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An Optimum Novel Technique Based on Golomb-Rice Coding for Lossless Image Compression of Digital Images

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Abstract

New innovative research trends are more essential in the area of image compression for various imaging applications. These applications require good visual quality in processing. In general the tradeoff between compression efficiency and picture quality is the most important parameter to validate the work. The existing algorithms for still image compression were developed by considering the compression efficiency parameter by giving least importance to the visual quality in processing. Hence, we proposed a novel lossless image compression algorithm which efficiently suited for various types of digital images. Thus, in this work, we specifically address the following problem that is to maintain the compression ratio for better visual quality in the reconstruction and considerable gain in the values of Peak Signal to Noise Ratio (PSNR) in two directions of research. We considered medical images , satellite extracted images and natural images for the inspection and proposed a novel procedure named as Novel Optimized Golomb Rice Coding (NOGR) to increase the visual quality of the reconstructed image. The result of the proposed technique outperforms present techniques and the results are simulated using MATLAB.

Keywords: *Lossless Image Compression, Visual quality, Golomb-Rice, JPEG-2000, JPEG-LS, PSNR*

1. Introduction

Digital images have become very common in the present societal needs, especially in the electronic industry and other applications like medical imaging, satellite imaging, multi-media applications, and high speed data internet data paths. The concept of image processing lead to the evolution of different image acquisition devices like still and video cameras, web cameras. Our work is to designate a novel technique for solving the forward as well as inverse problems in the still image compression. The solutions derived from these forward and inverse matrix computations facilitated a comprehensive meaning for the image compression for JPEG 2000 and JPEG –LS [1-3].

2. Literature Survey

JPEG 2000 still image compression standard supports both lossy and lossless compression schemes whereas JPEG-LS is a Lossless image compression scheme. The JPEG-LS uses statistical based coding techniques such as Golomb, Huffman coding and Golomb Rice (GR) coding techniques. Now-a-days most of the VLSI based companies and multi-media application oriented industries are offering the Golomb and Golomb Rice coding for their applications. Thus, it is observed from the literature survey that the necessity of optimization is an essential parameter in image compression.

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P. Sumithra *et al.*, [14] derived a compression algorithm using the GC technique. In their research work it was shown that the results were compared with existing coding techniques along with the standard EBCOT. The maximum PSNR achieved is 68 dB. The work was executed for bpp values ranging from 0.01 to 0.75 bpp. James J. Meany *et al.*, [11] derived a technique in this area. The algorithm uses split field coding to attain less complexity.

The development of different techniques for the images of various types of domains is the critical issue in the research area. Thus, we investigated and developed a lossless image compression termed as a Novel Optimized Golomb Rice (NOGR) coding technique. The reconstruction of the image resembles with the original input image at the receiving side with good visual quality.

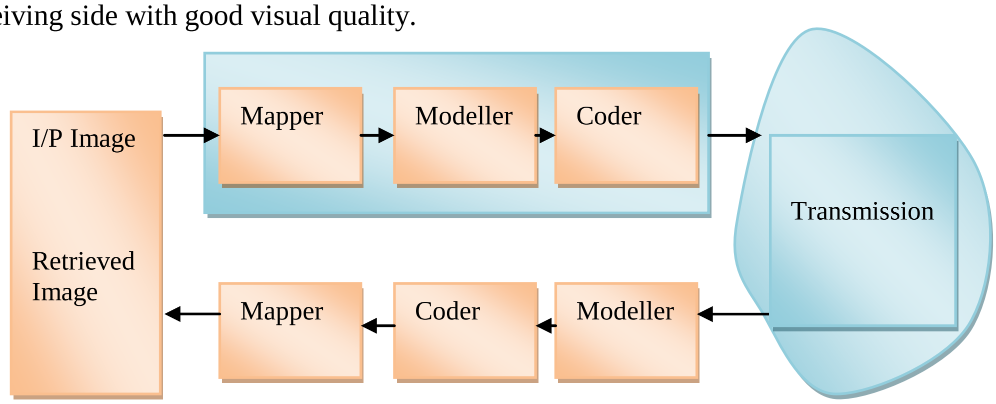

Figure 1. The Block Diagram of Lossless Image Compression

3. Brief Note on Golomb-Rice Coding

Golomb coding invented by Solomon Golomb emerged as an important tool in lossless compression. The well- known coding technique in the area of lossless image compression is Embedded Block Coding with Optimal Truncation (EBCOT). Due to its limitations regarding computation time and image sizes the Golomb-Rice coding considered as the replacement for EBCOT. After that the DCT compression using the GR coding technique proposed by Kadayam Thyagarajan becomes an interesting look towards lossless image compression. We considered DWT highly reduces the redundancy than DCT.

