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Robust Medical Image Watermarking Based on Contour let and Extraction Using ICA

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ABSTRACT

In this paper, a medical image watermarking algorithm based on contourlet is proposed. Medical image watermarking is a special subcategory of image watermarking in the sense that images have special requirements. Watermarked medical images should not differ perceptually from their original counterparts because clinical reading of images must not be affected. Watermarking techniques based on wavelet transform are reported in many literatures but robustness and security using contourlet are better when compared to wavelet transform. The main challenge in exploring geometry in images comes from the discrete nature of the data. In this paper, original image is decomposed to two level using contourlet and the watermark is embedded in the resultant sub-bands. Sub-band selection is based on the value of Peak Signal to Noise Ratio (PSNR) that is calculated between watermarked and original image. To extract the watermark, Kernel ICA is used and it has a novel characteristic is that it does not require the transformation process to extract the watermark. Simulation results show that proposed scheme is robust against attacks such as Salt and Pepper noise, Median filtering and rotation. The performance measures like PSNR and Similarity measure are evaluated and compared with Discrete Wavelet Transform (DWT) to prove the robustness of the scheme. Simulations are carried out using Matlab Software.

Introduction

Digital watermarking is the process by which a discrete data stream called a watermark is hidden within a host multimedia signal by imposing imperceptible changes on the signal. In many proposed techniques, this procedure entails the use of a secret key that must be used to successfully embed and extract the watermark. One major driving force for research in this area is the need for effective copyright protection scenarios for digital media. In such an application, a serial number or copy protection code is watermarked into the signal to protect to assign ownership or user rights. It is expected that an attacker will attempt to remove the watermark by intentionally modifying the watermarked signal. Thus, we must strive to embed the mark such that it is difficult to remove (without the use of the key) unless the marked signal is significantly distorted. A popular analogy for watermarking is the process of data communications in which the goal is to effectively communicate the watermark information using information hiding techniques. Therefore, it is crucial for the future development of networked multimedia systems that robust methods are developed to protect the intellectual property right of data owners against unauthorized copying and redistribution of the material made available on the network. Furthermore, it is an important issue to develop a robust watermarking scheme with a better tradeoff between robustness and imperceptibility [1].

Digital watermarking emerged as a tool for protecting the multimedia data from copyright infringement. In digital watermarking an imperceptible signal ''mark'' is embedded into the host image, which uniquely identifies the ownership. After embedding the watermark, there should be no perceptual degradation. These watermarks should not be removable by unauthorized person and should be robust against intentional and unintentional attacks. Different watermarking techniques have already been published in the literature [5].

This paper considers the particular case of medical image watermarking. Watermarking has become an important issue in medical image security, confidentiality and integrity (Giakomaki et al., 2003). Medical image watermarks are used to authenticate and/or investigate the integrity of medical images. One of the key problems with medical image watermarking is that medical images have special requirements. A hard requirement is that the image may not undergo any degradation that will affect the reading of images. Generally, images are required to remain intact to achieve this, with no visible alteration to their original form (Planitz and Maeder, 2006). The three mandatory security characteristics are:

- Confidentiality, which means that only the entitled users have access to the information
- Availability, that is the ability of the information system to be used in the normal scheduled conditions of access
- Reliability, based on the outcomes of integrity and authenticity.

Curve let transform was defined to represent two dimensional discontinuities more efficiently, with least square error in a fixed term approximation. Curve let transform was proposed in continuous domain and its discretization was a challenge when critical sampling is desired. Contour let transform was then proposed as an improvement of curve let transform. The contour let is a directional multi resolution expansion, which can represent images containing contours

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efficiently. Contour let transform possess all features of wavelets and also shows a high degree of directionality and anisotropy. One of the unique properties of contour let transform is that we could have any number of directional decompositions at every level of resolutions.

Moreover, the conventional watermark detection uses transform techniques to decompose the corrupted image, of which the ownership is determined, and from which the watermark is recovered. In general, toward the aim of watermark recovery, some detection systems require previous knowledge of the watermark such as its location, the strength, the threshold or the original image. Also in some cases, the watermarking system requires embedding multi- information such as sources, authors, creators, owners, distributors or authorized consumers of a document. Therefore, a watermarking algorithm must be able to embed watermarks to satisfy those requirements.

Besides, the intelligent detection technique, Fast ICA is implemented for extraction without the use of previous knowledge of the watermark and even the transformation process. Robustness and transparencies of the above scheme is demonstrated with simulation results.

