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Abstract - This paper emphasizes on designing of a novice quantizer that is more suitable for compressing images through curvelet transform. This compression algorithm is tested on various images like plain, textured and building images. The results are compared with the existing techniques like curvelet with existing quantizer, wavelet with existing quantizer and wavelet with proposed quantizer. The proposed algorithm "curvelets with proposed quantizer" outperforms the existing techniques. The performance is evaluated through visual clarity, Peak Signal to Noise Ratio (PSNR) and compression metrics such as Compression ratio and Bit-rate.

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Curvelets with New Quantizer for Image Compression

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Abstract - This paper emphasizes on designing of a novice quantizer that is more suitable for compressing images through curvelet transform. This compression algorithm is tested on various images like plain, textured and building images. The results are compared with the existing techniques like curvelet with existing quantizer, wavelet with existing quantizer and wavelet with proposed quantizer. The proposed algorithm "curvelets with proposed quantizer" outperforms the existing techniques. The performance is evaluated through visual clarity, Peak Signal to Noise Ratio (PSNR) and compression metrics such as Compression ratio and Bit-rate.

Keywords: Quantizer, Compression ratio, Bit-rate, curvelet, wavelet.

I. Introduction

Past few years have produced abundant results in compression techniques for images because they are being used widely in internet technologies etc. So far wavelet based compression of digital signals and images is a topic of interest. Throughout the scientific and engineering disciplines many hundreds of papers published [1-8] in journals, in which a wide range of tools and ideas have been proposed and studied. The major drawback associated with wavelet based techniques are their inability to capture geometry of two dimensional edges, though they have proven their worth in number of fields. Hence, the field of image processing requires a true 2-dimensional transform that can efficiently handle the intrinsic geometrical structure which is the key in visual information.

Candes and Donoho [9] developed a new multi-scale transform which is called as the curvelet transform. It was the first proposed in the context of objects $f(x_1; x_2)$ defined on the continuum plane $(x_1, x_2) \in \mathbb{R}_2$, which is Motivated by the needs of image analysis. The new transform is believed to capture image information more efficiently than the wavelet transform by giving basis elements in addition to having the qualities of wavelet. Basis functions in curvelets are

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with variety of elongated shapes with different aspect ratios and are oriented at variety of directions. In particular, it has been designed for representing edges and other singularities along curves efficiently compared to traditional transforms, i.e. using very few coefficients for a given accuracy of reconstruction. Approximately for representing an edge to squared error $1/N$ requires $1/N$ wavelets and only about $1/\sqrt{N}$ curvelets.

In this paper practical implementations of proposed compression method is focused. The next section discusses the quantizer design for proposed compression method, section 3 demonstrates the algorithm of new compression technique and section 4 explains the simulation results. Finally, the superiority of proposed technique over existing methods is demonstrated using PSNR and compression metrics.

II. QUANTIZER DESIGN AND CODING

The uniform quantizer is the most commonly used scalar quantizer for transform based image compression due to its simplicity. It is also known as a linear quantizer since its staircase input-output response lies along a straight line (with a unit slope). Two commonly used linear staircase quantizers are the midtread and the midrise quantizers.

a) Existing Quantizer

From MATLAB tool box, it is observed that the quantizer is defined as:

$$y = Q_T(x)$$

$$\text{where: } Q_T(x) = 0, \text{ if } |x| < T$$

$$Q_T(x) = \text{sgn}(x) * [x/T], \text{ otherwise} \quad (1)$$

The input values for quantizer are created with evenly spacing and bin size (T) is assumed as 0.1. The quantization curve is as shown in Fig. 1(a). From the quantization curve, it can be said that the above quantizer is midtread.

For decompression, de-quantized values are computed using the following equation.

$$Dq = \text{sgn}(Q) * (\text{abs}(Q) + 0.5) * T \quad (2)$$

Where Q are quantizer output values and Dq are de-quantized values. In the above equation 0.5 is chosen to get the de-quantized values at the mid-point of each quantization bin. De-quantized real values are shown in Fig. 1(b).