From the basics of the GR code, the non-negative integer of each code is to be extracted first. For the encoding process the extracted non-negative integer '*i*' and the rank '*k*' is to be considered. Then, we encoded the code word prefix that is $\lfloor i/2^k \rfloor$ using unary code. Here the suffix is $i \bmod 2^k$ using *k*- bit natural binary code [5]. The Golomb parameter, quotient and run length at zero condition are derived. The concatenation process is elevated for remainders and quotients.

4. The Concept of Proposed Optimized Technique

We developed a novel method of optimization called NOGR coding and tested on different images. GR coding was proposed with a prefix code. We here propose the Optimized Golomb Rice coding in such a manner that prefix codes are optimized with reference to the local value with in a small window. The window was constructed with the help of the concept of considering the properties of neighboring elements.

The architecture of the developed technique is shown in the block diagram shown in Figure 2. The qualitative parameters are extracted from the scalar quantization for helping in the preceding stage to zero out any artifacts emerging from the technique for high efficiency. For making the perfect decoding, steps taken such that the generated codeword is unique in representation and is reversible.

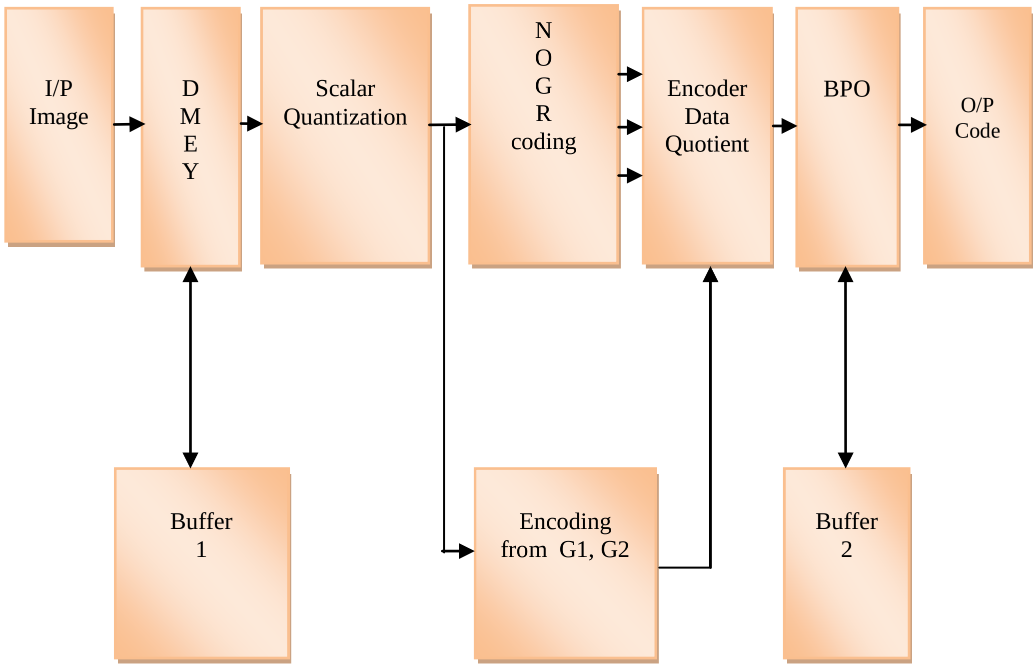

Figure 2. The Block Diagram of Proposed Technique

BPO in the figure is Bit Plane Order. The two buffers and the bit plane encoder are used to store the image for reference. The image can be extracted whenever the necessity arises. Among 8-bit and 16-bit, the 8-bit was selected for our applications. The output of the encoder used for the decoding process is as usual same in the reconstruction process. The generated alphabet is stored and transmitted to the receiving section for the decoding process without any interruption. In many of the real time application images, the low frequency components consist of more information.

