

A MODIFIED VECTOR QUANTIZATION BASED IMAGE COMPRESSION TECHNIQUE USING WAVELET TRANSFORM

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ABSTRACT

An image compression method combining discrete wavelet transform (DWT) and vector quantization (VQ) is presented. First, a three-level DWT is performed on the original image resulting in ten separate subbands, these subbands are then vector quantized. VQ indices are Huffman coded to increase the compression ratio. An error correction scheme employed to improve the peak signal to noise ratio (PSNR) of the reconstructed image. The error correction scheme is an iteration process which continuously checks the image quality after sending the Huffman coded bit stream of the error codebook indices through the channel. Ten error codebooks are also generated in the error correction scheme using the difference between the original and the reconstructed images in the wavelet domain. The proposed method shows better image quality in terms of PSNR at the same compression ratio as compared to other DWT and VQ based image compression techniques found in the literature.

Keywords: Wavelet transform, Vector Quantization, Codebook.

1. INTRODUCTION

Data compression is the process of converting data files into smaller files for efficient storage and

transmission. There are two types of image compression technique, namely i) Lossless and ii) Lossy compression. In this work lossy compression technique is used. In this paper, a combined approach of image compression, based on the wavelet transform as explained in [1] and Vector quantization as explained in [2] is presented.

2. PRINCIPLE OF VECTOR QUANTIZATION

Vector quantization is a powerful tool for digital image compression. A vector quantizer (VQ) is defined as a mapping Q of K dimensional Euclidean space R^K in to a finite subset Y of R^K , shown in the following equation: $Q: R^K \rightarrow Y$ Where $Y = \{\bar{x}_i; i = 1, 2, 3, \dots, N\}$, is the set of reproduction vectors and is called a vector quantizer codebook, and N is the number of vectors in Y . For generating codebook there exists different algorithms, like a) Linde, Buzo and Gray (LBG) algorithm as explained in [2], b) Self Organizing Feature Map (SOFM) as explained in [3], etc. SOFM algorithm is used in the proposed method. The schematic diagram of a full search vector quantizer is shown in Figure 1.

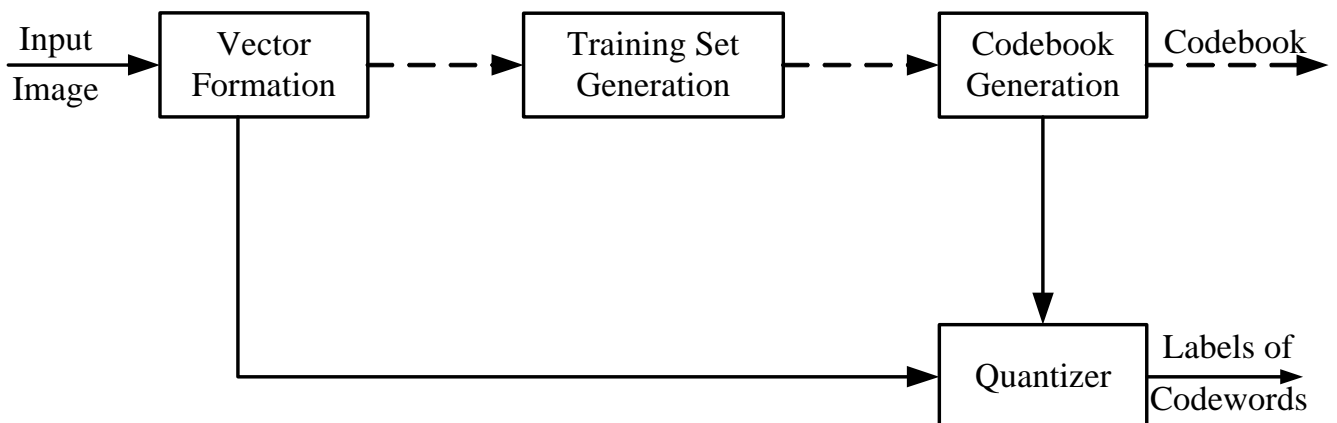


Figure 1: Schematic of Vector Quantization.

3. PRINCIPLE OF WAVELET TRANSFORM

Wavelet transform decomposes an image into a set of different resolution sub-images, corresponding to the various frequency bands. Wavelets are a class of functions used to localize a given signal in both space and scaling domains. Wavelets automatically adapt to both the high-frequency and the low frequency components of a signal by different sizes of windows as explained in [1]. DWT of signal $x(t)$ is defined by the equation: $x(t) = \sum_{m,n} c_{m,n} \psi_{m,n}(t)$, where,

$c_{m,n} = 2^{\frac{-m}{2}} \int x(t) \psi_{m,n}(t) dt$. The coefficients $c_{m,n}$ characterizes the projection of $x(t)$ onto the base formed by $\psi_{m,n}$.

