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Region of Non Interest based Medical Image Authentication in Wavelet Domain Using Fuzzy Inference System

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Abstract

Medical images produced from different modalities are stored in image database. Teleradiology technology transmits those images through network to other physicians for diagnosis, which initiates the need for integrity and authenticity. Authenticity of medical images in health care systems proves that the information belongs to one patient should be taken from the right source. Embedding an appropriate authentication message through watermarking helps us to achieve security for the transmitted messages. In the proposed work authentication technique has been developed in wavelet domain of a medical image. The authentication message is embedded in the singular values of Region of Non Interest (RONI) pixels. The watermark strength of the pixels in the RONI portion is predicted using fuzzy inference rules. The proposed system achieves high Peak Signal to Noise Ratio (PSNR) values with less image distortion.

Key Words: Authenticity, Watermarking, Fuzzy Inference System, Region of Non Interest.

1. Introduction

Health care system implements teleradiology to transmit medical images through networks for physician's interpretation and for sharing studies with radiologists. Teleradiology impose a serious threat to image security such as image retention, malpractice liability, along with authentication and integrity issues [1]. Integrity ensures that the information has not been modified by non-authorized people whereas authentication helps to prove that the information belongs to correct person and it is from reliable source [2]. Medical image watermarking in teleradiology addresses the problem of security and authentication of medical images that is transmitted over the networks. Watermarking is the process of imperceptibly adding medical information like EPR (Electronic Patient Record), hospital logo, patient identifiers, and doctor's signature to the cover image. The hidden data in the medical image can be used to verify the authenticity of the images [3] [4]. Medical image watermarking system strictly expects the properties such as imperceptibility, robustness and payload to maintain the image fidelity.

Medical image watermarking system is associated with the process of designingthe three core components such as watermark generation, embedding and detection.Normally watermark is embedded in the spatial or frequency domain of the image based on the imperceptibility and robustness property. Watermark detection procedure gives results to prove authentication and integrity [5].Watermarking methods are either visible or invisible. Visible watermarking embeds watermark like logo to show the important information through watermarked image, whereas invisible watermarks addresses authentication and integrity issues. Invisible watermarks can be robust, fragile, semi-fragile and hybrid combining robustness and fragile nature.

Watermark embedding is always expected to meet two requirements: to protect the image continuously and to accept some point of degradation.With these requirements, in the proposed work watermark is embedded in the Region of Non Interest, whereimage degradation will not lead to misdiagnosis. Fuzzy logic is also incorporated in the system to predict ambiguity that exists among the image pixels. A rule based fuzzy inference system is designed based on the texture of the image to predict the watermark strength for every pixel in the image. This proposed research work investigates the imperceptibility and robustness of the medical images by embedding and extracting the watermark in the Region of Non Interest which is strictly the border pixels of the image.

2. Related Works

Hussain Nyeemet. al [2015] proposed content-independent embedding scheme for multi-modal medical image watermarking in the spatial domain. The scheme embeds watermark bits in the RONI part of the medical image utilizing least significant bits. The proposed work focused only on embedding high payload in the LSB's of different modality images but the robustness of the medical images are not considered [6].

Chun Kiat Tan et.al [2011] presented DICOM [Digital Imaging and Communication in Medicine]medical image security protection using dual layer reversible watermarking with tamper detection capability. Public-key Cryptography concepts are utilized to embed the watermark to secure a random location signal and integrate a tamper detection and localization feature [3].

Charu Agarwal et.al [2015] presented a novel gray-scale image watermarking using hybrid Fuzzy-BPN architecture. In this model Human Visual Characteristics are utilized using Fuzzy Inference System and Back Propagation Neural Networks, to embed permuted binary watermark in gray scale images. Even though the system is robust to eight different image processing attacks it achieves only marginal PSNR and SSIM [Structure Similarity Measure] measures [7].