5. Flow Chart OF Nogr Coding

We investigated here the optimization techniques for a good reversible DWT decomposed image through the proposed technique. Various types of images were selected for simulation to measure the performance levels of the technique. The input image is grouped in blocks of 4*4 pixels to minimize the computational complexity [12]. The quotient and remainder values are preserved from each encode step.

By selecting the optimum compression technique, the flexibility was achieved for the requirement of various specified applications in the work. The Discrete Wavelet Transform (DWT) family embedded is Bi-orthogonal 3/5. This Bi-orthogonal 3/5 helps in the perfect reversible process [6]. The filter taps are having 3 and 5 filter coefficients for LPF and HPF designs respectively. [12, 13].

The Discrete Meyer (DMEY) wavelet efficiently worked [13] and gives better results with NOGR. The compression and reconstruction results are studied and evaluation done to show the comparative better performance with existing methods. Due to its reversible nature, the DMEY embedded in the developed algorithm. We selected level-2 as it gives a better approximation of the original image.

The flow chart of the proposed technique is shown in Figure 3. The frequency response diagram of DMEY is shown in Figure 4.

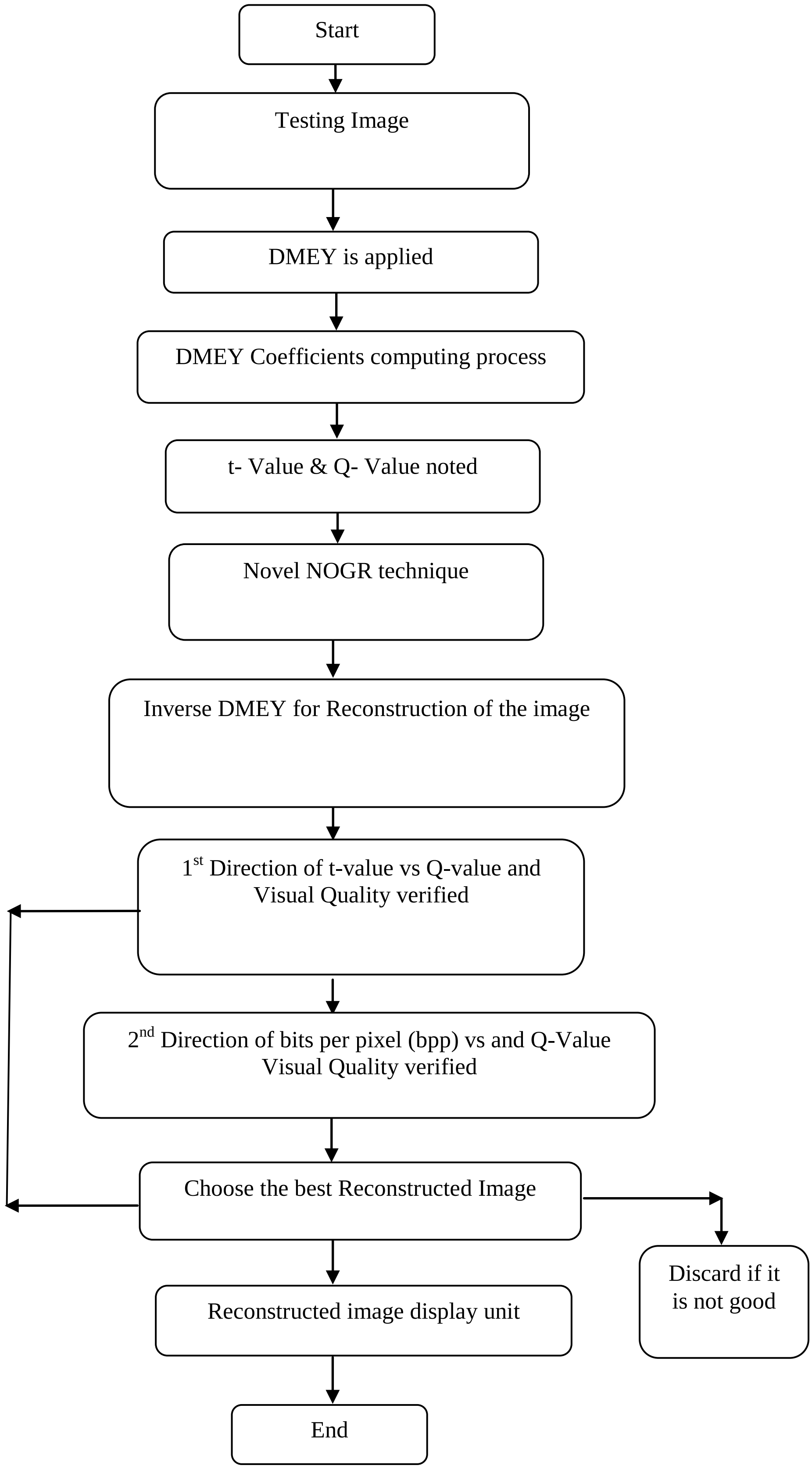

Figure 3. The Flow Chart of the Proposed Coding

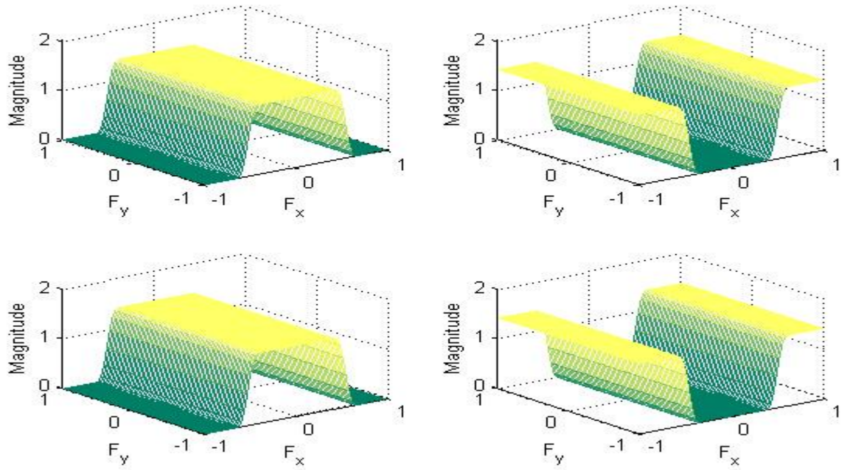

Figure 4. The Frequency Response diagram of DMEY Wavelet

6. Scalar Quantization