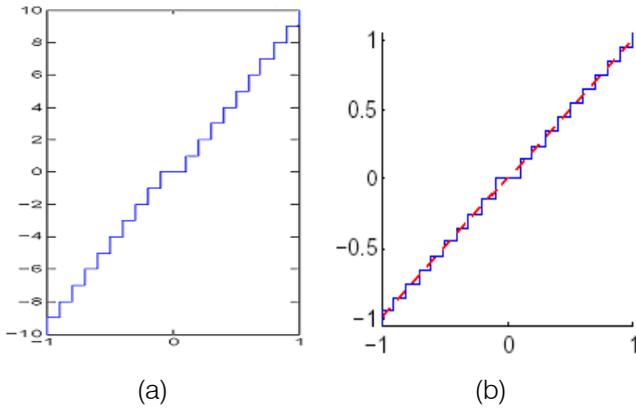


Fig. 1: Existing Quantizer (a) Quantization curve (b) De-quantized values

It is known that the subinterval size of the midtread quantizer is larger than the midrise quantizer. Hence for the uniformly distributed input, the average quantization error of the midtread quantizer is larger than that of midrise quantizer.

b) Proposed Quantizer

The two constraints to be considered while designing quantizer are as follows:

1. Quantizer must have average quantization error as low as possible.
2. De-quantized values must be exactly at the mid-point of each quantization bin.

Since the source considered for compression application is uniformly distributed, midrise quantizer is preferred, which satisfies the first constraint.

To obtain the midrise quantizer and to satisfy second constraint, the midtread quantizer equations are restructured as:

$$y=Q_T(x)$$

$$\text{where: } Q_T(x) = 0, \text{ if } |x|<T$$

$$Q_T(x) = \text{sgn}(x) * ([x/T]+K)*T, \text{ otherwise (3)}$$

The input values for quantizer are created with evenly spacing and bin size(T) is assumed as 0.1. Here K is a constant.

For decompression, de-quantized equation is modified as:

$$Dq=\text{sgn}(Q) * ([\text{abs}(Q)/T]-M)*T \quad (4)$$

Where Q are quantizer output values, Dq are de-quantized values and M is a constant.

The above equations are tested for different values of K and M. Finally for K=0.8 and M=0.3 the quantization and de-quantization curves are efficient and the de-quantized values are exactly at the mid-point of each quantization bin as shown in Fig. 2.

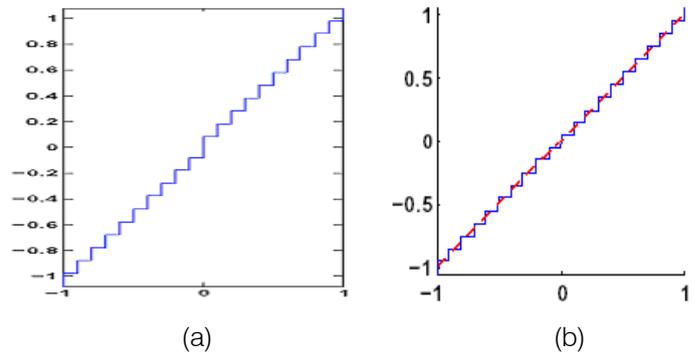


Fig. 2: Proposed Quantizer with K=0.8 and M=0.3 (a) Quantization curve (b) De-quantized values

The quantization curve resembles midrise quantizer. Hence the proposed quantizer suits for the assumed uniformly distributed source, whose quantization equation becomes as:

$$y=Q_T(x)$$

$$Q_T(x) = 0, \text{ if } |x|<T$$

$$Q_T(x) = \text{sgn}(x) * ([x/T]+0.8)*T, \text{ otherwise (5)}$$

and the de-quantization equation as:

$$Dq=\text{sgn}(Q) * ([\text{abs}(Q)/T]-0.3)*T \quad (6)$$

Where Q are quantizer output values and Dq are de-quantized values.

The purpose of an entropy encoder (symbol encoder) is to reduce the number of bits required to represent each symbol at the quantizer output. For simplicity one of the entropy encoding technique i.e. an arithmetic coding, which is an integral part of MATLAB tool box has been used to serve the purpose.

