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A SECURE MEDICAL IMAGE WATERMARKING TECHNIQUE USING NO-REFERENCE QUALITY METRICES

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ABSTRACT

In this paper, a secure medical image watermarking technique with No-Reference quality measurement method based on spread spectrum technique and discrete wavelet transform using ROI processing is proposed. In this method, the original image is divided into two separate sub-images called ROI and non-ROI. Region of interest (ROI) is the decision area in a medical image which is very important .This area may indicate a disease and must resulted in a right diagnosis. A spread spectrum embedding algorithm is used to embed a binary mark into DWT transform of non-ROI part of image.This method is useful when guaranteeing a certain level of quality is an important and vital concern. At the receiver side, ROI part with least degradation is extracted. Then the mark is extracted from non-ROI part and a measure of its degradation is used to estimate the quality of the original image. The performance of the proposed method is evaluated by calculating MSE and PSNR (of original and extracted mark) and measuring their correlation with degradation of the whole image. The applications of this work include compression and storage of images with an acceptable quality level, or compression and transmission over a network for telemedicine applications while preserving an appropriate quality level.

Key Words: Image quality, spread spectrum, ROI processing, objective quality measurement, No Reference

1. INTRODUCTION

Advents of multimedia combined with information andcommunication technology boost the potential ofmedical information handling and sharing with applicationsranging from telediagnosis to telesurgery and cooperativeworking session. At the same time, these benefits introduceconcomitant risks for shared electronic patient records(EPR) and call for more secure information management.Originally devoted to multimedia document Digital RightsManagement, watermarking has also attractive propertiesthat fit within the healthcare domain, although the interestsat stake are different [4][5].

The two main objectives of watermarking areforeseen in the medical domain [4]: data hiding for thepurpose of inserting meta-data to render the image moreusable and information protection with application likeintegrity control.Despites its attractiveness, multimedia watermarkingmethods may encounter limitations in medical images. Theadded watermark signal frequently alters the host image inan irreversible manner and may mask subtle details.Consequently, proposed solutions try to preserve the imagediagnosis quality value avoiding critical information loss.

In this paper, we purposed a secure medical image watermarking techniqueusing No-Reference quality metrices.It has been reinforced through extensive research that the diagnostically important regions of medical images – the region of interest (ROI) - must be compressed by a lossless or a near lossless algorithm in order to preventing from a wrong diagnosis due to a poor image quality. Most of the quality metrics proposed in the literature are Full Reference (FR) metrics. The major drawback of the FR quality metrics for huge databases is that a large amount of reference information has to be provided at the final comparison point.

It is essential to develop No Reference (NR) quality metrics that blindly estimate the quality of an image. Most of the proposed NR metrics estimate annoyance by detecting and estimating the strength of commonly found artifact signals. In this paper we use a spread spectrum technique in order to data hiding(watermarking) and producing a reliable metric for estimating the quality of image[1] we use watermarking in order to data hiding into non-ROI part of the image while preserving the quality of ROI part and in a manner which can estimate the quality of original image.

Watermark must have the following characteristics [2]:

1. ***Imperceptibility***. The watermark must not degrade the image or multimedia file but also retains in the file so that it must be invisible, until and unless required to be visible.
2. ***Security***. The watermarking method should be in sucha way that it uses some private key or encryption with keys.

3. ***Robustness***. The embedded watermarks should not beremoved or eliminated by unauthorized distributors usingcommon processing techniques including; compression,filtering, cropping, quantization and others.
4. ***Adjustability***. The algorithm should be tune-able tovarious degrees of robustness, quality, or embeddingcapacities to be suitable for diverse applications.
5. ***Real-time processing***. Watermarks should be rapidlyembedded into the host signals without much delay.