Among the two quantization techniques, the scalar Quantization is essential for arranging the DWT coefficients in the prescribed set of amplitude levels. In general either uniform or non uniform quantization can be performed [12]. But the preferable is non-uniform for lossy compression techniques because of its nature of variation from one static sub-band image to another. The static image is then reconstructed using the general decompression process with level-2 and the reconstructed image was displayed for performance measure.

7. NOGR Coding Procedure

The procedure of developed NOGR coding is explained in the following section.

Step 1: The parameter has to be fixed to non integer value.
Step 2: Generating of the code word by encoder.
Step 3: Select Unary coding for Quotient and Truncated Binary encoding for the Remainder as per GR procedure.
Step 4: For GR code $\log_2(M)$ bits are necessary and they can be loaded.
Step 5: Bit Reversal order of given data is applied.
Step 6: Rearrange the new data into two groups G1 and G2.
Step 7: Flip the G1 bits and transmit after the conversion in to Gray code.
Step 8: Flip the G2 bits and transmit after the conversion in to Gray code.
Step 9: For different t-values ranging from 1 to7 considered for Q-values from 4 to 34 Checked.
Step 10: Quality of the image with respect to PSNR checked and considered for Processing.
Step 11: For different bits per pixel (bpp) values ranging from 0.01to 0.8 were considered and PSNR values are estimated at Q=0 and Q=34
Step 12: Quality of the image with respect to PSNR checked and considered for Processing.
Step 13: Then the data sent through the selected transmitting medium.
Step 14: End.