III. THE ALGORITHM

The following steps are involved in the compression algorithm of Curvelet Transform.

1. Read input image f .
2. Apply the 2D FFT and obtain Fourier samples $\hat{f}[n_1, n_2], -n/2 \leq n_1, n_2 < n/2$.
3. For each scale j and angle l , form the product, $\tilde{U}_{j,l}[n_1, n_2] \hat{f}[n_1, n_2]$
4. Wrap this product around the origin and obtain, $\tilde{f}_{j,l}[n_1, n_2] = W(\tilde{U}_{j,l} \hat{f})[n_1, n_2]$, where the range for n_1 and n_2 is now $0 \leq n_1 < L_{1,j}$ and $0 \leq n_2 < L_{2,j}$ (for θ in the range $(-\pi/4, \pi/4)$)
5. Apply the inverse 2D FFT to each $\tilde{f}_{j,l}$, hence collecting the discrete coefficients $c^D(j, l, k)$.
6. Quantize the coefficients with the proposed quantizer.
7. Entropy code the quantizer outputs.
8. Apply inverse operations to the result of step 7.

Based on the algorithm stated above, a compression technique has been developed for images of different sizes, which is tested using Curvlab[10] and MATLAB tools. The algorithm developed is working to a

satisfaction and results are encouraging in case of curvelets. The performance of the algorithm is evaluated using the following metrics and index

$$\text{Compression ratio}(\%) = \frac{\text{Output file size(bytes)}}{\text{Input file size(bytes)}} \tag{7}$$

$$\text{Rate(bpp)} = \frac{8 * (\text{Output file size(bytes)})}{\text{Input file size(bytes)}} \tag{8}$$

$$\text{psnr} = 10 \log_{10} \frac{M_1 \times M_2 \times \max(f(i, j))^2}{\sum_{i=1}^{M_1} \sum_{j=1}^{M_2} [f(i, j) - f'(i, j)]^2} \text{dB} \tag{9}$$

where M_1 and M_2 are the size of the image. $f(i, j)$ is the original image, $f'(i, j)$ is the decompressed image.

IV. Results and Discussion

In the simulation, the proposed algorithm is tested on various images like plain (Barbara), Building and Textured images. The results are presented in Figs. 3 to 5 and in Table 1. The results indicate that there exists a qualitative difference between the methods considered for compression and reconstruction of image under test. The following observations are made from the results.

1. The curvelet with proposed quantizer algorithm enjoys superior compression ratio over wavelet with existing quantizer, curvelet with existing and wavelet

with proposed quantizer algorithms. The performance is judged mainly through visual clarity and through PSNR.

2. The curvelet with proposed quantizer reconstruction displays higher sensitivity even at higher compression ratios.
3. In case of plain (Barbara) image the curvelet with proposed quantizer performs better at all compression ratios compared to other algorithms. When it is tested on Building and Textured images at low compression ratios curvelet with existing quantizer performs better compared to other algorithms, but at higher compression ratios curvelet with proposed quantizer outperforms the other algorithms irrespective of image.



Fig. 3: Barbara image for compression ratio of 1:20 (a) Original image (b) Wavelet with existing quantizer (c) Curvelet with existing quantizer (d) Wavelet with proposed quantizer (e) Curvelet with proposed quantizer



