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Coding Digital Images using Ridgelet Transformation in Watermarking Applications

[1]***Madduru Sambasivudu***, Assistant Professor, Malla Reddy College of Engineering and Technology, Secunderabad Email: samba.siva57@gmail.com

[2]***Dr.V S Giridhar Akula***, Principal, Malla Reddy Institute Of Engineering and Technology,Secunderabad,Email:principalmriet@gmail.com

Abstract:

Image Watermarking provides copyright protection to digital images by hiding important information in original image to declare ownership. Perceptual transparency and robustness, capacity and blind watermarking are main features those determine quality of watermarking scheme.
An effective image coding technique which involves transforming the image into another domain with Ridgelet function and then quantizing the coefficients with modified TRUST has been presented in this paper. Ridge functions are effective in representing functions that have discontinuities along straight lines. Normal Wavelet transforms fail to represent such functions effectively. TRUST has been defined for normal wavelet decomposed images as an embedded quantization process. If the coefficients obtained from Ridgelet transform of the image with more discontinuities along straight lines have to subject to quantization process with TRUST, the existing structure of the TRUST should be modified to suit with the output of the Finite Ridgelet Transform (FRIT). In this paper, a modified SPIHT algorithm for FRIT coefficients has been proposed. The results obtained from the combination of FRIT with modified TRUST found much better than that obtained from the combination of Wavelet Transform with TRUST

Keywords:

Watermarking, Ridgelets, Wavelets, Ridge function, Image coding, Modified TRUST, Partitioning.

Introduction:

Watermarking is a way of embedding a key into the original data in order to increase security and copyright protection. Image watermarking algorithms are revolving around two categories based on the domain which is used for embedding the watermark: spatial and frequency domain techniques. The success of wavelets is mainly due to the good performance for piecewise smooth functions in one dimension. Unfortunately, such is not the case in two dimensions. In essence, wavelets are good at catching zero-dimensional or point singularities, but two-dimensional piecewise smooth signals resembling images have one-dimensional singularities. Intuitively, wavelets in two dimensions are obtained by a tensor-product of one dimensional (1-D) wavelets and they are thus good at isolating the discontinuity across an edge, but will not see the smoothness along the edge. This fact has a direct impact on the performance of wavelets in many applications. While simple, these methods work very effectively, mainly due to the property of the wavelet transform that most image information is contained in a small number of significant coefficients around the locations of singularities or image edges. However, since

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wavelets fail to represent efficiently singularities along lines or curves, wavelet-based techniques fail to explore the geometrical structure that is typical in smooth edges of images. Therefore, new image processing schemes which are based on true two-dimensional (2-D) transforms are expected to improve the performance over the current wavelet-based methods.

In this paper, we propose a new watermarking algorithm in ridgelet domain which is based on spread spectrum technique. First, we find the best place to insert the watermark bits. More specifically, the host image is partitioned into several nonoverlapping blocks in a way that curved edges appear as several straight edges. After applying ridgelet transform, we find a direction with the highest variance intensity for each single block in order to insert the watermark bits. Second, we encode the scrambled watermark bits by pseudo random sequences which are randomly generated through a uniform probability density function.

Ridgelet Transform

The continuous ridgelet transform of an integrable bivariate function f(x) is given by

$$CRT_f(a,b,\theta)=\int_{R^2}\psi_{a,b,\theta}(x)f(x)dx$$
…………………………… (1)

where ridgelets $x_1\cos\theta+x_2\sin\theta=const$ in 2-D are defined from a wavelet type function in 1-D $\psi(x)$ as

$$\psi_{a,b,\theta}(x)=a^{-1/2}\psi((x_1\cos\theta+x_2\sin\theta-b)/a)$$
…………………………… (2)

Wavelets: $\psi_{scale,\text{ point-position}}$

Ridgelets: $\psi_{scale,\text{ line-position}}$

The Fig 1 shows the Ridgelet function oriented at an angle θ and constant along the lines $x_1\cos\theta+x_2\sin\theta=const$.