We proposed the NOGR coding and implemented in two directions of research in lossless image compression. The first direction is to that the processed image should be with good visual quality. The reason is the main objective of research is to suit the algorithm for all types of compression related applications. For this, the efficiency of the algorithm is tested by increasing the threshold value or integer value (*t*-value) and the quality factor or quantization value (*Q*) values in the coding scheme. The observations clearly showed that the data bits are increased as per variations of *t* and *Q* values. The threshold value has an influence on the preceding coding. At the *Q* value of 34 the quality of the processed image was observed for fine quality [12]. At the same time, PSNR values are comparatively higher than the existing methods. At the value of *Q*= 34 the result estimated the higher PSNR value and good quality in the image. Thus the data transfer of the compression process is good enough. The corresponding values of different images are tabulated in Tables 1, 2 and 3.

The second direction of research is to perform the proposed algorithm by considering the relationship between the *Q*- value and PSNR values. Thus, the developed algorithms compared with the present valuable contributions mentioned in the references [8] and [14]. Simulated graphs are incorporated in the preceding section.

We considered image pixels of 8 bit. The quantized version of the DWT transformed coefficients especially LL band and the quotient, the remainder derived from the GR coding were taken as inputs for NOGR algorithm. The proposed algorithm begins with a bit reversal of all transformed pixel values. Then the encoded data bits are made into two groups namely G1 and G2. At first, G2 bits are inverted [12]. After that the inverted G2 bits are encoded using gray code to allow data bits to transmit *i.e.*, the output bits are allowed to any channel for transmission. The condition considered is that the DWT level-2 is applied for the image to decompose it into sub-bands. Bi-orthogonal 3/5 implemented for the perfect reversible process and suited for the medical, satellite and natural images.

8. Simulation Results

The NOGR technique was tested on different image sizes and the results are incorporated in the Tables 1 to 6.

The general formula for calculating the PSNR is stated below. The performance of the algorithm estimated with respect to PSNR value and Visual quality.

$$PSNR = 20\log 10\left(255 \Big/ \sqrt{MSE} \right)$$

The description of the Aerial image processing is follows.

We applied the NOGR algorithm on the aerial image extracted from the gallery of satellite images. The DMEY decomposes the image to the second level using reversible wavelet family and the DMEY coefficient version of the image is given as inputs to the proposed algorithm. The compressed image and the decompressed image are shown in the Figure 6. It is observed that the reconstructed image is near the appearance of the original image. Thus, the objective of research work is achieved.

Figure 5. The Original, Compressed and Decompressed Images of Aerial

Figure 6. The Original, Compressed and Decompressed Images Baboon

Figure 7. The Original, Compressed and Decompressed Images of Head

Table 1. The Results of the Developed Algorithm and Existing Techniques (Lena)

Image (Lena)			
t-value	Existing	Q-Value	Developed
	PSNR in dB		PSNR in dB
1	16..89	4	18.98
2	29.18	8	31.09
3	28.92	12	32.85
4	36.92	19	39.16
5	43.39	21	47.06
6	52.41	24	56.12
7	68.31	25	70.46
8	69.35	34	72.56

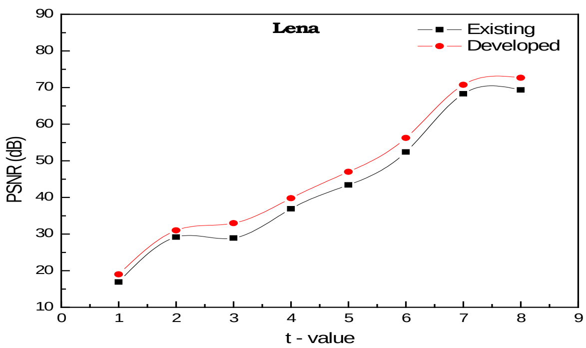

Figure 8. The Comparative Graph between the Existing and Developed Techniques (Lena)

Now, the resulting images are studied and viewed at different values of *Q*.

Q =4, the image with better compression ratio and poor [13].
Q = 12, image quality is better than 4 but reduction in compression ratio.

Finally, at *Q* = 34, the PSNR value reaches highest and the good visual image noticed. Thus, the aim of the work is achieved.

