Digital Image Watermarking Based on Independent Component Analysis and Ridgelet Transform

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ABSTRACT

Abstract

In Medical Field telemedicine and tele diagnosis is gaining momentum at a faster rate. So security and authentication for medical images are very important. This paper describes a new solution to digital watermarking of medical images. It uses Independent Component Analysis (ICA) to project the image into a basis with its components as satistically independent as possible. Since edges and noise play a fundamental role in image understanding , hence this Ridgelet transform is a good way to enhance the edges and reduce the noise. In the transformed image embedding and extraction processes to be performed .The watermark is adaptively applied to the image based on the smoothness of the area, to increase robustness within the limits of perception. Thus the patient information is saved and transmitted in a confidential way.

Key words:

Watermarking, Independent,Transform

1. Introduction

The advances in multimedia and communication technology provided new ways to store, access and distribute medical data in a digital format. Watermarking usually consists of the use of perceptually invisible authentification techniques. In this sense, "controlled" distortion is introduced in a multimedia element [1]. And the owner wants to "protect" this content. The goals are on the one hand the verification of the owner and the detection of forgeries of an original image. Medical imagery is a field where the protection of the integrity and confidentiality of content is a critical issue due to the special characteristics derived from strict ethics, legislative and diagnostic implications. Medical images should be kept intact in any circumstance and before any operation they must be checked for(2).

Recently watermarking techniques are used in the protection of the integrity and confidentiality of medical images.Rigidlets[3] and curve lets take the form of basic elements that exhibit very high directional sensitivity and are highly anisotropic. Therefore they represent edges better that wavelets and are well suited for multi scale edge enhancements. We propose to use the change of basis provided by ICA [4] or Blind Separation of Sources [5] methods. Consider a $K^2* 1$ vector X_i projected into a space of K^2 components y_i as statistically independent as possible.

2. Independent Component Analysis(ICA)

The ICA problem consists of finding this change of basis represented by a $k^2 * k^2$ matrix B.

$$Y_t = Bx_t \quad t= 1,2,\ldots \qquad (1)$$

Let's matrix be an intesity image of size $n \times m$. The matrixis divided into blocks of $k \times k$ $C_{p,q}$. The entry $C_{p,q}(i,j)$ with indexes

$$\begin{aligned} i,j &= 1,2,\ldots,k \\ p &= 1,2,\ldots,n/k \\ q &= 1,2,\ldots,m/k \end{aligned} \qquad (2)$$

is the sample t = m(p-1)/k+q of the component k (i-1) + j of vector x_t.The analysis and synthesis expression yields

$$\begin{aligned} x(k(i-1)+j)_{(m(p-1)/k+q)} &= C_{p,q}(i,j) \\ &= I(k(p-1) + i,k(q-1) + j) \end{aligned} \qquad (3)$$

By applying ICA to x_t we obtain the ICA components y_t of the image. It is possible to use ICA to define a set of basis functions to build a group of images. The watermark is detected through ICA and embed all the information of watermark into the image and also extract all the characteristic information of the watermark. In this paper firstly a radon transform is proposed. This method provides richer information in the image. For real world application the system is practical.

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3. The Ridgelet Transform

Ridgelet transform theory(5) is included for review. Let Ψ be in $L^2(R)$ with sufficient decay and satisfies the admissibility condition,

$$\mathbf{K}_{\Psi} := \int \frac{\left|\hat{\psi}(\xi)\right|^2}{|\xi|^2} d\xi \subset \infty \quad \text{..............(4)}$$

That $K_\Psi = 1$.
For a> 0,b $\in$ R and $\Theta \in [0,2\pi]$,Ridgelet basis functions are defined by equation 2.

ψ a,b, Θ (x):=$a^{-1/2}$ Ψ (x1cos Θ +x2sin Θ -b/a).......(4)
Radon transform for $f \epsilon L^2 \left(R^2\right)$ *is* given by equation 3

Rf(Θ ,t)=
$$\int f(x_1, x_2)\delta(x_1 \cos\Theta + x_2 \sin\Theta - t)dx_1 dx_2. \quad (5)$$

where δ is the Dirac distribution.

For $f \in L^1\left(R^2\right)$ is represented as a continuous superposition of Ridgelet coefficient and is given by

$$R_f(a,b,\Theta) = \int f(x)\overline{\Psi}_{a,b,\Theta(x)} dx \text{ ......(6)}$$

Any Function $f \in L^1(R^2) \cap L^2(R)^2$ is represented as a continuous superposition of Ridgelet functions.

$$f(x) = \iiint R_f(a,b,\Theta)\Psi a,b,\Theta(x)\frac{da}{a^3}db\frac{d\Theta}{4\Pi} \quad (7)$$

Equation 4 is also given by the wavelet transform of the Radon transform f.

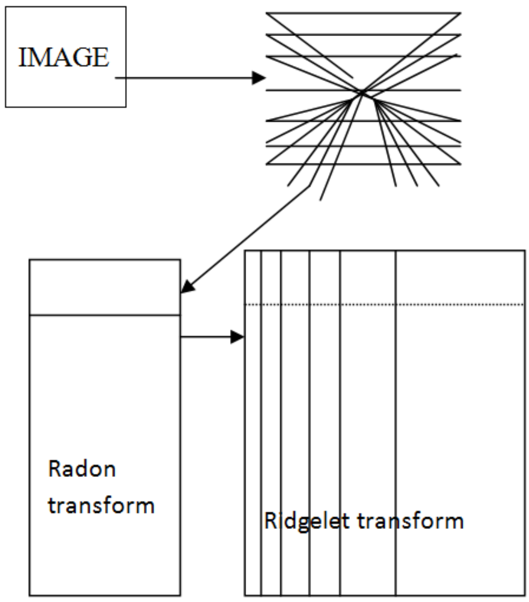
$$R_f(a,b,\Theta) = \int R_f(\Theta,t)a^{-1/2}\Psi((t-b)/a)dt \quad .(8)$$

4. Watermarking

In this section we apply ICA to the watermarking of an image. We first address the problem of inserting the watermark and then the watermak extraction.

