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EVALUATING THE PERFORMANCE OF MEDICAL IMAGES IN A WATERMARKING APPLICATION

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Abstract

This paper captures how different types of images perform differently as a result of their variation of sources or means of capture using a particular watermarking application. The performance of the watermarking application was measured using the standard quality metrics on different sets of images (Angiogram, CT and Ordinary Test Images). The performance evaluation metric employed in this research is Structural Similarity Index Measure (SSIM) (Ayuba, 2013), which yielded some sets of result for Angiogram, CT and Test Images. A statistical analysis of Variance was conducted to determine which set of images are the most suitable for the application. The results show that, similarity of original and watermarked image is higher using Angiogram followed by CT image while the least among them is the Test Image. Angiogram and CT images are more suitable for the watermarking application.

Keywords: *Watermarking, Angiogram, CT, SSIM, Application*

Introduction

The two basic medical procedures for diagnosing patients are visual perception and rendering of interpretation which constitutes the fundamental decision making aspect in medicine (Krupinski, 2000).

The introduction of automation in the Healthcare System such as Picture Archiving and Communication System (PACS), Hospital Information System (HIS), Radiology Information System (RIS), Computer Aided Detection (CAD for Radiology) and other Computer Aided Diagnostic applications, is to improve on the efficiency of services rendered to the community. Further technological advancement includes the integration of Computer Tomography (CT) and Magnetic Resonance Imaging (MRI) for diagnosing various ailments such as cancer, trauma, heart and musculoskeletal disorder of the body (Ayuba, 2013).

These applications or systems mostly run in a Distributed Processing platform using either wireless or wired, intranet or internet which poses some security threats such as manipulation, distortion, and exchange of medical data in transit. It is clear that optimizing qualitative life is the focus of all health care systems and technology and security can play a great role towards achieving this (Hunink, 2001).

According to Ayuba (2013), transfer of digital medical images within and outside a network makes authenticity and integrity verification requirement a necessity. This can be achieved using the watermarking technique. Watermarking is a means of proffering security to medical image through integrity verification that guards against unauthorized persons modifying the image while Authentication determines whether the image certainly belongs to the right patient (Ayuba, 2013).

Digital Imaging and Communication in Medicine (DICOM) is an advanced form of Picture Archiving and Communication System (PACS) which was designed to cater for network security issues. However, DICOM cannot proffer security to images outside the network because it stores security information on the header file of the data on transit (Ayuba, 2013).

It was highlighted in a medical image watermarking review that data encryption using digital signature is not sufficient to provide the required protection because digital signature stores information on the header file thereby separating it from the original image and it cannot withstand file conversion (Ayuba, 2013).

Medical image watermarking is more advantageous over Virtual Private Network (VPN) and Data Encryption through confidentiality and integrity verification. According to (Planitz & Maeder, 2005), Medical image watermarks are used to authenticate (i.e. trace the origin of an image) and investigate the integrity (i.e. detect whether changes have been made on the image) of medical images.

Variation of image source (i.e. Angiography, CT, MRI etc) plays an important role in the performance of a watermarking application due to differences in image features. The adopted quality metric for detecting the level of degradation that may exist between original and watermarked images are Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM) (Pal, Ghosh, & Bhattacharya, 2012). The research evaluates the best image for medical watermarking using SSIM quality metric.

Hypothesis:

Ho: There is no significant difference among the mean performance of the images used for evaluating the performance of the watermarking application (U1=U2=U3)

HA: There is significant difference among the mean performance of the images used for evaluating the performance of the watermarking application (U1≠U2≠U3).

Methodology

The widely adopted watermarking techniques are basically spatial and frequency domain types. However, the frequency domain watermarking has proven to be more robust in comparison with its counterpart (i.e. the spatial domain watermarking strategy) (Ayuba, 2013).

In 2007, Navas demonstrated that spatial domain watermarking technique can be prone to image degradation and should not be employed in medical imaging. The watermarking technique suitable for medical imaging must be lossless in order to comply with the stringent requirement for quality (Navas, 2007).

