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Spiral Scan Order based Vector Quantization for Compressing Medical Test Image

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***Abstract*—** The rapid growth of technology needs massive data storage for online transmission. Medical data occupies huge space for storage which has to be reduced for effective transmission, specifically for telemedicine applications. This emphasises the need of image compression which creates extra storage space to store more data. This paper presents a novel implementation of vector quantization using spiral scan order for enhancing the quality and compression as well. The standard metrics like Peak Signal to Noise Ratio (PSNR), Structural Similarity (SSIM), Compression Ratio (CR) and Bit Rate (BR) are used to evaluate the performance of the proposed method. Experimental results demonstrate the merits of the proposed method in terms of compression metrics than other existing methods

***Keywords*—**Spiral Scan Order, Image Compression, Vector Quantization

I. INTRODUCTION

In recent days, the digital image processing is invariably applied in all fields that process digital images. Mainly, digital image processing focuses on two major tasks such as improvement of pictorial information for human interpretation and processing of image data for storage, transmission and representation for autonomous machine perception. The techniques of digital image processing has exploded and they are now used for all kinds of tasks like Image enhancement/restoration, Artistic effects , Medical visualisation, Industrial inspection, Law enforcement and Human computer interfaces. Image compression is one of the essential applications in digital image processing. Normally, when we process the image data the redundant and irrelevant information will be added which is unavoidable in image processing. The main aim of image compression is to eliminate the unwanted and noisy information from the original data [1]. At the same time, the valuable information is reconstructed using image compression without losing relevant information. Significantly in medical field, image compression plays a vital role for reducing the data storage and transmission cost.

The objective of image compression is to reduce the bit rate of image vector without compromise in image quality [2]. The process of image compression has encoding and decoding process. In encoding phase, the original image vector is converted into compressed stream with reduced bit rate [3]. In the decoding phase, the compressed stream of image blocks are reconstructed using reverse process of encoding phase. In image compression, various techniques have been used to enhance the performance of compression. Specifically, spiral scan order has a unique feature to improve the compression performance than the other scanning techniques. Compression methods can be lossy or lossless based on the quality of the reconstructed image. Generally, most of the lossy methods are block based which work by dividing the image into blocks in the same sequence as they appear in the image. Examples are BTC [4-5] Vector Quantization [6-8] and transform based methods [9-11]. In this paper, an innovative approach of creating blocks out of pixel values read out in spiral scan order is introduced and compression is achieved by applying vector quantization. Spiral order is an inspired scanning procedure for budding researchers to overcome the complexity of storage and transmission cost.

Basically, spiral scan order is a directional order scanning process. The first position of the image pixel is the starting point of spiral order which is called as a root node. Each pixel of an image has been scanned in the clock wise order. Finally, it reaches the end point of the image pixel that is called as a destination point as shown in Fig.1.

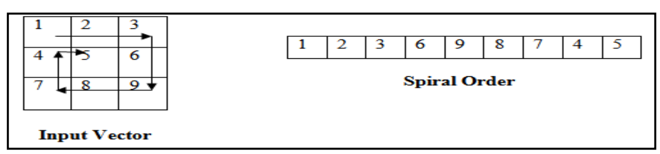


Figure 1. Spiral Scan Order

Also, the spiral order destination point is the centre point of the image vector. In reverse spiral order, the pixel is scanned in anti-clock wise direction. The root point is considered as a destination point and the destination point will be the root point of the spiral order. The main advantage of spiral scan order is that it reduces the bit rate as there is high correlation among successive pixels in this order and hence it is a best choice for voluminous data compression.

II. RELATED WORK

Several existing works have implemented the process of spiral scan order for different applications.

K.C. Tam, et al. [12] presented a spiral scan cone beam reconstruction algorithm using back projection. B.Karthikeyan, et al. [13] described a performance analysis of different scanning paths on lossless image compression for radiographic welding images. Lukasz Blaszak, et al. [14] proposed a spiral scan to replace the raster (linear) scan of macro blocks. Nasir Memon, et al. [15] presented an analysis of some common scanning techniques for lossless image coding. Ivana Pace and Francis Zarb [16] presented a comparative study for sequential and spiral scanning techniques using Brain CT. Pasumpon Pandian, A. and S.N. Sivanandam [17] proposed a hybrid algorithm for lossless image compression using simple selective scan order with bit plane slicing. Afshan Mulla et al. [18] described a comparison of different image compression techniques.

The rest of the paper is organised as follows: Section 3 describes the flow of the proposed work. The performance of the proposed method is discussed in Section 4 using Tables and Visual Representation from the outcome of the method. The merits and future enhancement of the proposed method is presented in Section 5.