However, the use of the embedding system with the purposeof estimating the quality of the host image changes thepriority and importance of these constraints. Invisibility forexample, is a very important constraint because our goal isdrastically reduced if the mark is visible. Robustness, on theother hand, is not so important .In fact if the mark is toorobust, the extracted mark will not be affected unless thehost image is severely degraded. If the mark is too fragile,the extracted mark will be lost by small degradations making it difficult to differentiate between medium or highly degraded images. Thus, for our application, the mark has to be semi-fragile and ideally it should degrade at around the same rate as the host image. To address this issue, we should meet some constraints described in [6].

There are several methods of embedding the watermark. The watermark can be embedded in spatial or frequency domain. Generally, frequency domain watermarking is more robust than the spatial domain. DCT and DWT are the methods by which an image can be converted into frequency domain. In some of the techniques, watermark is embedded by using combined DCT and DWT methods. In this paper, we have implemented our watermarking algorithm using DWT due to its certain advantages over DCT.

2. Literature Review

Coatrieux et. al[23] in 2000 explained the attractive properties of watermarking that fit within the healthcare domain. They explained the main objectives of watermarking that are data hiding for the purpose of inserting meta-data to render the image more usable and information protection with application like integrity control. They provided a solution for the authentication of the image source, as required for distributed EPR .The approach is based on inserting the UIDs (Unique IDentifiers). The watermark allows verifying the header-raw data association and the image origin retrieval even if its format has been changed. They explained briefly all the watermarking methods for medical images.

Kalra et. al[2] in 2011 proposed Robust Blind Digital Watermarking Usinf DWT and Dual Encryption Technique in which a blind digital watermarking algorithm is presented which is robust enough to resist the watermark against the attacks. The algorithm exploits the random sequence generated by Arnold and Chaos transformations. Discrete wavelet transformation of third level decomposition is used to convert the image into its frequency domain. The binary watermark is embedded into its HL3 domain.

Nakhaie and Shokouhi[1]in 2011 proposed a No Reference Medical Image Quality Measurement based on Spread Spectrum DWT using ROI Processing. In this method they divide the original image into two separate sub-images called ROI and non-ROI. Region of interest (ROI) is the decision area in a medical image which is very important .This area may indicate a disease and must resulted in a right diagnosis. They use the spread spectrum embedding algorithm to embed a binary mark into DCT transform of non-ROI part of image. At the receiver side they extract ROI part with least degradation. Then the mark is extracted from non-ROI part and a measure of its degradation is used to estimate the quality of the original image. The performance of their proposed method is evaluated by calculating MSE and PSNR (of original and extracted mark) and measuring their correlation with degradation of the whole image.

3. PROPOSED METHOD

The block diagram of the proposed method is shown infigure 1. This figure shows the embedding procedure. Atthe receiver side we extract the embedded mark fromwatermarked image and use it for presenting a No Referencequality measurement metric. In this work we divide theoriginal image into two sub-images called ROI and non-ROIparts. ROI part is determined by a mask whose precise sizeis determined by a specialist .So we have:

$$o(i,j)=x(i,j) + y(i,j) \qquad (1)$$

Where o is the host image, x is the ROI part and y is thenon-ROI part. The indices i and j corresponds to thehorizontal and vertical positions. This is illustrated in figure2.

