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Hybrid Image Watermarking Technique Based on ICA and Shearlet Transforms.

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ABSTRACT

Immense growth in the field of Digital Networks such as Digital Media, Internet has made a huge impact in the IOT and Wireless Communication Sectors. Problems like Ownership duplication and un allowed copying of information are been faced often here. In this paper a hybrid scheme using Independent Component Analysis (ICA) and Discrete Shearlet Transform (DST) is presented. In this way, the host image is divided into N/2xM/2 images and then N/2xM/2 images are decomposed using ICA, and then its high power component is decomposed by DST and the gray-scale watermark image is embedded into DST coefficients. The proposed method is examined on the images with different textures and resistance is evaluated against various attacks like image processing and geometric attacks. The results show good transparency and high robustness in proposed method.

Keywords: Digital Image watermarking, Independent Component Analysis, Shearlet transform

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INTRODUCTION

The fast development of the multimedia technologies including the internet, digital media has been a major source for the illegal process of faking documents, editing and processing which can lead to easy distribution and manipulation of digital images. Security and Protection of data is an important issue in this field of discussion. Watermarking is used for hiding the information for the purpose such as identification and ownership protection. In image watermarking technique information is embedded onto the host image which contains some messages for owner identification. The main challenge in this area is to achieve the least distortion in image quality and protection of embedded data against intentional removal attacks. So far, none of the methods have been able to cover all the aspects of watermarking but they try to achieve balanced optimal values for robustness, transparency and capacity, because these three attributes are mutually orthogonal to each other[1].

With the categorization of two, spatial and frequency domains, watermark is inserted in. In the case of spatial class, watermark is directly embedded in host image components. It has easy implementation along with low computational cost, but are fragile against attacks. I the other case , by changing the coefficients image magnitude by embedded watermarking. With more resistant against image processing attacks and malicious manipulation, those methods can embed more information. Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), and DWT are Some of the well-known frequency domain transforms. Among those DCT-based methods are robust against simple image processing attacks like blurring and low-pass filtering without the resistant against rotation, resizing, and cropping attacks[2].

DWT compared to other frequency transforms is more efficient because it can be expressed in time and frequency and its multi-resolution representation . Having features such as similarity of DWT to the human visual system (HVS) and good modeling of HVS, space frequency localization and multi-resolution. Representation cause DWT is used in watermarking and image processing researches, as well as it is suitable for identifying frequency regions of the image signal such that the watermark can be effectively embedded. The main limitation of the Wavelet transform is its low ability to capture the directional information[2][3].

In this context, some of these multi-scale transforms are Ridgelet , Contourlet, Curvelet, and Shearlet. These transforms are used in various image processing applications like denoising, compression, segmentation, image retrieval and feature extraction[4][5] . Although most of the multi-scale representations are over complete and have high computational complexity, but they are used since they can represent fine details of the natural images[6]. Shearlet compared to transforms like Contourlet, Curvelet, and Ridgelet obtains a unique combination of mathematical ridgeness and computational performance which in dealing with edges is efficient and computationally effective [7]. A watermarking method based on chou's model using multi-resolution and multi-directional features of Shearlet transform[8].

In digital watermarking, based on two approaches ICA has been recently applied. One approach is based on some transform domain coefficients , or the mixture of the host image, and the watermark . In this, to extract the watermark ICA is applied at detection. Other approach is based on the original results [9], on the other hand we also have methods to embed the watermark based on ICA.

In our proposed technique, we introduce an image watermarking algorithm using Independent Component Analysis and Discrete shearlet Transform (DST). The cover image is separated into N/2 x M/2 observation images. And then we have applied ICA to all observation images, Now we have four independent components. Then choose the two components from high frequency level. Selected sub band is shearlet transformed. The two independent watermark information or image is embedded into the corresponding position. Make the whole image Inverse shearlet and Inverse ICA transformed to get watermarked image.