This research adopts Hybrid Transformed Watermarking where two frequency transforms are employed Discreet Cosine and Discreet Wavelet Transform respectively (Ayuba, 2013).

This method (i.e. Hybrid Transformed Watermarking) transforms signal into an elementary independent manner while containing the algorithm that can de-correlate the input signal. Its formula converts sequence of real number into complex number (Ezhilarasan, Thambidurai, Harish, Muthuraman, Arulsezhian, Arun, Anand, Kumar, Krishnan, 2008).

$$f_j \quad \sum_{k=0}^{n-1} x_k \cos\left[\frac{\pi}{n} j\left(k + \frac{1}{2}\right)\right]$$

The fundamental idea of the wavelet transform is to denote any arbitrary function as a superposition of a set of such wavelets or basis functions. The wavelets are acquired from a single mother wavelet through multiplicative scaling and shifting (Mohanty, 1999).

$$h_0 = \frac{1+\sqrt{3}}{4\sqrt{2}}, h_1 = \frac{3+\sqrt{3}}{4\sqrt{2}}, h_2 = \frac{3-\sqrt{3}}{4\sqrt{2}}, h_3 = \frac{1-\sqrt{3}}{4\sqrt{2}}$$

A comparative analysis of DCT and DWT transform watermarking techniques as discussed by DWT shows a better result. The concept of combining the two transform is meant to remedy the side effect of one transform over the other (Ezhilarasan, Thambidurai, Harish, Muthuraman, Arulsezhian, Arun, Anand, Kumar, Krishnan, 2008).

High Performance & Effective Watermarking Application for Medical Images

This watermarking application was employed on medical images for the purpose of authenticity and integrity verification. The application inserts watermark into a given medical image and extracts the same watermark so as to ascertain the originality of the image. The application can also be used to extract the result of the Structural Similarity Index Measure (SSIM) on the three (03) categories of images (Angiogram, CT Scan and Ordinary images).

Embedding Technique

The application uses a hybrid transformation where the original image undergoes a Discreet Cosine Transform (DCT) which will be further transformed into Discreet Wavelet Transform (DWT) and the watermark image or text will be inserted into the combined transformed image to obtain a watermarked image. The Figure below indicates the embedding process.

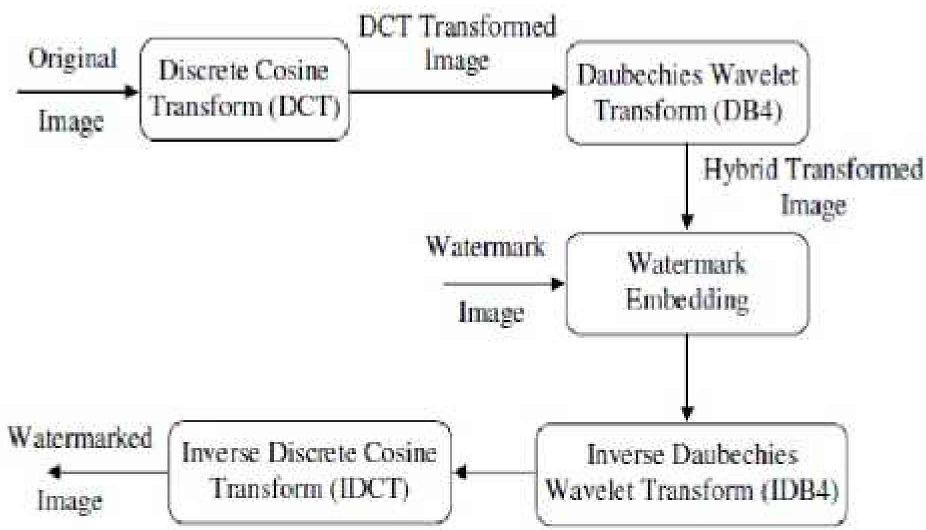

Figure 1: Embedding Process (Umaamaheshvari, 2012)

Embedding Algorithm

Input: Original Image (*I*), Watermark Image (*W*), Patient ID (*ID*)

a. Conversion: Original Image (*I*) to gray scale (*GI*), Watermark (W) to Binary (BW) or Patient ID (ID) to Binary (BinID).