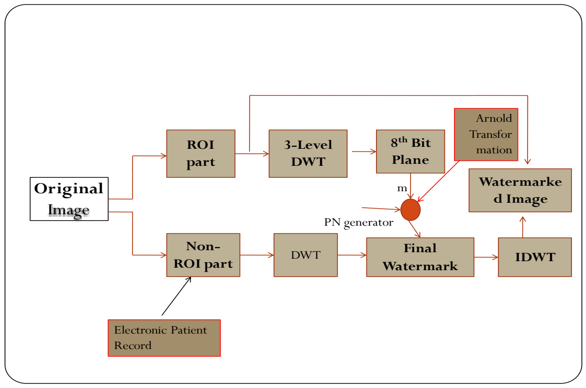


Fig1: Block diagram of the proposed method

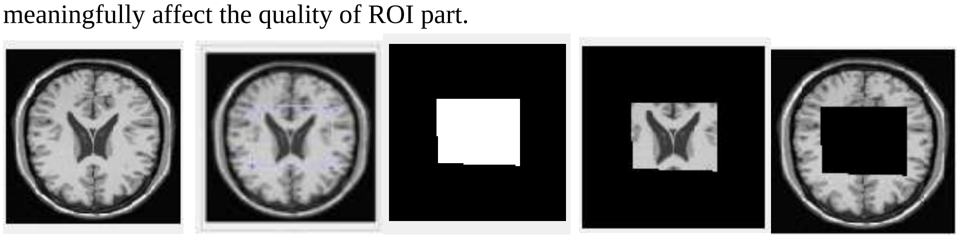
3.1. Embedding procedure

A 3-level wavelet transform of ROI image and 8th bit plane of resulted image is usedto make an initial binary mark called ***m***.

$$m(i,j) = \text{8th bit-plane of}(\text{3-level DWT of }(x(i,j))) \qquad (2)$$

In fact 3-level wavelet transform of the image is just to construct an initial mark which has a smaller size than original image. The initial mark could be any binary image because the final mark is a multiplication of initial mark and a pseudo random image. Although there are many embedding algorithms such as spiral embedding around ROI part in the spatial domain [2], since our final goal is estimating the quality of original image, we embed the constructed mark into special frequencies of DWT domain of non-ROI image with use of spread spectrum technique. This method shows better results for the purpose of quality assessment. As stated before, we should not alter quality of ROI part. It seems that mid frequencies of DWT domain is appropriate for the purpose of assessing the quality of an image. Embedding the mark in low frequencies can change the whole luminance of an image and causes visible impairments, on the other hand embedding the mark in high frequencies produces a very fragile mark which is not robust enough against different types of noise.

By dividing the original image into ROI and non-ROI parts and embedding the mark into mid frequencies of non-ROI part we have less variations in low frequency regions of non-ROI part .One of these low frequency regions which is important for us is the places onto which we want later add the ROI image. So by using of this technique in addition to embed the mark in a manner that can estimate the quality of whole image, we do not meaningfully affect the quality of ROI part.



a)MRIb) ROI Selecting c) Mask (d) ROI Image (e)Non-ROI Image

Fig 2(a-e): Procedure of dividing original image to ROI and non-ROI parts

As can be seen in figure 1, a pseudo-noise generator is used to generate a pseudo random image called ***p***=*p(i,j)* withvalues -1 and 1,with a zero mean and Gaussian distribution.

The next mark M is obtained by multiplying the binary mark image, ***m***, by the PN image ***p***.

$$M(i,j)=m(i,j).p(i,j) \qquad (3)$$

The final mark is obtained by taking the Arnold Transformation of mark M:

$$w(i,j) = \text{Arnold transformation}(M(I,j)) \qquad (4)$$

Since the final mark which is to be embedded in the original image has a random nature and it does not contain any information about the image, the proposed method is a No Reference metric. The next stage is embedding the final mark into DWT of non-ROI Part. Perform the embedding of the watermark in the original image as given in (5) below:

$$X_w = \begin{cases} \frac{+\sigma^2}{\alpha} & , if\ wk = 1 \\ \frac{-\sigma^2}{\alpha} & , if\ wk = 0 \end{cases} \qquad (5)$$

Where, Xw is the watermarked image before inverse DWT. Wk is the watermark bit at k" th position and k=0,1,2,……..1023. σ2 is the standard deviation of the original image and α is the depth of the watermark to be embedded.