FarhadRahimi et.al [2011] implemented a dual adaptive watermarking scheme in contourlet domain for DICOM images. The singular value vector bits are embedded to the Region Of Interest (ROI) and RONI of the images with different embedding strength. Lowpasssubband coefficients of contourlet domain of ROI and RONI are used for embedding the watermarks. The system achieves only reasonable PSNR and Normalized Correlation measures[8].

M.Imran et al [2013] proposed an adaptive watermarking technique based human visual system and fuzzy inference system. The perceptual quality of the watermark embedded image is controlled by determining adaptive scaling factor for each individual pixel value. To determine the adaptive scaling factor, texture masking and fuzzy inference system were used. The proposed system resists the attacks only with marginal correlation coefficient values[9].

N.Ramamurthy et al [2012], described a watermarking system to minimize the effect of various attacks on watermarking images using fuzzy logic approach. A blind robust watermarking algorithm using dynamic fuzzy inference system is developed in wavelet transform domain. The proposed system is not robust to salt and pepper noise and also achieves less PSNR values [10].

All the reviewed work embeds and extracts the watermark only with a compromise in the properties like robustness and imperceptibility. The proposed work aims to embed an invisible watermark in RONI region by utilizing the strength from the fuzzy inference system. Medical images from different modalities will not contain unique features, but the proposed system investigates the texture of the different modality images using a range filter and also by incorporating fuzzy logic the system predicts watermark strength according to the texture property.

3. Methodology

In the proposed work watermarking is performed in the wavelet domain of the image. Initially range filter is employed to predict the texture of the pixel values, whichin turn can characterize the texture of an image because they provide information about the local variability of the intensity values of pixels in an image [11]. That is in areas with smooth texture, the range of values in the neighborhood around a pixel will be a small value and in cases of rough texture, the range will be larger. Range of values is calculated as follows:

J = range of (I),

returns array J, where each output pixel contains the range value (maximum value − minimum value) of the 3-by-3 neighborhood around the corresponding pixel in the input image I. The image I can have any dimension. The output image J is the same size as the input image I. The result after applying the range filter quantify intuitive qualities described by terms such as rough, smooth, medium as a function of the spatial variation in pixel intensities.

Mamdani fuzzy inference system is utilized to predict the strength of the watermark for each pixel [9]. Membership functions for smooth, medium and rough values of range are assigned using trapezoidal and triangular functions.Watermark strength forms another input for the inference system and membership functions for the variables small, large and medium is allocated using trapezoidal and triangular functions. The input variables are executed using the following rules:

If range is smooth, THEN watermark strength is small

If range is medium, THEN watermark strength is medium

If range is rough, THEN watermark strength is large

The membership function for range values and watermark strength of the image is depicted in Fig.1and Fig. 2.

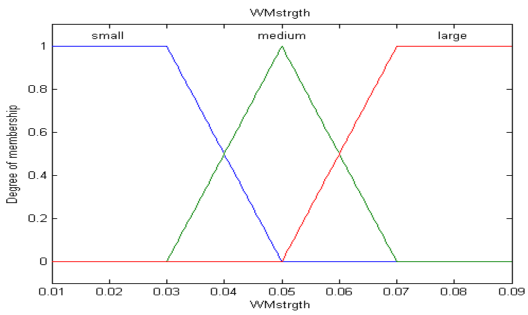


Fig. 1: Membership values of Range

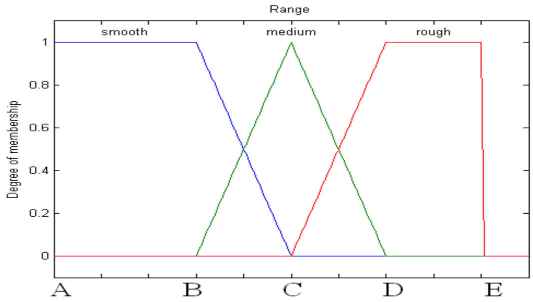


Fig. 2: Membership values of Watermark

The values of A, B, C, D and E in Fig.1.are calculated as follows:

$$A = \min_{i=1 \text{ to } M} \min_{j=1 \text{ to } N} (\text{Range})$$

$B = (A + C)/2$where C is defined as follows:

$$C = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} \text{Range}(i, j)$$

$D = (C + E)/2$where E is defined as follows:

$$E = \max_{i=1 \text{ to } M} \max_{j=1\text{to } N} (\text{Range})$$

After predicting the watermark strength, the border pixels of the image is separated as Region of Non Interest (RONI) and remaining are considered as Region of Interest pixels. Watermark image of size 64 x 64 is embedded in the singular values of horizontal details by applying DWT on RONI portion of the image using additive technique. Additive technique is carried out as follows:

The host image pixel values h(i,j) are directly altered using additive approach with the watermark image pixel values w(i,j) [12] [13].

wm(i,j) = h(i,j) + (Watermark Strength*α(i) * w(i,j))

α(i) represents the scaling factor (i.e.) allowable amount of distortion while embedding in the image. Watermark strength for each pixel is utilized from the fuzzy inference system. The scaling factor (α) used in the proposed system is equal to 0.1.

Medical image watermarking in spatial domain utilizing RONI and fuzzy inference system is performed using following embedding procedure:

Step 1: Original medical image H is read.

Step 2:Applying range filter on the image, texture statistics such as rough, smooth and medium values of the pixels are analyzed.

Step 3: Membership functions for range values and watermark strength is assigned

Step 4: Rules are designed to predict the watermark strength.

Step 5: Fuzzy Inference System is evaluated using membership functions and rules

Step 6: Watermark strength is predicated using fuzzy inference system and utilized for embedding

Step 7: The cover image taken for embedding the watermark is divided into ROI and RONI regions.

Step 8: Discrete Wavelet Transform is applied to the RONI portion of the image. LL, LH, HL and HH details of the RONI portion is obtained

Step 9: Singular Value Decomposition (SVD)is applied on the HL details of the RONI.

Step 8: The watermark, which is considered as the authentication message is embedded in the singular values of RONI region of the image using additive technique and final watermark embeddedimage is obtained.

The watermark embedded in the host image is extracted using the following procedure:

Step 1: Watermark Embedded image WM is read.

Step 2: ROI and RONI portion are divided to extract the watermark. The watermark is extracted as follows:

EW = (Watermarked svd – original svd) / (Watermark Strength * alpha factor)

Step 3: The watermark embedded is extracted and compared with the original watermark W using correlation coefficient measure. The correlation between the original and extracted watermark is calculated using the following equation.

$$\mathrm{NC} = \frac{\sum_i \sum_j \mathrm{W}(i,j) * \mathrm{EW}(i,j)}{\sqrt{\sum_i \sum_j \mathrm{W}(i,j)^2 * \sum_i \sum_j \mathrm{EW}(i,j)^2}}$$

W – Original watermark

EW– Extracted watermark

4. Results and Discussion

The test images used to experiment the medical image watermarking using fuzzy inference system is obtained from www.barre.nom.fr\medical\samples[14] and Medpix websites. Experiments are conducted to test the image degradation using PSNR measure. The algorithm is tested using MATLAB r2012a. The following figures illustrate the proposed algorithm.