III. PROPOSED METHOD

A brief description about the proposed work is presented in this section. In the first phase, the input image is read in a spiral order which is converted into a single vector. This vector is divided into non-overlapped blocks of size [nxn]. The second phase applies vector quantization to the image blocks for reducing the dimension using k-means clustering technique. The output of clustering process is the codebook and respective code indices for input blocks. The choice of size of the block and codebook depend on the desired quality. A relatively small block size and large codebook size yield high quality images but with low compression ratio. Hence the block size and codebook size should be chosen carefully so as to achieve a balance between quality and compression rate. It has been found out through our experiments that [2x2] block size and 128 codebook size yields optimal quality and compression ratio.

In the decoding process, the image is reconstructed with the code vectors of corresponding code indices and arranging them in spiral order. The novelty of this approach is the use of spiral order for creating image blocks as its merits are multi-fold. First it preserves the edge pixels by putting them in the same block. Second, the correlation among neighbouring pixels are exploited. Third, the spiral order aligns with the region of interest in medical images.

Proposed Algorithm

Encoding Process (*Phase I)*

Step 1: Initialize an input image

Step 2: Read an input image in spiral scan order

Step 3: Divide the spiral order sequence formed in Step 2 into non-overlapped blocks.

(Phase II)

Step 4: Apply Vector Quantization (VQ) to the image blocks.

Step 5: Generate the VQ codebook using k-means clustering algorithm along with the code indices.

Decoding process

Step 1: Reconstruct an image blocks using VQ codebook using its respective indices.

Step 2: Rearrange the image blocks using spiral scan order.

Step 3: Reconstruct image by rearranging the image block.

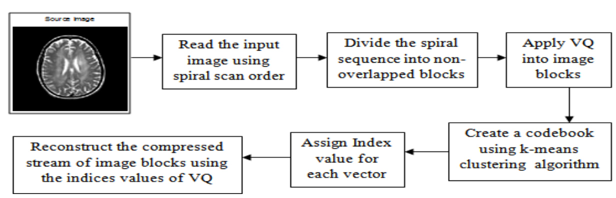


Figure 2. Encoding Process of the Proposed Method

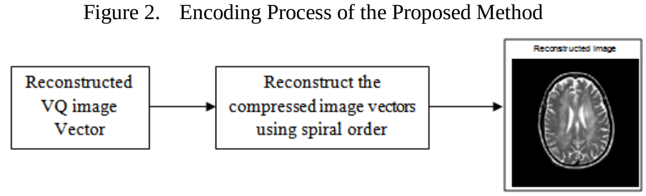


Figure 3. Decoding Process of the Proposed Method

IV. RESULTS AND DISCUSSION

The performance of the proposed method is evaluated by experimenting the results using five medical test images MRI_Brain, MRI_Knee, MRI_Spine, Mammogram Image and X-ray image. The performance is analyzed using standard compression metrics like Peak Signal to Noise Ratio (PSNR), Structural Similarity (SSIM), Compression Ratio (CR) and Bit Rate (BR) in equations (1), (2) , (3) and (4) .

Peak Signal to Noise Ratio (PSNR) is used to evaluate the quality of the compressed image.

$$PSNR = 20 \log_{10} \frac{255}{\sqrt{MSE}} \qquad .....(1)$$

Structural Similarity (SSIM) helps to measure the similarity between the original and compressed image using Eq. (2).

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \qquad ....(2)$$

Compression performance of the proposed method is measured using the Eq. (3)

$$CR = \frac{Original\ Imagesize}{Compressed\ Imagesize} \qquad ....(3)$$

Reduced bit rate of pixel in compressed image is measured using Bit per pixel (Bpp).

$$Bpp = \frac{Original\ Imagesize\ in\ Pixels}{Total\ number\ of\ bits\ in\ Compressed\ Image} \qquad ....(4)$$

Also, the computation complexity is minimized using proposed method and hence it is recommended for fast transmission applications.