Let GI = {x(i,j) |0<=1<=n, 0<=j<=n} such that x(i,j) is element between 0 to 255

b. Apply DCT to GI to get resultant Transformed Gray scale Image (TGI)

TGI = {x'(i,j) |0<=i<=n, 0<=j<=n},

$$TGI = \begin{bmatrix} P1,1 & P1,2 & P1,3 \\ P2,1 & P2,2 & P2,3 \\ P3,1 & P3,2 & P3,3 \end{bmatrix}$$

c. Apply DWT Daubechies 4 on TGI to obtain a Hybrid Transformed Gray scale Image (*HTGI*), HTGI = {x"(i,j) | 0<=i<=n, 0<=j<=n}

d. Subtract the whole number from the Mantissa of the Matrix

e. Insert the Binary bits of the watermark into the whole number part of every pixel until the whole Binary Array contents are placed into the Matrix

f. Apply inverseDWT transform to the **HTGI** to obtain Inverse HTGI

g. Apply inverseDCT transform to the InverseHTGI to obtain InverseDCT(InverseHTGI InverseHTGI) which is the resultant Watermarked Image

Output:

Watermarked Image (*WI*)

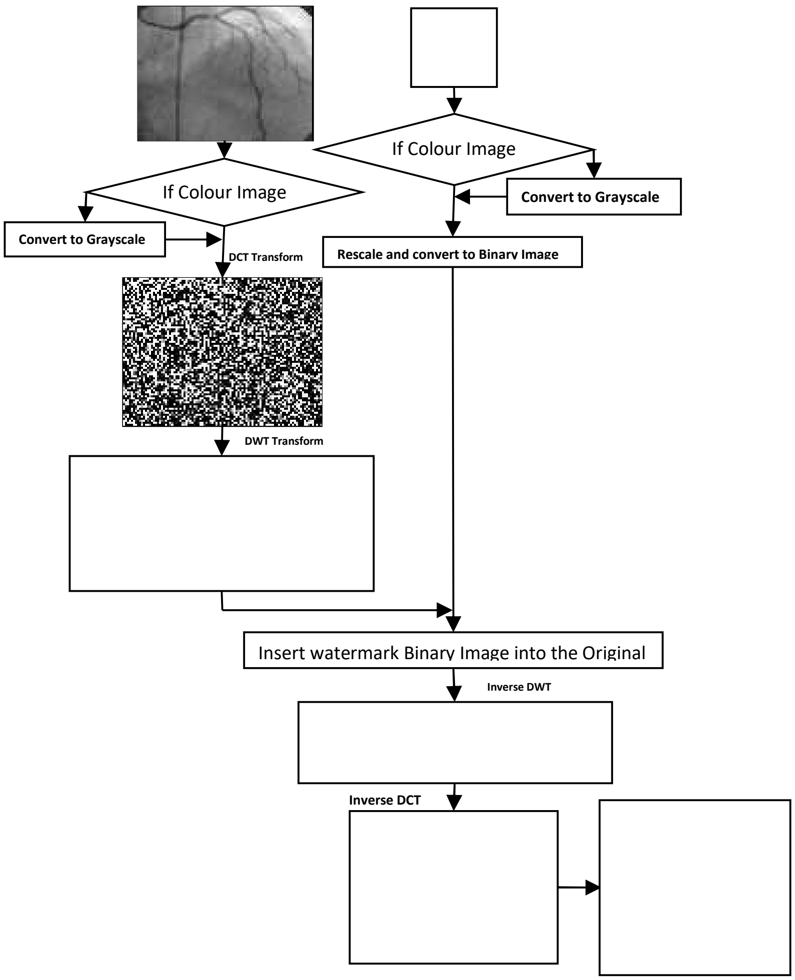

Figure 2: Representation of Embedding Algorithm (Ayuba,

Quality Metrics

The research uses a mathematical model for comparing the original and the watermarked images and presents their structural analysis. The model is given below as:

$$SSIM(x,y) = \frac{(2\mu x\,\mu y + c1)(2\sigma xy + c2)}{(\mu x^2 + \mu y^2 + c1)(\sigma x^2 + \sigma y^2 + c2)}$$