This paper is organized as follows: Section II reviews the DWT. Section III discuss contour let transform, Section IV discusses the watermark embedding algorithm. In section V, watermark extraction technique ICA is explained. Simulation results are presented in section VI and conclusions are drawn in section VII.

Discrete Wavelet Transform

A two dimensional DWT is shown in Fig. 1, where L and H are the low pass and high pass analysis filters, LL1 to HH1 are are the low band and high band output coefficients at level 1 [3]. where $\downarrow$ denotes down sampling by a factor of two, LL2 to HH2 are the low band and high band output coefficients at level 2.

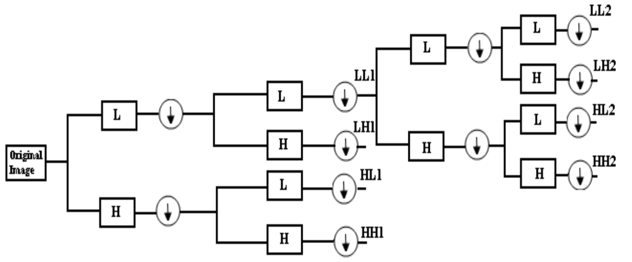

Fig 1. A two dimensional decomposition using DWT for two levels

Contour let Transform

Contour let transform is a multi-resolution and multidirectional transformation technique which is used in image analysis for capturing contours and fine details in images [4].The contour let transform is composed of basis functions oriented at different directions in multiple scales with flexible aspect ratios. This frame work should form a basis with small redundancy unlike other transform techniques in image processing, Contour let representation contains basis elements oriented at variety of directions much more than few directions that are offered by other separable transform technique. One way to obtain a sparse expansion for images with smooth contours is first apply a multistage wavelet like transform to capture the edge points, and then local directional transform to gather the nearby edge points into contour segments. With this insight, we can able to construct a double filter bank structure shown in Fig. 2 where the laplacian pyramidal (LP) filter is used to capture the point discontinuities, followed by a directional filter bank (DFB) to link point discontinuities into linear structures. The overall result is an image expansion using basic elements like contour segments, and thus it is named contour let transform. The combination of this double filter bank is named pyramidal directional filter bank (PDFB). An example of frequency partitioning of a PDFB is shown in Fig. 3. Fig. 7 shows a multiscale and directional decomposition using a combination of a LP and a DFB. Band pass images from the LP are fed into a DFB so that directional information can be captured. The scheme can be iterated on the coarse image. The combined result is a double iterated filter bank structure, named contour let filter bank, which decomposes images into directional sub bands at multiple scales [8].

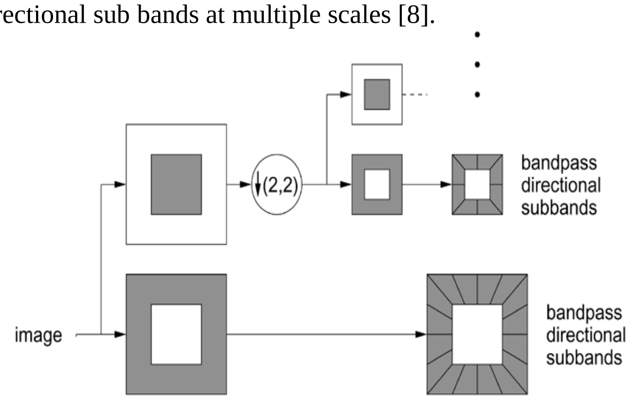

Fig 2. Contour let filter bank

Watermark Embedding

The original image is decomposed into using low pass filter followed by Directional Filter Banks. The proposed watermark embedding scheme is shown in Fig. 4. The original image is passed through a low pass and high pass filter where the low pass output is decomposed using DFB. The resultant sub-bands are ordered as per low to high frequency components. The watermark is embedded in each of these Contour let sub-bands and corresponding PSNR values are calculated. The embedded Contour let coefficients are combined together using Inverse DFB. Once again passed through inverse wavelet low pass and high pass filters to obtain watermarked image.

$$W_{CF}(i, j) = CF(i, j) + \alpha . W_{i,j} \quad (5)$$

where $W_{CF}(i, j)$ is the watermarked Contour let coefficients (1 to 7), $CF(i, j)$ is the Contour let coefficient (1 to 7), $W_{i,j}$ is the watermark and α denote the embedding factor.