The range of frequencies in which the mark is inserted, strongly depends on the application. Then we do inverse DWT and due to preserving the quality of ROI part, we calculate an offset matrix which is resulted from watermarking. AT the final stage, we add the ROI part to inverse DWT of watermarked non-ROI part:

$$o'(i, j) = y'(i, j) + x(i, j) \qquad (6)$$

Where y' is the inverse DWT of non-ROI watermarked part and o' is the final watermarked image illustrated in fig4.Now the image is ready to be compressed in different qualities for storage intentions or to be transmitted over communication channel for telemedicine applications

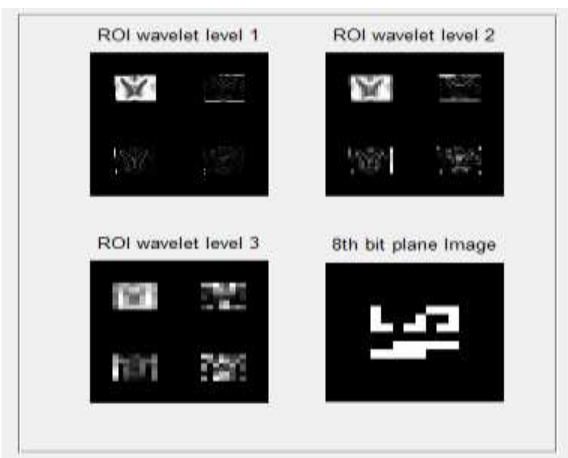


Fig3: Initial mark construction

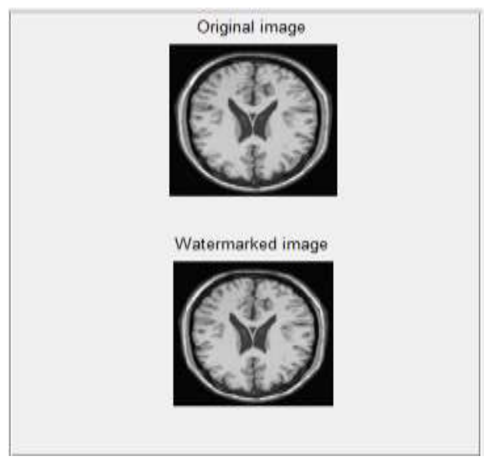


Fig 4: Final watermarked image

3.2. Detection procedure

After compression and/or transmission, at the receiver side we separate the received image into ROI and non-ROI parts again and we subtract the calculated offset matrix from that to obtain the important ROI part of the image with least degradation. At the next stage we extract the embedded mark from non- ROI part .For that reason we do again DWT of non-ROI part and then multiply the same PN image to the same DWT coefficients as follows:

Extract the watermark as given in (6) below:

$$W_k = \begin{cases} wk = 1 & , if\ Xw(i+4, j+4) = \frac{+\sigma^2}{\alpha} \\ wk = 0 & , if\ Xw(i+4, j+4) = \frac{-\sigma^2}{\alpha} \end{cases} \qquad (7)$$

Where, Xw is the pixel where watermark was embedded. wk is the extracted watermark bit.Take the inverse Arnold transformation of the reverse Chaoss image to get the desired extracted watermark.Now when errors are added while compression ortransmission, the extracted mark $m_r$is an approximation ofthe original mark *m*.
A measure of the degradation of the original mark is givenby the *MSE* of the extracted mark m_r:

$$MSE = \frac{1}{I.J}\sum_{i}\sum_{j}\left[m(i,j) - m_r(i,j)\right]^2 \qquad (8)$$

where*I.J* is the size of the mark.The less the amount of errors caused by processing,compression or transmission, the smaller *MSE* is. On theother hand, the more degraded the image, the higher *MSE* is.Therefore, the measure given by *MSE* can be used as anestimation of the degradation of the original image. In factwith considering some constraints such as choosing a semi fragilemark, we can reach to a same degradation rate for thehost image and the mark [1].