4. PROPOSED IMAGE COMPRESSION METHOD

In this work the image is subjected to 3-level 2-D DWT and then VQ is used to different subbands for compression. For improving the compression ratio of the transmitted data these vector indices are subjected to Huffman coding as explained in [4]. Whole compression process of this work is divided into three steps, i) Codebook generation, ii) Encoding of the original image and iii) Decoding of the image. All these steps will now be discussed.

4.1 Codebook generation step

Proposed method uses a total of twenty codebooks, ten codebooks for original image reconstruction and other ten are used to reconstruct the error images. In the codebook generation step four different standard images were used to generate ten original codebooks and also ten error codebooks. In the ten original codebook generation step, each of these images are subjected to go under 3-level decomposition of DWT. These generates ten wavelet subbands for each of the original images. Similar subbands of each images were then combined to form a single image, so there were ten separate images available at this stage. Using these ten separate images, ten separate codebooks were generated using SOFM. Then in the ten error codebook generation step, using these generated ten codebooks ten subband images were reconstructed. Then these ten reconstructed images are compared with the original ten images in the wavelet domain,

the error of this comparison is taken to generate the error codebooks. In this case also SOFM was used.

4.2 Encoding process

Details of the encoding process is shown schematically in Figure 2. In this step, the test image was subjected to 3-level DWT. Then each of these available ten subbands was vector quantized using the original codebooks, here separate codebook was used for different subbands. The codebook indices of this VQ process were transmitted to the decoder after Huffman coding. Here Peak Signal to Noise Ratio (PSNR) of the transmitted image was calculated to test the image quality, if the calculated PSNR was higher or equal to the desired PSNR then the process ends, otherwise starts the progressive error correction method. In this progressive error correction method error between the original image and the reconstructed image (I.E), was calculated in the wavelet domain. These errors between the original and reconstructed image (R.I.) was again subjected to vector quantization using the available error codebooks. Error codebook indices were also transmitted to the decoder after Huffman coding. Then the reconstructed image errors (R.I.E) were added with the previously reconstructed image, and thus R.I. was modified. Then again for this modified reconstructed image PSNR is calculated. This calculated PSNR was tested with the desired PSNR again, if this PSNR was equal or greater than the desired the process ended, otherwise the process repeated calculating I.E, then R.I.E and then modify R.I. and continues until the desired image quality is achieved. There was a manual termination of the iteration process by setting the number of iteration equal to three, considering the case of infinite loop. If the image quality did not meet with in these iteration limit the process was supposed to end by force.

4.3 Decoding process

Details of the decoding process is schematically shown in Figure 3. The decoder first receives the Huffman coded bit-stream of the VQ indices corresponding to the original wavelet coefficients from the channel. It then reconstructs the codebook indices of different wavelet subbands. In the initial stage the receiver receives the reconstructed image and successively in the later steps it receives image errors. The receiver adds the received errors for each subbands. In the final step the image is reconstructed using 3-level inverse DWT.