Table 2. The Results of the Developed Algorithm and Existing Techniques (Aerial)

Aerial Image			
t-value	Existing PSNR in dB	Q-Value	Developed PSNR in dB
1	18.66	4	20.44
2	21.86	8	23.77
3	22.90	12	24.45
4	34.52	19	36.67
5	39.88	21	41.64
6	46.98	24	48.92
7	65.44	25	67.40
8	67.66	34	69.66

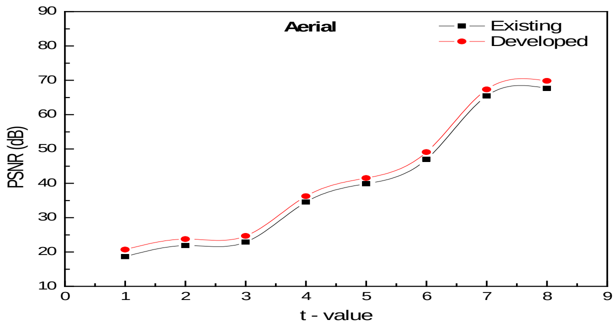

Figure 9. The Comparative Graph between the Existing and Developed Techniques (Aerial)

Table 3. The Results of the Developed Algorithm and Existing Techniques

Baboon			
t-value	Existing PSNR in dB	Q-Value	Developed PSNR in dB
1	18.45	4	20.40
2	21.34	8	23.48
3	23.01	12	24.46
4	33.67	19	36.46
5	40.45	21	42.56
6	46.98	24	48.84
7	65.72	25	68.80
8	66.98	34	71.68

The *Q*- value range even in this case is also considered as 4 to 34 which in turn affect the compression ratio. Similarly, [12] it is noticed that in all the cases at the *Q* value of 34 the image appeared in good quality with better compression ratio. The key observation is that the derived PSNR values shown slight variations depending upon the chosen images.

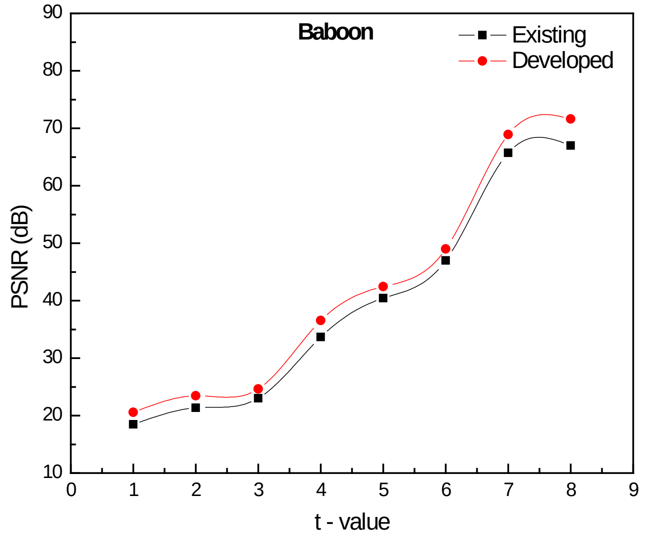

Figure 10. The comparative Graph between the Existing and Developed techniques (Baboon)

The derived values are incorporated in the Tables 4, 5 and 6 and the corresponding graphs are shown in Figures 12, 13 and 14.

Table 4. Performance Comparison Results with Existing Techniques (Chest)

bits per pixel (bpp)	PSNR in dB at Q=0				PSNR in dB at Q=34			
	EBCOT	Ref [8]	Ref [14]	Our NOGR Algorithm	EBCOT	Ref [8]	Ref [14]	Our NOGR Algorithm
0.01	28.14	28.14	29.09	31.18	28.32	28.32	28.92	32.85
0.2	35.68	35.68	36.13	38.04	36.10	36.10	36.92	39.16
0.4	42.8	42.8	43.72	45.16	43.22	43.22	43.39	47.06
0.6	52.06	52.06	52.95	54.08	52.06	52.06	52.41	56.12
0.75	67.71	67.71	67.91	69.24	67.71	67.71	68.31	70.46
0.8	68.56	68.56	69.71	71.56	68.68	68.68	69.35	72.56