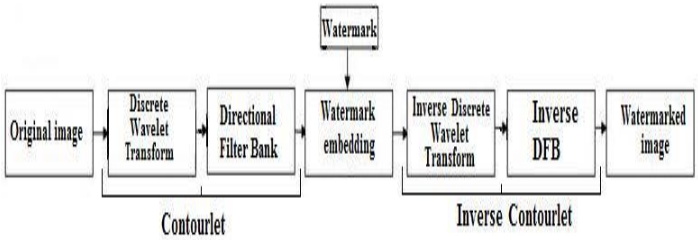

Fig 3. Proposed watermark embedding scheme

Independent Component Analysis

This section briefly reviews ICA algorithm and how ICA is applied to watermark extraction. ICA aims at extracting unknown hidden components from multivariate data using only the assumption that the unknown factors are mutually independent. Independent component analysis (ICA) is a novel statistical technique that aims at finding linear projections of the data that maximize their mutual independence. ICA has received attention because of its potential applications in signal processing such as in feature extraction, and Blind Source Separation (BSS) with special emphasis to physiological data analysis and audio signal processing. The goal of BSS is to recover the source signals given only sensor observations that are linear mixtures of independent source signals. ICA is a statistical technique for obtaining independent sources, S from their linear mixtures, X, when neither the original sources nor the actual mixing, A are known [7].

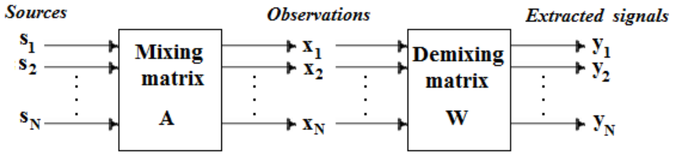

Fig 4. Mixing and De mixing model of an ICA

This is achieved by exploiting higher order signal statistics and optimization techniques. The result of the separation process is a de mixing matrix W, which can be used to obtain the estimated unknown sources, $\bar{S}$ from their mixtures. This process is described by Equation 9 and a schematic illustration of the mathematical model is shown in Fig.3.

$$X = AS \rightarrow \bar{S} = WX \quad (6)$$

Kernel *ICA*

The Kernel ICA algorithm [3] uses the contrast function based on Canonical Correlation analysis in a Reproducing Hilbert Kernel Space. The outline of the algorithm is given as follows:

(i) Let $x_1, x_2, ..., x_m$ and $y_1, y_2, ..., y_n$ be the data vectors and $K(x, y)$ be the kernel.

(ii) Data is whitened and the whitening matrix P is obtained

(iii) Then the contrast function $C(w)$ is minimized with respect to w.

(iv) The contrast function is minimized in the following way:

(a)The Centered Gram matrices are $K_1, K_2, ..., K_m$ of the estimated sources $\{y_1, y_2, ..., y_m\}$, where $y_i = w.x_i$ are computed.

(b)The minimal eigen value of the generalized eigen vector equation $\hat{\lambda}_F(K_1, ... K_m)$ is defined as $K_k \alpha = \lambda D_k \alpha$.

(7)

(c)Then $C(w) = \hat{\lambda}_F(K_1, ..., K_m) = -\frac{1}{2} \log \lambda_F^k (K_1, ..., K_m)$ (8)

(v) The demixing matrix W_d is calculated by

$$W_d = wP \quad (9)$$

and the independent components are estimated by

$$\hat{S} = W_d X \quad (10)$$

To perform Kernel ICA, a linear mixture of image is generated to demix the watermark signal from the mixtures. Therefore ICA is applied directly on the watermarked image.

The mixtures can be modeled as

$$X_1 = a_{11} CF_1 + a_{12} W$$

$$X_2 = a_{21} CF_2 + a_{22} W$$

$$X_3 = a_{31} CF_3 + a_{32} W \quad (11)$$

where X_1, X_2, X_3 are mixtures, CF is the watermarked contour let coefficients, a is a mixing matrix, W is the watermark matrix and K is a random key in the embedding process. Applying the above mentioned ICA algorithms to those mixtures, matrix watermark W is extracted. Similarity measure between original and extracted watermark is calculated using the formula given below:

$$Sim(X, X') = \frac{X.X'}{\sqrt{X'.X'}} \quad (12)$$

Where X - Original watermark, X' - Extracted watermark

Simulation Results

The proposed watermarking scheme is tested on Bone image of size 256 x 256. Two level DWT is followed by DFB is performed on the original image. The frequency sub-bands are selected to embed watermark as explained in Section IV. A medical logo image of size 64 x 64 is used as watermark and α is set to 0.3 by repeated simulation to ensure the invisibility of the watermark. Fig. 5 shows the Original image, Fig. 6 and fig.7 shows the one and two level decompositions. Fig, 8 shows the Contour let coefficients using DFB and fig. 9 shows the watermark and Fig. 10 shows the watermarked image for seventh sub-band. Watermark is embedded in all sub-bands of Contour let transform and their corresponding values are tabulated in Table1. From the results, it is inferred that watermark embedded in 7^{th} sub-bands generates more PSNR when compared to other sub-bands. From the results shown in Fig. 10 it is inferred that, both original and watermarked images are evidently indistinguishable and imperceptible. The robustness of the above watermarking scheme is validated against various attacks like Salt & Pepper noise, Median Filtering and Rotation are shown in figs. 11-13 respectively. Table 2 compares the values of PSNR and Similarity measure for wavelet and Contour let. The watermarked image of Contour let has a PSNR value of 52.5996 dB and DWT has a PSNR value of 46.2498. After implementing various attacks, Contour let possess a high PSNR value when compared to DWT. These values are tabulated in Table 2. The watermark detection using Kernel ICA extracts the watermark perfectly from the watermarked image. Fig. 14 shows the extracted watermark and figs. 15-17 shows the extracted watermarks from various attacks.

Fig 5. Original image (Bone)

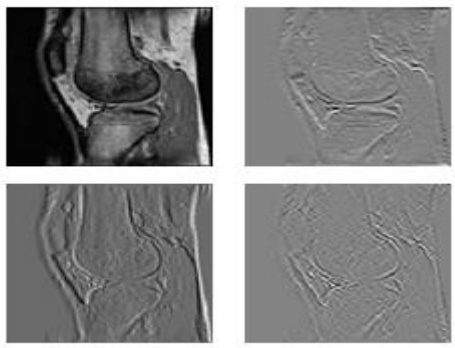

Fig 6. One level decomposition

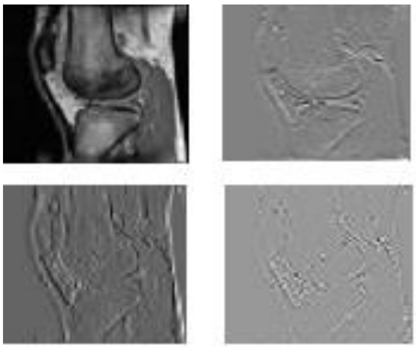

Fig 7. Two level decomposition

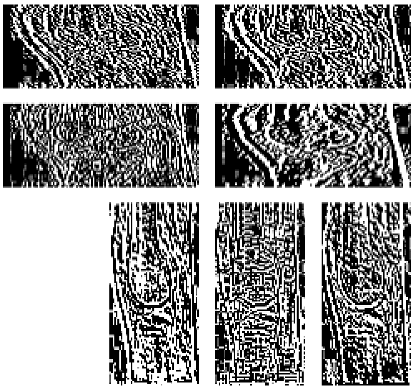

Fig 8. Contour let coefficients obtained using DFB

Fig 9. Watermark

Fig 10. Watermarked image from seventh sub-band

Fig 11. Salt & pepper noise attack

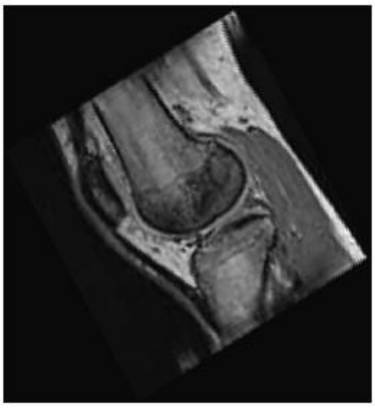

Fig 12. Rotation

Fig 13. Median filtered attack

Fig 14.Extracted watermark from watermarked image

Fig 15. Extracted watermark from salt & pepper noise

Fig 16. Extracted watermark from Rotation

Fig 17. Extracted watermark from Median filtering

Table 1. PSNR values for various sub-bands

Sub-bands	PSNR(dB)
1	47.5321
2	45.4211
3	48.6871
4	41.3256
5	50.7632
6	48.3409
7	52.5996

Table 2. Performance comparison of DWT and contour let

Attacks	PSNR(dB)		Similarity Measure	
	DWT	Contourlet	DWT	Contourlet
Watermarked image	46.2498	52.5996	0.9365	0.9840
Salt & pepper Noise	34.7459	37.7076	0.8932	0.9420
Rotation	33.9065	31.6681	0.9012	0.9502
Median Filtering	37.7654	42.1034	0.9134	0.9493

Conclusion

Contour let based digital watermarking using Kernel ICA is attempted in this paper work. The above mentioned scheme is robust against attacks and also possess considerable PSNR and similarity measure values. Hence Contour let proves its imperceptibility and robustness and it performs better than wavelet transform.

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