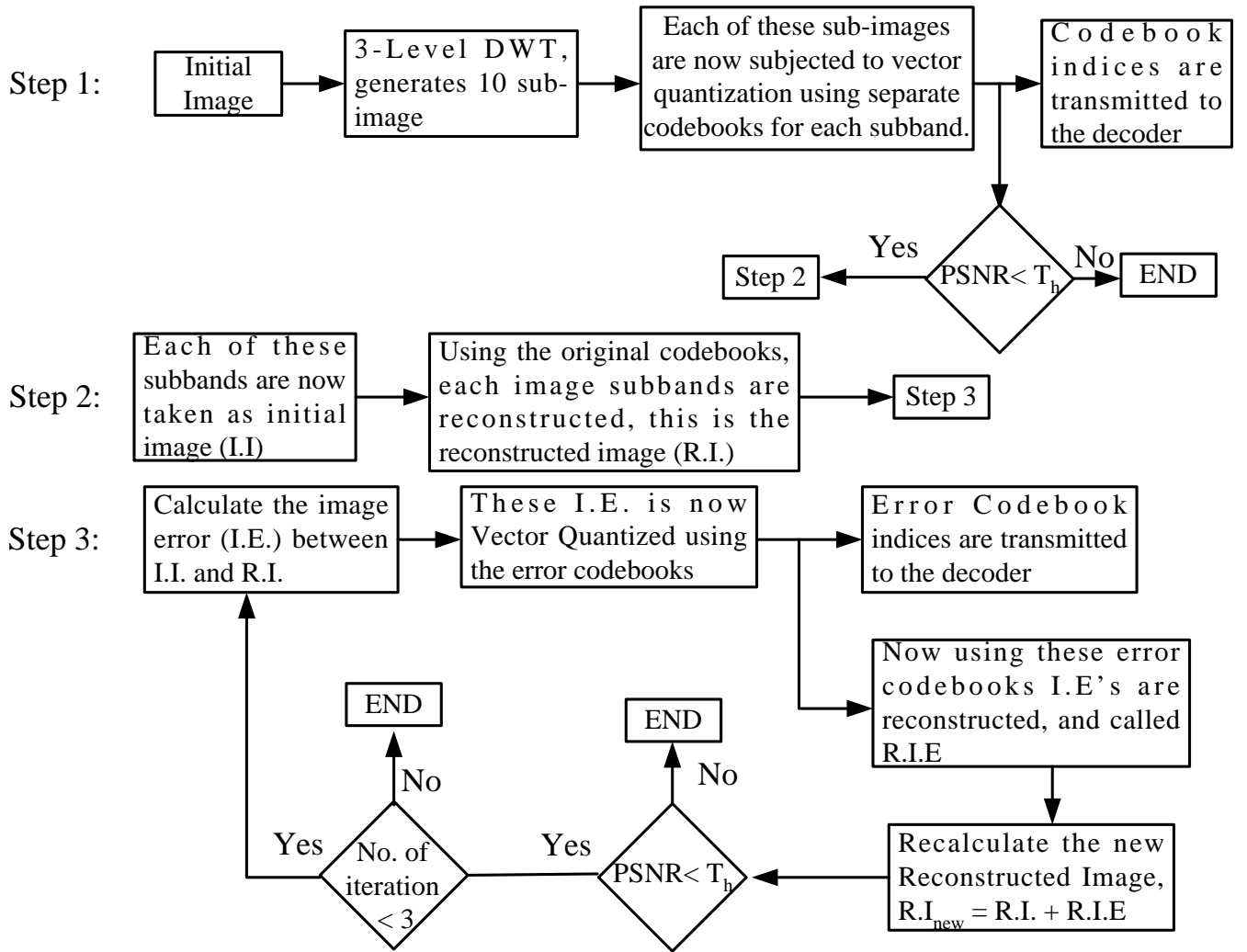


Figure 2: Detailed schematic diagram of the encoder.

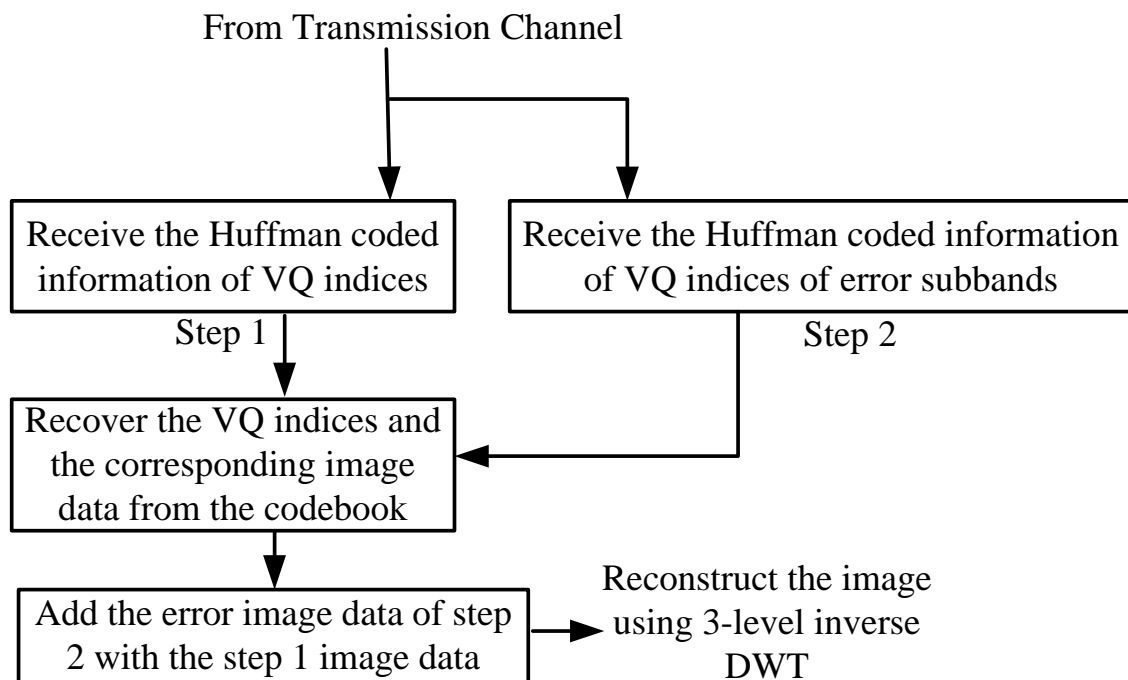


Figure 3: Steps involved in the decoding process of the proposed method.