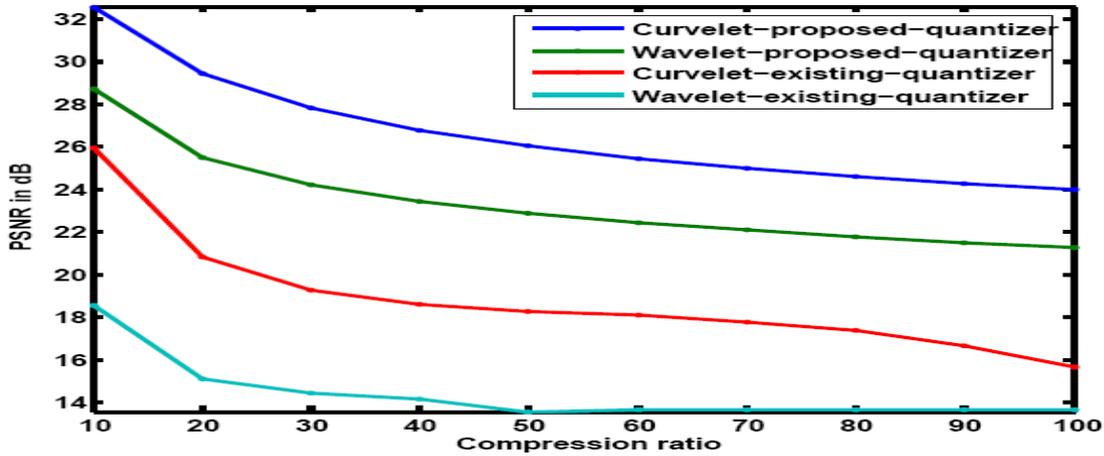


Fig. 4: PSNR Vs Compression ratio corresponding to Wavelet with existing quantizer, Curvelet with existing quantizer, Wavelet with proposed quantizer and Curvelet with proposed quantizer for Barbara image

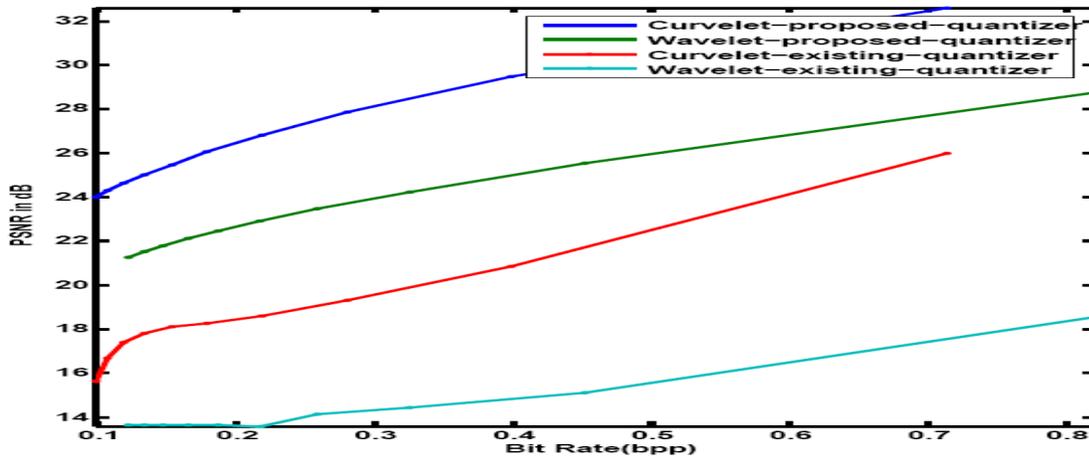


Fig. 5: Bit rate Vs PSNR corresponding to Wavelet with existing quantizer, Curvelet with existing quantizer, Wavelet with proposed quantizer and Curvelet with proposed quantizer for Barbara image

Table 1: PSNR Vs Compression ratio for various algorithms w.r.t. Barbara image

S.No	Compression ratio	PSNR in dB(Barbara image)			
		Wavelet With existing quantizer	Curvelet With existing quantizer	Wavelet With proposed quantizer	Curvelet With proposed quantizer
1	10	18.5611	25.9800	28.7499	32.6106
2	20	15.0924	20.8571	25.5371	29.4896
3	30	14.4269	19.2967	24.2425	27.8719
4	40	14.1493	18.6013	23.4729	26.8112
5	50	13.5877	18.2636	22.9075	26.0476
6	60	13.6517	18.1034	22.4776	25.4763
7	70	13.6520	17.8048	22.1051	25.0048
8	80	13.6514	17.4066	21.7726	24.6282
9	90	13.6510	16.6934	21.5213	24.2929
10	100	13.6500	15.6489	21.2750	24.0100

V. CONCLUSION

In this paper practical implementations of proposed compression method is focused, tested on

various types of images and it is proved that curvelet with proposed compression algorithm outperforms the existing techniques even at higher compression ratios.

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