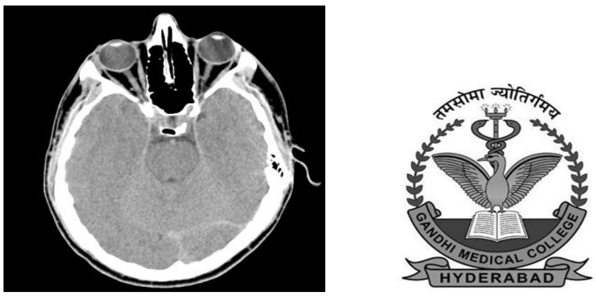
Step4 Use the U and V matrix of the original image to get the watermarked image.

Step5 The reverse process is done for retrieval purpose.

Step6 The performance of the retrieved image is verified using PSNR, Pearson Correlation Coefficient, and Image Quality Index.

5. RESULTS AND DISCUSSIONS

Here the medical image used is CT scan of size 512×512 and the watermark used is 256×256, any value below 256×256 can also be used as the watermark. The watermark used here is the hospital logo; this watermark is used for the authentication purposes. The original image and the watermark are given in the figure 1.



(a) **(b)**

Figure 1 (a) CT scan (b) watermark (logo)

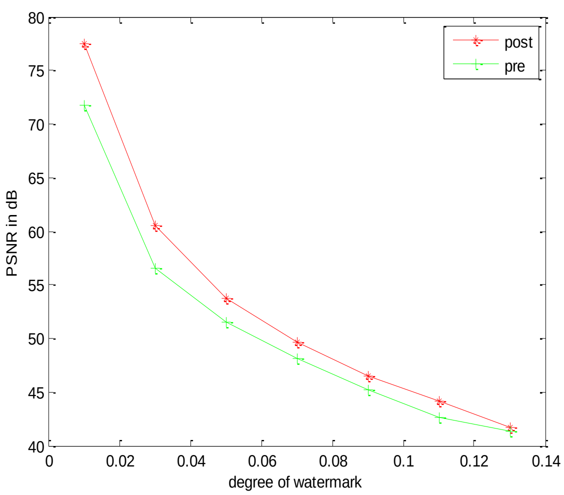
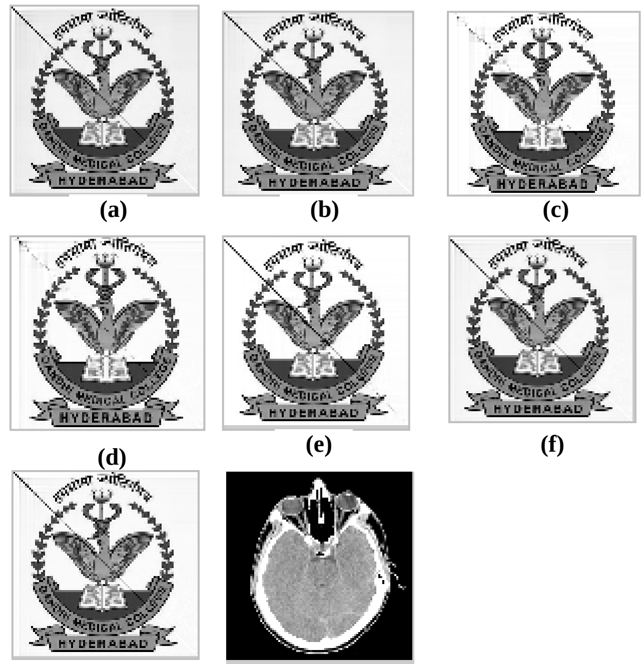


Figure 2 PSNR comparison of pre embedded and post embedded watermarked image

Figure 3 shows the retrieved watermark for different values of alpha after pre - embedding is done , the alpha value is varied in the range of 0.01- 0.13 such that as the alpha value increases the robustness increases but a large increase in the alpha value causes the original image quality to be get reduced. Therefore the alpha value cannot be increased beyond a particular limit.

Figures 4, 6 shows the performance of both the post and pre embedding algorithm, figure 4 gives the variation of image quality index for different alpha values. Figure 6 shows the Pearson Correlation Coefficient, which is usually considered as the similarity measure between the original and retrieved watermark. Since the quality of the medical image is high even after the embedding of the watermark, there is no necessity of further finding the similarity measure. The PSNR comparison is also done for retrieved watermark in both the case that is after using pre embedding and post embedding algorithm, it is shown in the table1. Figure 5 shows the extracted watermark after post embedding.

The analysis shows that the watermark embedding in the post diagonal elements gives better results than that of embedding in the pre diagonal elements. The PSNR comparison of the pre embedded and post embedded watermarked image is given in the figure 2.