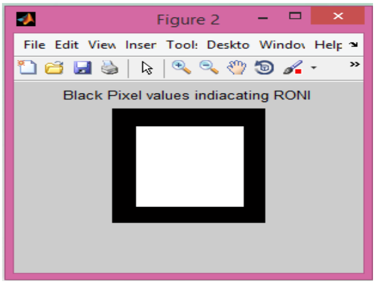


Fig.1 Original Image

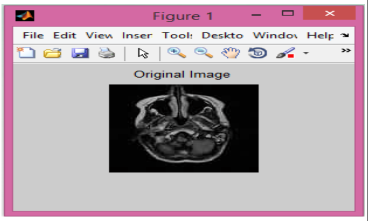


Fig.2 Pixels indicating RONI

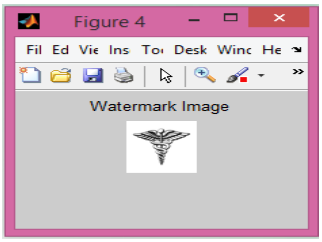


Fig.3 Watermark Image

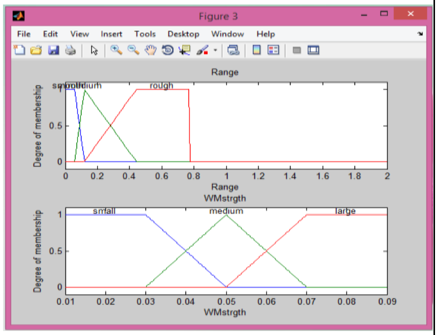


Fig.4 Range&Watermarkmembership values

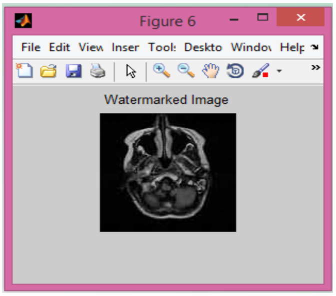


Fig.5 Watermark Embedded Image

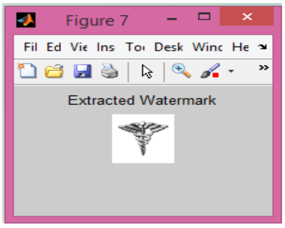


Fig.6 Extracted Watermark

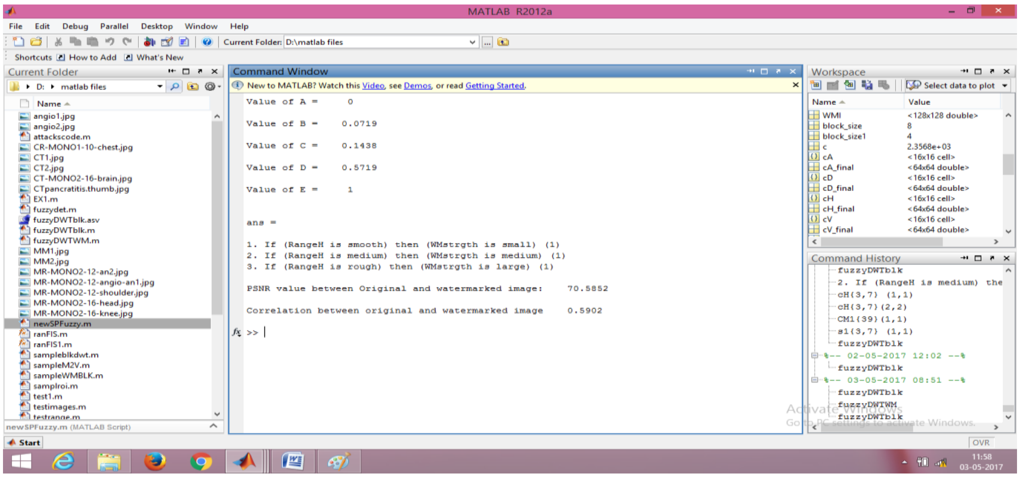


Fig. 7: MatLab window showing the Membership values with rules, PSNR and Correlation values

5. Performance Analysis

The proposed medical image watermarking approach using fuzzy inference system is compared with the existing [FIS-SVD] [9]to test the image fidelity. The existing work is tested for medical images and PSNR values for the given algorithm in [9] and proposed are tabulated in the Table.1. Error measure Peak Signal to Noise Ratio (PSNR) is used to compute the image distortion in the watermark embedded image. PSNR values are calculated as follows:

$$PSNR = 10\log_{10}\left[\frac{\sum_{i=1}^{N}\sum_{j=1}^{N}[h^{*}(i,j)]^{2}}{\sum_{i=1}^{N}\sum_{j=1}^{N}[h(i,j) - h*(i,j)]^{2}}\right]$$