Table 1. Performance Analysis of the Proposed Method

Image	Quality Metrics		Compression Efficiency		Computation Time
	PSNR	SSIM	CR	BR	
MRI_Brain	49.95	0.987	3.12	2.56	20.55
MRI_Knee	48.24	0.984	3.15	2.53	14.05
MRI_Spine	51.87	1	3.16	2.52	60.58
Mammogram	50.32	0.967	3.06	2.61	11.59
X-ray Image	50.14	0.998	3.11	2.57	9.48

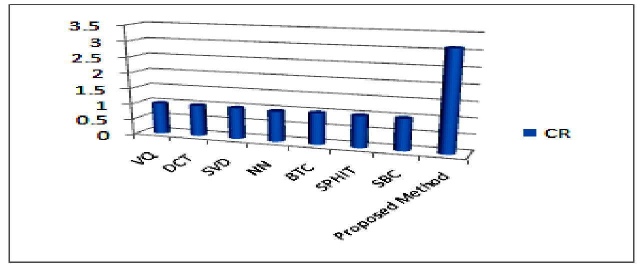
Table 1 shows the performance of the proposed method using standard compression metrics. The results of PSNR value range of (48-51) proves the efficiency of the proposed method and makes it a perfect choice for medical image compression. Spiral order reduces the bit rate of the compressed image.

Table 2. Performance Analysis of the Proposed Method

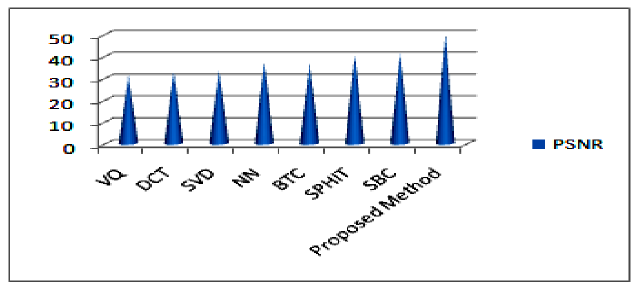
Methods	File Size	CR	MSE	PSNR
VQ	507408	0.9984	45.71	31.53
DCT	507544	0.9966	33.34	32.90
SVD	507544	0.9966	26.56	33.88
NN	507544	0.9966	12.48	37.16
BTC	507452	0.9983	11.96	37.35
SPHIT	507540	0.9982	6.11	40.26
SBC	507540	0.9982	4.75	41.35
Proposed Method	**524288**	**3.121**	**0.66**	**49.95**

In Table 2 the comparative analysis of the proposed and existing method [19] are evaluated using CR, MSE and PSNR Values. The proposed method reveals higher compression and image quality as well.

Performance of the proposed method is graphically represented in Fig. (4).



(a)



(b)

Figure 4. Graphical representation of Comparative Analysis of Proposed Method

The performance of the proposed method is visually represented in Fig.5. The quality of the compressed image shows the effectiveness of the proposed method.

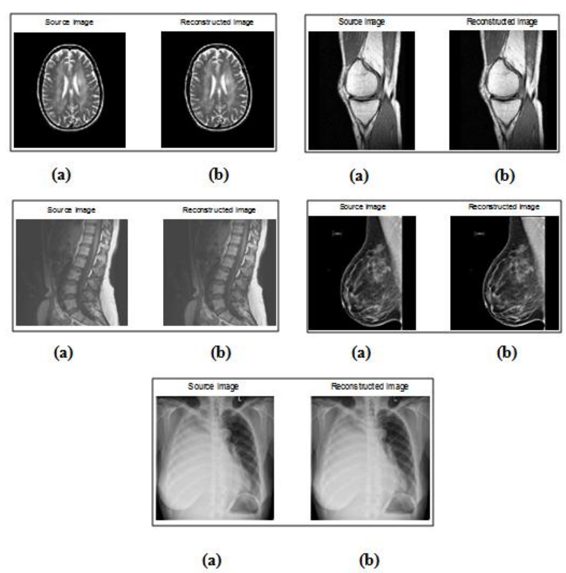


Figure 5. Visual Representation of the Proposed Method

V. CONCLUSION

This paper presents an effective spiral scan order based novel method of vector quantization for enhancing the image quality and compression performance. The proposed method achieves good compression and quality compared to existing methods. This work could be an ultimate choice for telemedicine application for transmitting the valuable medical image data in an effective manner.

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Authors Profile

Dr. M. Mary Shanthi Rani holds Ph.D in Computer Science and has more than 13 years of teaching experience .She has great passion for teaching and is currently working as Assistant Professor in the Department of Computer Science and Applications, Gandhigram Rural Institute (Deemed to be University), Gandhigram. She has nearly sixty two publications in International Journals and Conferences .Her research areas of interest are Image Compression, Information Security, Ontology, Biometrics and Computational Biology. She has served in various academic committees in designing the curriculum for B.Sc. and M.C.A courses as well. She has also served as reviewer of Peer-reviewed International Journals and Conferences. She is a Life member of Indian Society for Technical Education. She has the credit of being the Associate Project Director of UGC Indo-US 21st Knowledge Initiative Project.

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