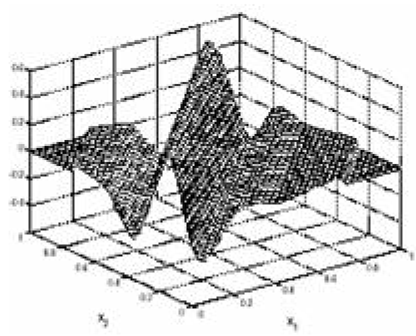

Fig 1 Ridgelet Function

In 2-D, points and lines are related through the Radon transform, thus the wavelet and ridgelet transforms are linked through the Radon transform. More precisely, denote the Radon transform as

$$Rf(\theta,t)=\int_{R^2}f(x)\delta(x_1\cos\theta+x_2\sin\theta-t)dx$$
.... (3)

Then the ridgelet transform is the application of a 1-D wavelet transform to the slices (also referred to as projections) of the Radon transform, and is denoted as

$$CRT_f(a,b,\theta)=\int_R\Psi_{a,b}(t)R_f(\theta,t)dt$$
…..………………..….. (4)

Instead of taking a 1-D wavelet transform on the radon transform, the application of a 1-D Fourier transform would result in the 2-D Fourier transform. Let $F_f(\omega)$ be the 2-D Fourier transform of $f(x)$, and then we have

$$F_f(\xi\cos\theta,\xi\sin\theta)=\int_R e^{-j\xi t}R_f(\theta,t)dt$$
.... (5)

This is the famous projection-slice theorem and is commonly used in image

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reconstruction from projection methods. In short, the ridgelet transform is the application of 1-D wavelet transform to the slices of the radon transform, while the 2-D Fourier transform is the application of 1-D Fourier transform to those radon slices.

Proposed algorithm

- Represent the image data as intensity values of pixels in the spatial co-ordinates.
- Apply Ridgelet Transform (Orthonormal Ridgelet Transform) on the image matrix and get the Ridgelet coefficients of the image.
- Quantize the available coefficients using the **TRUST** Algorithm
- Use any form of entropy coding on the bit stream available from the TRUST encoder

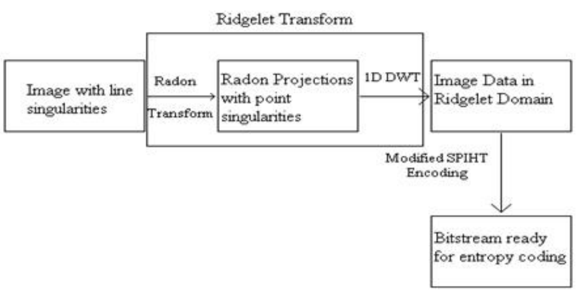

Fig 2: Image Compressions using Ridgelet

The problem in applying such an algorithm to the Ridgelet decomposed image is that the form in which ridgelet decomposes the image is different from that of wavelets.

3. Results

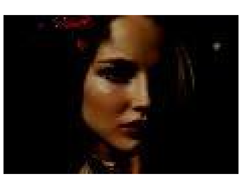

Fig3 (a) Fig3 (b)

Fig3(c) Fig 3(d)

Fig 3: Test images of Lenna

The images in Fig 3 were subjected to Ridgelet transform which uses 1-D dyadic wavelet decomposition. The parameters like CR, RMSE and PSNR were calculated for various numbers of planes. The results obtained are compared with the TRUST encoded images after normal 2-D wavelet decomposition up to the equal number of levels.

No. of bit planes excluded	CR		RMSE		PSNR	
	Proposed scheme	Existing scheme	Proposed scheme	Existing scheme	Proposed scheme	Existing scheme
6	49.2102	67.1132	22.8602	30.7691	19.1252	20.2246
5	29210	31.2467	23.5422	30.2331	21.4135	20.5078
4	12.2342	16.2444	16.6667	29.9898	23.9282	21.0340
3	8.6249	9.5448	19.6421	29.9418	22.3715	21.0664

Table 1: Comparison of CR, RMSE and PSNR values of Test images

Here the performance is very good even when most of the coefficients are dropped .

4 Conclusion

The results are found to be comparable with conventional wavelet based compression. Experimental results clearly show that the proposed compression technique results in higher quality reconstructed images compared to that of other prominent

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algorithms operating at similar bit rates for the class of images where edges are dominant with minimum variation in compression ratio.

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