PRILIMINARY

Discrete Shearlet Transform

The concept of using simple mathematics which is under stable and taken from the affine systems theory is been utilized in the case of Shearlet. Its direction is been controlled by shear matrices instead of rotations and provides optimal sparse representations. Shearlet transform is employed in many problems such as applied mathematics, signal processing like operators decomposition, inverse problems, edge detection, and image restoration [10]. Shearlet is a framework of the affine system which extracts geometrical features of multi-dimensional signals. This transform is an affine system and includes a shearlet function which is parametrized with scaling, shear and translation such that shear parameter captures direction of the singularities[11].

For image I, Shearlet transform is a mapping in the form of relation (1):

$$I \rightarrow SH\psi I(a, s, x) \quad (1)$$

Which depends to scale $a>0$, direction s and location x.

Figure 1, shows the filter bank decomposition for Shearlet transform. According to that, first the image is decomposed to a low-pass sub-band and a band-pass sub-band by Laplacian Pyramid (LP). Then, band-pass sub-band which demonstrates the difference between the original image and the sub-band low-pass filters is delivered to an appropriate shearing filter to complete multi-directional decomposition. This process is performed continuously on the low-pass sub-bands to obtain a multi-scale decomposition.

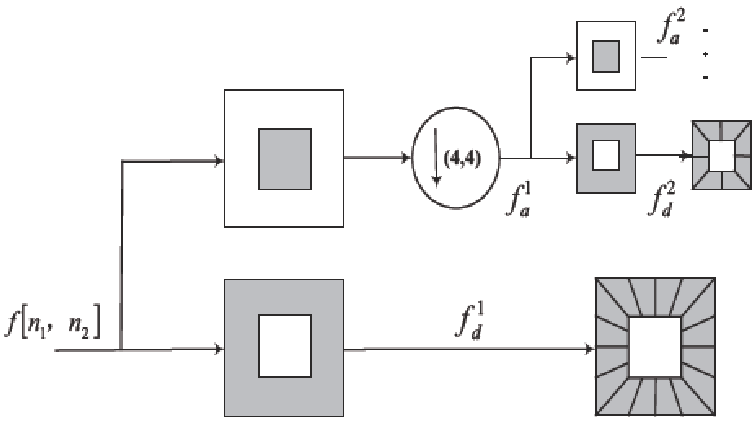

Fig 1: Filter bank decomposition of DST

Independent Component Analysis

Projecting a set of components on the other independent statistical set by Independent Component Analysis (ICA). In the simple ICA, the l entry of a sample t of a column vector sequence $\boldsymbol{x}_t$ are anticipated onto a space, possibly where the space of l components $\boldsymbol{y}_t$ as statistically independent. $l \times l$ matrix **A** is the possible representation by this projection.

$$\boldsymbol{y}_t = \boldsymbol{A}\boldsymbol{x}_t \quad (2)$$

PROPOSED SYSTEM

In this paper, ICA and DST are combined for improving robustness and transparency. Host image is divided into N/2 x M/2 images. Then ICA is applied to N/2 x M/2 Observation images. High power components (IC1 & IC2) chosen for applying DST. Then DST is applied on high power components.i.e.,IC1 & IC2. Watermark is embedded directly in selected sub band which is outcome of DST decomposition.

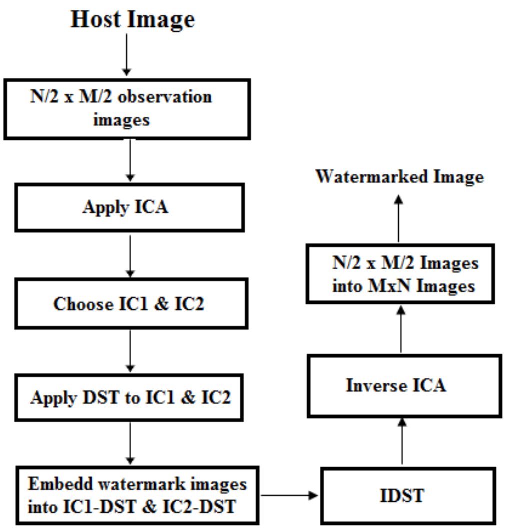

Fig 2: ICA-DST Approach

Watermark Embedding Algorithm

Steps of embedding watermark in host image is done as below:

1. Host image, A is changed into N/2 x M/2 Observation images.
2. ICA is applied to all the Observation Images.
3. Then, DST is applied on the high power components IC1 & IC2. Totally 21 sub-bands are obtained by setting 3 number of scales in DST and vector of Shearlet with levels [0,1,1]. So four and eight sub-bands are achieved in first, second and third scale respectively.
4. Two sub-bands (first scale and vertical orientation & first scale horizontal orientation) are selected as embedding host frequency.
5. Two Watermarks are embedded onto the selected sub-bands. According to the equation (3).
   $$A_W = B + \alpha W \quad (3)$$
   Where α stands for the scaling factor which is balancing factor between transparency and robustness and is adjusted by it and B embedding host frequency.
6. Finally, inverse DST and inverse ICA is performed on A_W respectively.

Watermark Extraction Algorithm

Extracting watermark from watermarked image is done as below

1. Watermarked image, A_W is changed into N/2 x M/2 Observation images.
2. ICA is applied to all the Observation Images.
3. Then, DST is applied on the high power components IC1 & IC2. Totally 21 sub-bands are obtained by setting 3 number of scales in DST and vector of Shearlet with levels [0,1,1]. Two sub-bands (first scale and vertical orientation & first scale horizontal orientation) are selected.
4. Extract two watermark images from selected sub-bands.
5. Apply inverse DST and inverse ICA to get cover image.

RESULTS AND DISCUSSION

The proposed DWT-DST scheme is implemented using Matlab. ShearLab 3D [59] is used in the proposed method for DST calculations. Size of all these images is 512×512 pixels. In our experiments, the watermark is a gray-scale image with size of 64×64 pixels. Table 1 shows these images respectively. To show effectiveness of our proposed scheme, transparency and robustness against different attacks which are the most important features of any watermarking system is quantified through Peak Signal-to-Noise Ratio (PSNR).

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Table 1: Input Images and Input Watermarks

<table>
<tr><th>Input Images</th><th>Input Watermarks</th></tr>
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Table 2: Results for host image

Watermarked Images	Recovered Watermark	Weighting factor (F),PSNR(db),Correlation(ρ)

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<table>
<tr>
<td></td>
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</td>
<td>F=0.02
PSNR=51.39
ρ=1</td>
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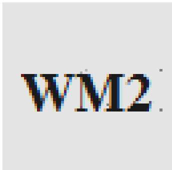
</td>
<td>F=0.04
PSNR=50.025
ρ=1</td>
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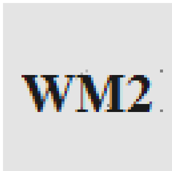
</td>
<td>F=0.02
PSNR=51.25
ρ=1</td>
</tr>
</table>

For robustness inspection of the proposed scheme the watermarked image was tested against several types of attacks namely Salt & Pepper noise, Gaussian noise and Speckle noise. We observe that ICA- DWT based watermarking attains the lowest distortion in the watermarked images in the lack of attacks and better performance for most of the attacks from Table 4.

Table 3: Performance of the ICA-DST based watermarking against various types of attacks

Attack	Watermarked Image	Extracted Image

Salt & pepper noise		 
Gaussian noise		 
Speckle noise		 

Table 4: PSNR Value Of ICA -DST for different types of Attacks

Image Type	**ICA-DST**
Salt & Pepper Noise	**50.137**
Gaussian Noise	**47.321**
Speckle Noise	**48.571**

CONCLUSION

In this study a blind image watermarking method is introduced using ICA and DST. Multi-directional properties of DST make this scheme suitable for various images having different textures. Applying two different techniques ICA and DST, sequentially on the image to decompose it, make this approach robust against different attacks. Since each of ICA and DST are resistant against some types of attacks separately, combination of them cover weakness of other transform against some attacks. So, results of tests on proposed method exhibit high transparency and acceptable robustness. Because this method is blind, it can be applicable in copyright protection.

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