h*(i,j) – pixel value of watermarked image

h (i,j) - pixel value of original image

N x N - size of the image

Recommended PSNR values must be > 35Decibels

Table 1: PSNR values

S.No	Image Types	Test Images	Proposed [RONI-FIS-SVD]	Existing [FIS-SVD]
01	MRI	MR-MONO2-16-knee.jpg	70.5852	57.7546
02		MR-MONO2-16-head.jpg	64.8266	52.3723
03		MR-MONO2-12-shoulder.jpg	68.9274	54.2029
04		MR-MONO2-12-angio-an1.jpg	67.5395	53.6302
05		MR-MONO2-12-an2.jpg	65.8041	51.3005
06	CT	CT-MONO2-16-brain.jpg	72.4323	55.4339
07		CR-MONO1-10-chest.jpg	75.5360	56.4371
08	Angiogram	Angio 1	72.1606	65.2275
09		Angio 2	69.6107	58.4885
10	Mammogram	MM1	69.7854	52.6430
11		MM2	63.5225	51.2074
12	Ultrasound	Ultrasound 1	62.0237	51.2701
13		Ultrasound 2	67.9833	56.9127
14		Ultrasound 3	69.0797	57.8375
15	X-Ray	XR1	67.7279	57.1827
16		XR2	68.2877	52.1449

The values of the above table values reveals that the proposed wavelet domain watermarking embedding technique results in less image degradation by achieving high PSNR values.

Table 2: Comparison based on PSNR and watermark size

Comparison Factors	Proposed [RONI-FIS-SVD]	Existing 1[9] [FIS-SVD]	Existing 2 [6] [RONI-LSB]
PSNR Values	60 -75 dbs	< 60 dbs	< 55 dbs
Watermark Size	64 x 64	64 x128	150 -180 bits

The values of the above table shows that the PSNR values achieved by the proposed system is high since RONI portion is chosen as border pixels and watermark is embedded into the singular values of the RONI. The proposed work embeds the watermark in the border pixels of the image which remains uniform for all the modality of images, hence the algorithm is tested with 80 images of four different modality images. The PSNR values range from 62 - 75dbs for all modality of images reveals that the less image degradation. The algorithm provides authentication for multiple modality of image sets which is represented in the Graph 1. The medical images are tested whether it withstands or resilient to cropping attack since the watermark is embedded in the RONI.The results of various cropping attacks and the extracted watermarks with the correlation values are tabulated in Table 3.

Graph 1: PSNR Values for different modality images

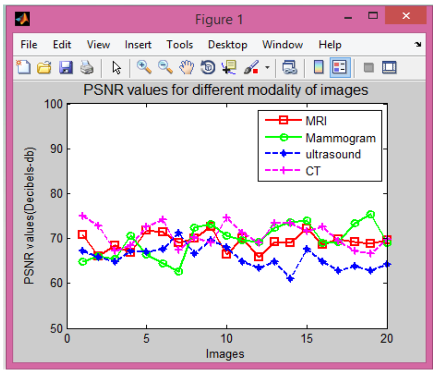
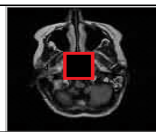
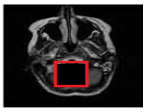


Table 3: Correlation for cropping attack

Cropped Image	**Extracted Watermark with Correlation value**
	 NC: 0.9766
	 NC:0.9766
	 NC:0.9766

6. Conclusion

In this paper, medical image watermarking in wavelet domain using fuzzy inference system has been developed to ensure medical image authenticity and integrity. RONI pixels of the image is considered for embedding which results in less image distortion. Experimental results reveals that the image degradation is too less by embedding watermark at RONI. The PSNR values are improved by 10% and hence image distortion is less compared to the existing system. Future works includes the improvement of algorithm to resist the geometrical and noise attacks and to improve the payload of the watermark by achieving the less image distortion.

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