Equation 1: SSIM Equation (Rouse & Hemami, 2008)

The use of the Structural Similarity Index Measure (SSIM) indicates correlation between the watermarked image and the original image. Correlation will always fall between -1.0 and +1.0. If the correlation is positive, we have a positive relationship which means the Watermarking Application is highly effective (Pal et al., 2012). However, if correlation is negative, the relationship is negative, that is there is no relationship between the original Image and the Watermarked Image which thus, signify that the Watermarking Application is not effective (Rouse & Hemami, 2008).

Data Presentation, Analysis & Interpretation of Result

Data:

The data was obtained from the Watermarking application using SSIM quality metric which gives the correlation between the original and watermarked image. Table 1 indicates the values obtained using the three (3) sets of images:

Table 1: Representing data for evaluating the performance of images in Watermarking Application

S/N	Angiogram Images		CT Scan Images		Ordinary Test Images	
	DESCRIPTION	SSIM	DESCRIPTION	SSIM	DESCRIPTION	SSIM
1	IM5.bmp	0.9764	CT Coronary Sinus Colour	0.8276	Baboon Color.jpg	0.5483
2	IM6.bmp	0.9587	CT Chest	0.7672	BaboonGray.jpg	0.7553
3	IM9.bmp	0.9760	CT Heart Angio.bmp	0.8793	BurgaerGirl.jpg	0.8358
4	IM10.bmp	0.9586	CT Heart Image2.bmp	0.8127	Cameraman.jpg	0.9287
5	IM11.bmp	0.9775	CT Lungs.bmp	0.7517	CrossProcess.jpg	0.7551
6	IM12.bmp	0.9626	CT Lungs2.bmp	0.8864	Girl.jpg	0.8550
7	IM13.bmp	0.9987	CT Lungs2.bmp	0.8902	LightHouse.jpg	0.4900
8	IM14.bmp	0.9995	CT Pulmonary.bmp	0.6924	BarbaraGray.bmp	0.8069
9	IM17.bmp	0.9880	CT Thoracic.bmp	0.7357	PepperColor.jpg	0.9516
10	IM18.bmp	0.9278	CT Heart VR.bmp	0.6374	PepperGray.jpg	0.7789

SPSS Result:

ANOVA

SSIM

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.250	2	.125	12.489	.000
Within Groups	.270	27	.010		
Total	.520	29			

Level of Significant = 0.05

Decision:

(I) IMAGE	(J) IMAGE	Mean Difference (I-J)	Std. Error	Sig.
ANGIOGRAM IMAGE	CT IMAGE	.1843200*	.0447445	.000
	TEST IMAGE	.2018200*	.0447445	.000
CT IMAGE	ANGIOGRAM IMAGE	-.1843200*	.0447445	.000
	TEST IMAGE	.0175000	.0447445	.699
TEST IMAGE	ANGIOGRAM IMAGE	-.2018200*	.0447445	.000
	CT IMAGE	-.0175000	.0447445	.699

We now reject Ho since F calculated is greater than F tabulated i.e. 12.489 > 3.35 at 2, 27 degrees of freedom.

It was further confirmed using pair wise comparison test or multiple comparison tests which shows that Angiogram images are much more significant when compared with Test Images followed by CT Images. Test Image is the least significant among the set of image.

Conclusion

Since, Ho is rejected and HA is accepted, it is necessary to conclude that there is a significant difference in the mean performance of the images used for evaluating the performance of the watermarking application. Moreover, multiple comparison shows the same result thereby proving that Angiogram images were the best followed by CT and Test Images.

In general, the Angiogram images are more similar followed by the CT Scan Images than the Test Images when used in the watermarking application. This therefore indicates that the Angiogram images are more suitable for use with the application when compared with CT and Test Images.

Recommendation:

Considering of the stringent requirements associated with medical imaging, it is therefore recommended that angiography should be used in acquiring medical images for watermarking application.

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