4.1 The watermark embedding scheme

The basic idea in watermarking is to add a watermark signal to the host data to be watermarked such that the watermark signal is unobtrusive and secure in the signal mixture but can partly or fully be recovered from the signal mixture later on.



In the last section we described in (3) how to decompose an image I into components x_t^I. . By applying an ICA algorithm and applying ridgelet transform (8)to the image to watermark, we get matrix B^I and ICA components y_t^I . Besides, suppose the watermark is another image W of the same size than I, n×m . We may obtain its ICA decomposition by dividing it in blocks
of the same size as before, k. This pair of decompositions may be written as

$y_t^I = B^I x_t^I$

$y^w = B^W x_t^w$ t = 1.......,mn/k^2 .....(9)

where the components, $y_t(i)$ I = 1.... K^2 , have been arranged in descending order of energy.
ICA based compression methods remove the r less energy ICA components of an image. We propose to replace these r components from y_t^I with the first k^2 –r ICA components of the watermark y_t^w. Note that any other interchange of components may be valid and the radon transform is applied.

Insertion Algorithm :

1 *Image components*. Compute the components x_t^I
And x_t^W of the image I and the watermark W by dividing it in blocks of k× k as in (3).

2 *ICA components*. Compute the ICA components

Y_t^w and y_t^I of the image and the watermark as in (4). Arrange the component in descending order of energy.

3.*Apply the radon transform* as in (6 and 8) and watermark the image components.

4 *Restoring watermarked image*. Restore the watermarked image V from components $x_t^V = B_t^{-1} y_t^V$ _
N

Once we have the image with the watermark we need to define the procedure to extract it.

4.2 The watermark extraction scheme

The aim of this section is the extraction of the watermark W f from the watermarked image V. We go back on the steps of algorithm 1. We first compute the components x_t^V as in (3). Next, the projected ones y_t^V by using B^I stored in step 4. Then we recover the ICA components of the watermark .

$$Y_t^W(h) = yt^V(k^2 - h + 1) \quad h = 1,\ldots\ldots,r \quad \ldots\ldots(10)$$

And set the rest of them to zero. The image is restored by using the Matrix B^W .

Extraction algorithm:

1 *Watermarked image components*. Compute the components x_t^V of the image V by dividing it in
k× k blocks as in (3).

2 *Watermarked image ICA components*. Compute the components y_t^V of the image as $y_t^V = B^I x_t^V$.

3. *Watermark ICA components*. Compute the components y_t^W of the watermark as in (10).
And apply inverse transform and get the components.

4 *Restoring the watermark*. Compute the components $x_t^W = B_W y_t^W$ and use (3) to obtain the watermark W.

5. Discussion

Imperceptibility: Imperceptibility means that the perceived quality of the host image should not be distorted by the presence of the watermark. As a measure of the quality of a watermarked image, the peak signal to noise ratio (PSNR) is typically used. PSNR in decibels (dB) is given below in Eq. 11.

$$PSNR_{dB} = 10 \log_{10}(MAX^2 I)/MSE \quad \ldots\ldots\ldots(11)$$

Robustness: Robustness is a measure of the immunity of the watermark against attempts to remove or degrade it, internationally or unintentionally, by different types of digital signal processing attacks.

An important issue in watermarking extraction is the knowledge of the original image in the extraction process. Our aim is to propose an extraction method not based in this knowledge. Notice that if we had this information, the ICA
components of the watermark could be added to the ones of the image instead replacing them as in [6] and [7]. This way the method would be more robust to attacks.

We use an image as the watermark. However, the watermark could be any signal such as a message. Notice that once the components of the watermark have been extracted, matrix _ _ is used to restore the watermark. In this sense this second matrix is the key of a cryptographic problem.

6. Experimental Results

Figure 6.a shows the scan image of a baby. Then we insert the logo into the image and its watermarked.

Fig 6.a.scan image

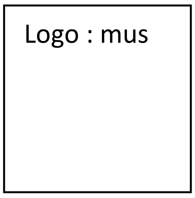
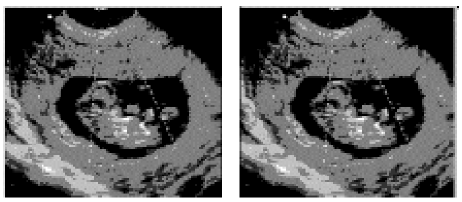


Fig 6.b Watermark



(a) (b)

Fig.4 Original (a) and watermarked (b) images

The parameters are optimally varied to achieve the most suitable for the characteristic of each image. We used the medical images and during extraction we are achieving almost good results compared to DWT and DCT.

7. Conclusions

In this paper we present a new approach to image watermarking based on independent component analysis and radon transform. We apply these concepts to write a new watermarking algorithm.

The experiments included show how this new method successes in extracting the watermark even when the image has been attacked. It also allows solving the authentication problem in fragile watermarking detecting any change in the image.

But there is still something in this method needed to be improved and optimized

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