Table 5. Performance Comparison Results with Existing Techniques (Peppers)

bits per pixel (bpp)	PSNR in dB at Q=0				PSNR in dB at Q=34			
	EBCOT	Ref [8]	Ref [14]	Our NOGR Algorithm	EBCOT	Ref [8]	Ref [14]	Our NOGR Algorithm
0.01	20.9	20.9	21.83	23.16	21.04	21.04	22.03	24.18
0.2	31.2	31.2	32.13	34.58	31.66	31.66	32.65	36.52
0.4	38.02	38.02	38.97	40.67	39.63	39.63	40.62	42.68
0.6	46.2	46.2	47.13	49.02	47.3	47.3	48.29	49.98
0.75	63.87	63.87	64.85	67.01	63.87	63.87	64.21	69.64
0.8	64.78	64.78	66.21	69.78	64.67	64.67	65.54	70.54

Figure 11. The Original, Compressed and Decompressed Images of Jupiter

Table 6. Performance Comparison Results with Existing Techniques (Jupiter)

bits per pixel (bpp)	PSNR in dB at Q=0				PSNR in dB at Q=34			
	EBCOT	Ref [8]	Ref [14]	Our NOGR Algorithm	EBCOT	Ref [8]	Ref [14]	Our NOGR Algorithm
0.01	19.48	19.48	20.4	21.87	19.53	19.53	20.46	23.04
0.2	26.26	26.26	27.21	28.48	26.86	26.86	27.79	30.06
0.4	32.96	32.96	33.95	36.01	35.52	35.52	36.47	38.14
0.6	41.45	41.45	42.44	44.56	43.85	43.85	44.81	46.86
0.75	48.89	48.89	49.88	51.78	50.39	50.39	51.38	53.98
0.8	50.64	50.64	52.06	54.04	51.32	51.32	52.04	56.16

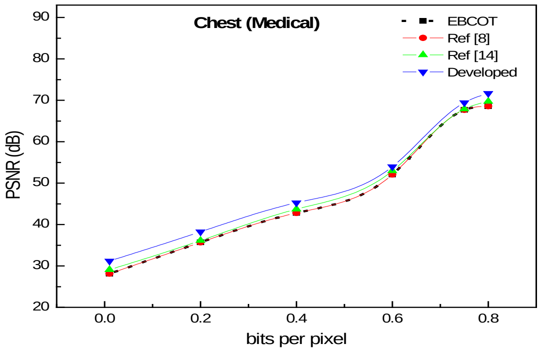

Figure 12. Comparison of Developed versus Existing Techniques (Chest)

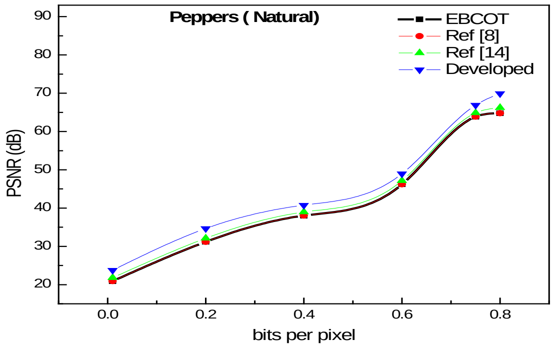

Figure 13. Comparison of Developed versus Existing Techniques (Peppers)

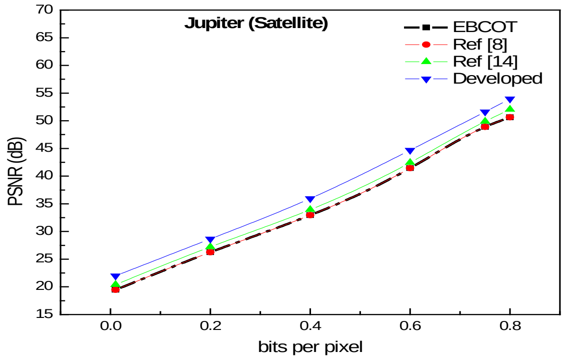

Figure 14. Comparison of Developed versus Existing Techniques (Jupiter)

9. Conclusion

The developed novel technique for the lossless image compression technique investigated the bottlenecks of the existing algorithms. The visual quality after reconstruction is good by maintaining the compression efficiency high when compared with existing methods. The PSNR parameter in the compression highlighted thus resulting good processed images. The proposed algorithm implemented on different images such as medical images, satellite images and natural images like Lena for the high visual quality. This Novel technique worked efficiently for large images also to reduce the complexity in processing. The proposed algorithm can be validated on VLSI implementation. This algorithm gives wide scope for further research in the area of lossless image compression particularly in medical imaging applications.

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