(a) **(b)** **(c)** **(d)** **(e)** **(f)** **(g)** **(h)**

Figure 3 Retrieved watermark for different alpha values after pre embedding (a) alpha=0.01 (b) alpha=0.03 (c) alpha= 0.05 (d) alpha=0.07 (e) alpha=0.09 (f) alpha=0.1 (g) alpha=0.13 (h) watermarked image after pre embedding for alpha = 0.05

Table 1 PSNR comparison of retrieved watermark after pre embedding and post embedding

Alpha	0.01	0.03	0.05	0.07	0.09	0.1	0.13
PSNR (pre)	25.3	27.55	30.06	31.22	30.1	26.32	24.9
PSNR (post)	25.6	40.4	42.5	39.89	39.33	37.47	36.77

From the table1 it should be noted that the post embedding gives a better performance. As the pre embedding has a less PSNR value compared to the post embedding, for further analysis we can use the post padding of the watermark.

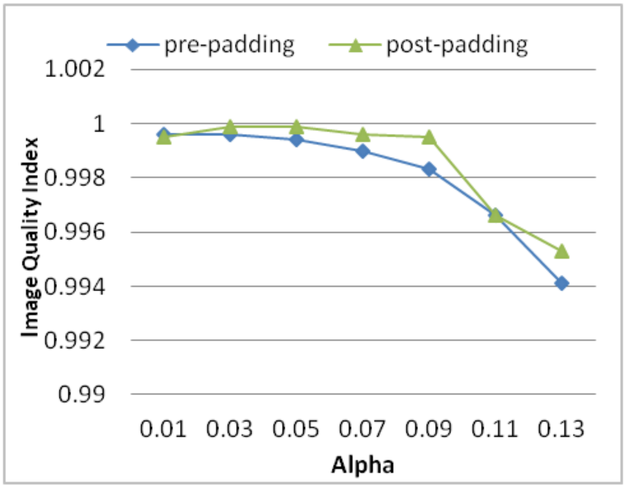


Figure 4 Image Quality Index of extracted watermark for different values of alpha

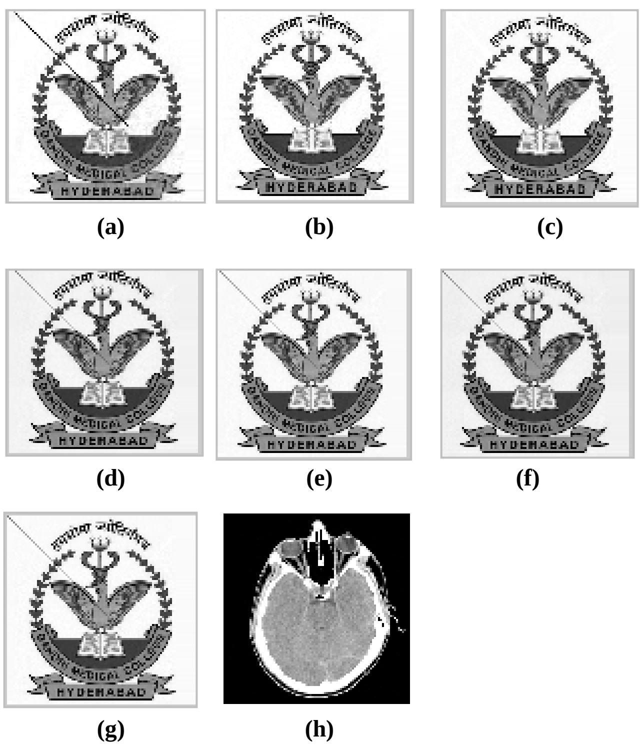


Figure 5 Retrieved watermark for different alpha values after post embedding (a) alpha=0.01 (b) alpha=0.03 (c) alpha= 0.05 (d) alpha=0.07 (e) alpha=0.09 (f) alpha=0.1 (g) alpha=0.13 (h) watermarked image after post embedding for alpha = 0.05

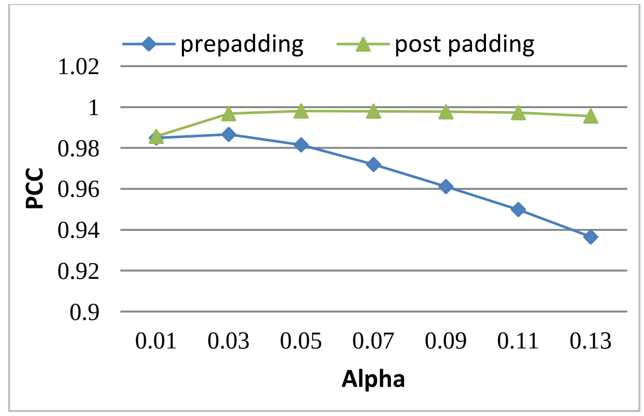


Figure 6 Pearson Correlation Coefficient (PCC) of extracted image against different alpha values

6. CONCLUSION

Nowadays watermarking methods are attaining great attention because of its advantages over encryption and steganography methods, here in this paper usual method of applying SVD for watermarking purpose is changed by simply applying the watermark in the post and pre diagonal elements so that the complexity of normal SVD can be reduced, still maintaining the image quality. Here from these results it is clear that the post application of the watermark gives a better result as compared to pre embedding method. Also it is found that the alpha value in the range 0.03-0.05 is giving a superior performance when compared to other values even though higher alpha values increases robustness of the watermark against attacks. Further the stability of the watermarking method can also be tested by applying different types of attacks.

7. REFERENCES

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