For generating different codebooks, four images namely Lenna, Couple, Frog, Baboon, were used. In the testing phase the images namely Peppers, Boat, Plane, Woman were used. In Figure 4, some reconstructed and original images are shown. Different PSNR and compression ratios as obtained from the testing phase are listed in table-1, here compression ratios are calculated after using Huffman coding of the VQ indices. All of the experimental images were of 512x512 pixels. In this table in case of Peppers, PSNR equal to 30.7023 with a compression ratio equal to 38.94 was obtained in the original

reconstruction, then in case of 1st error loop this PSNR was increased to 35.1845 with a compression ratio equal to 22.66. As in this case Huffman coded error codebook indices are supposed to be transmitted to the decoder, so there was a decrease in the compression ratio. In case of 2nd error loop the PSNR was increased to 38.6182 with further decreased compression ratio equal to 18.439. In case of other test images are listed in the same way in table – 1. In Table-2 comparison of different experimental results of the proposed method with the methods proposed in [5], [6] and [7] is presented. It is clear from table-2 that our proposed method gives superior results.



Fig. 6d: PSNR= 38.17,
and CR = 17.52

Figure 5: Different original and experimentally reconstructed image

Image	Original reconstruction		1 st Error Loop	2 nd Error Loop
Peppers	PSNR	30.7023	35.1845	38.6182
	CR	38.94	22.66	18.439
Boat	PSNR	29.87	34.57	38.175
	CR	36.965	21.569	17.52
Plane	PSNR	28.8031	33.5962	37.3361
	CR	41.2750	24.0239	19.3073
Woman	PSNR	36.4113	43.1257	48.7521
	CR	46.9092	27.42	21.9490

Image	Proposed Method						Available Methods	
	Original reconstruction		1 st Error Loop		2 nd Error Loop		FMFSVQ [5]	
	PSNR	CR	PSNR	CR	PSNR	CR	PSNR	CR
Peppers	30.7023	38.9378	35.1845	22.66	38.618	18.429	29.70	21.739
Woman	36.4113	46.9092	43.1257	27.42	48.752	21.949	31.71	23.392

	Original reconstruction		1 st Error Loop		2 nd Error Loop		Method in [6]	
	PSNR	CR	PSNR	CR	PSNR	CR	PSNR	CR
Plane	28.8031	41.2750	33.60	24.02	37.34	19.307	35.378	16
	Original reconstruction		1 st Error Loop		2 nd Error Loop		Method in [7]	
	PSNR	CR	PSNR	CR	PSNR	CR	PSNR	CR
Boat	29.87	36.965	34.57	21.569	38.175	17.52	28.00	25.0

6. CONCLUSION

In this paper a technique of digital image compression based on multiresolution analysis using wavelet transform and vector quantization is proposed. It is seen from table – 2 that in case of the Feature Map Finite State Vector Quantization (FMFSVQ) based method as explained in [5], for the image Peppers, PSNR of 29.70 obtained at a compression ratio equal to 21.739 but in case of our proposed method it is seen that for a compression ratio equal to 22.66 PSNR was equal to 35.1845 which represents much higher quality image. Also for the same method in case of the image Woman PSNR was equal to 31.71 with a compression ratio equal to 23.392 but in case of our proposed method for a compression ratio of 27.42 the PSNR was equal to 43.1257 which represent further improvement in image quality. Again for the wavelet and VQ based image compression technique as explained in [6], for the image Plane PSNR was equal to 35.378 with a compression ratio equal to 16, but in case of our proposed method at compression ratio equal to 19.307 PSNR was equal to 37.34 which indicates better image quality. But in case of VQ and wavelet based method as explained in [7], for the image Boat we compression ratio for the same quality image, for example according to the method explained in [7] for the image Boat PSNR equal to 28.00 with a compression ratio equal to 25.0 but in case of our proposed method for the same image quality with PSNR equal to 29.87 our compression ratio was equal to 36.965 which indicate better performance in data transmission through the channel. Now we can conclude that this proposed method provides satisfactory image quality with a reasonably high compression ratio.

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