4. RESULTS

The performance of the watermarked image can be evaluated on the basis of peak signal to noise ratio (PSNR) in decibels (dB). Higher the value of PSNR better is the quality of the watermarked image. PSNR more than 30 dBs is considered to be the acceptable quality image in which watermark is making no alteration to the quality of the image.We examined the performance of our proposed metric with measuring correlation of whole image degradation and *MSE* and *PSNR* of the extracted mark. We considered 100 different images which were compressed by JPEG qualities from 1 to 100 and 100 other images which were degraded by Gaussian noise with zero mean and standard deviation0.01 to 0.1. As shown in figures 7 and 8, for the proposed metric the results are strongly correlated and the output dynamic rangeis higher as well.

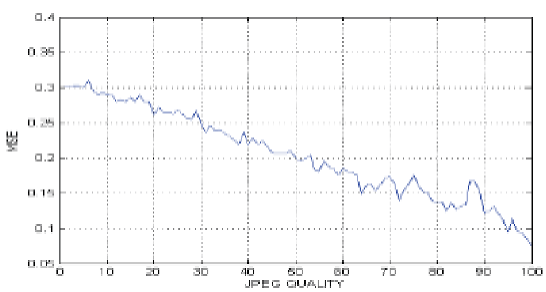


Fig 5(a)

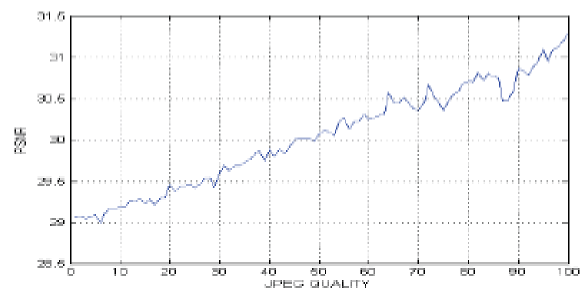


Fig 5(b)

Fig5: (a)MSE (b) PSNR in embedding the watermark in DCT domain

As shown in figures 7 and 8, for the proposed metric the results are strongly correlated and the output dynamic range is higher as well.

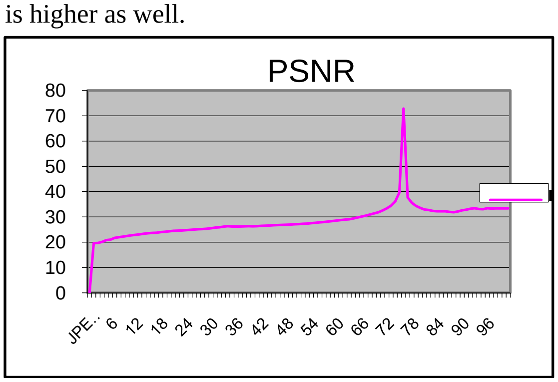


Fig 6(a)

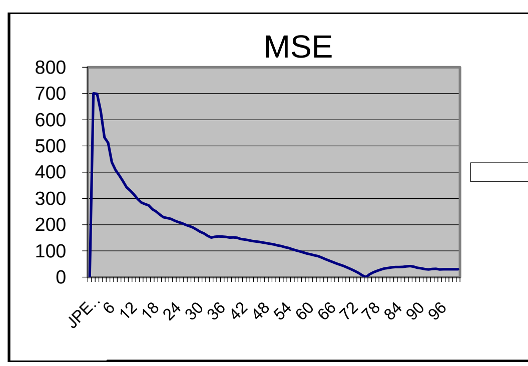


Fig 6(b)

Fig 6: (a)PSNR (b)MSE in embedding the watermark in DCT domain

5. CONCLUSION

The main idea of this paper is presenting a watermarking method using spread spectrum and discrete wavelet transform based on ROI processing which is appropriate for No Reference quality measurement. We evaluated the performance of the method by measuring correlation of the degradation of original image with objective metrics such as *PSNR* and *MSE*.

Results show that while preserving the quality of ROI part, there is a reasonable relationship and strong correlation between *MSE* and *PSNR* of extracted mark and different compression qualities

6. REFERENCES

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