Modified LOG-EXP Based Image Compression Algorithm

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Summary
It is known that LOG – EXP transform based image compression algorithm proposed by S.C.Huang, L.G.Chen and H.C.Chang offers high Compression Ratio (CR) and high image quality compared to JPEG for any specified value of Peak-Signal to Noise Ratio (PSNR). In this paper, a modified LOG – EXP transform based image compression algorithm obtained by using arithmetic coding in the place of Huffman coding is proposed to reduce the computation time of the original LOG – EXP transform based algorithm. The proposed algorithm is found to be several times faster. It possesses almost the same CR and image quality as that of the algorithm of S.C.Huang, et.al. Also, FPGA implementation of the proposed algorithm is carried out on Xilinx Spartan 3E platform. The clock speed of the architecture has been found to be 96 MHz and the percentage resource utilization is 52%.
Key words:
Image Compression, LOG-EXP Transform, Snakescan, Repeat Reduction, Arithmetic Coding

1. Introduction

Since the last decade, there is an enormous amount of multimedia communication in integrated data services such as Internet, Mobile multimedia, data sensing in sensor networks, videoconferencing, facsimile transmission, document and medical imaging using voice, text, image and video [1]. In image communication, images are compressed and transmitted. Image compression is necessary for one or more reasons such as reduction of storage space, reduction of transmission time and bandwidth constraint. The important requirements of any compression technique are high CR, high quality and high speed [1].

The JPEG still image compression standard [2] satisfies these basic requirements and is widely used in many multimedia applications. The main drawbacks of JPEG are block artifacts and low throughput [1],[3]. To overcome the above drawbacks in JPEG, S.C.Huang, L.G.Chen and H.C.Chang [1] proposed a LOG-EXP based still image compression algorithm. The speed of this algorithm is limited because of the presence of Huffman coding block.

In this paper, two modifications are carried out in the algorithm of [1] to reduce the compression time without sacrificing CR and image quality. The proposed algorithm is compared with that of [1] in terms of computation time and CR for different values of PSNR, by considering three images namely, Lena, Pepper and Mandrill, each of size 512 x 512. It is found from MATLAB implementations that the proposed algorithm requires lesser computation time on the average by a factor of 10, compared to that of [1].

In Section 2, the proposed algorithm is explained. In Section 3, the performance evaluation of the proposed algorithm is presented. In Section 4, results obtained using FPGA implementation of the proposed algorithm is discussed. The paper concludes in Section 5.

2. Proposed Algorithm

Fig.1. shows the block diagram of the proposed compression and decompression system which is a modification of the algorithm of [1]. Two modifications are introduced in the proposed scheme as compared to the algorithm of [1], namely, the level shifting of image data by 256 and usage of arithmetic coding in place of Huffman coding. The steps in the proposed algorithm are as follows:

1. Pixels are scanned using snakescan of [1].
2. Each pixel is level shifted by adding a value equal to 256.
3. Logarithm based on $\log_2$ is computed for each level shifted pixel to get log transformed image. The addition of 256 to each pixel causes log values of all the pixels to have a value 8 $(1000)_2$ in the integer portion which need not be explicitly stored for processing. This is in contrast to the algorithm of [1] where the integer part of the log values of the pixels varies between 0 and 7 which needs to be considered for processing. In this paper, only the fractional part is considered for processing. The fractional part of the log values are truncated to 3 decimal digits.
4. Repeat reduction block outputs are of the form (x_i, y_i, p_i) where x_i is the log value of the pixel, y_i is the number of continuous occurrences of x_i and p_i is the probability of occurrence of the pattern (x_i, y_i) in the entire image.

Manuscript received September 5, 2008.
Manuscript revised September 20, 2008.

5. A codebook with index is created where each entry consists of (x_i, y_i, p_i). The maximum number of entries in the codebook is 256.

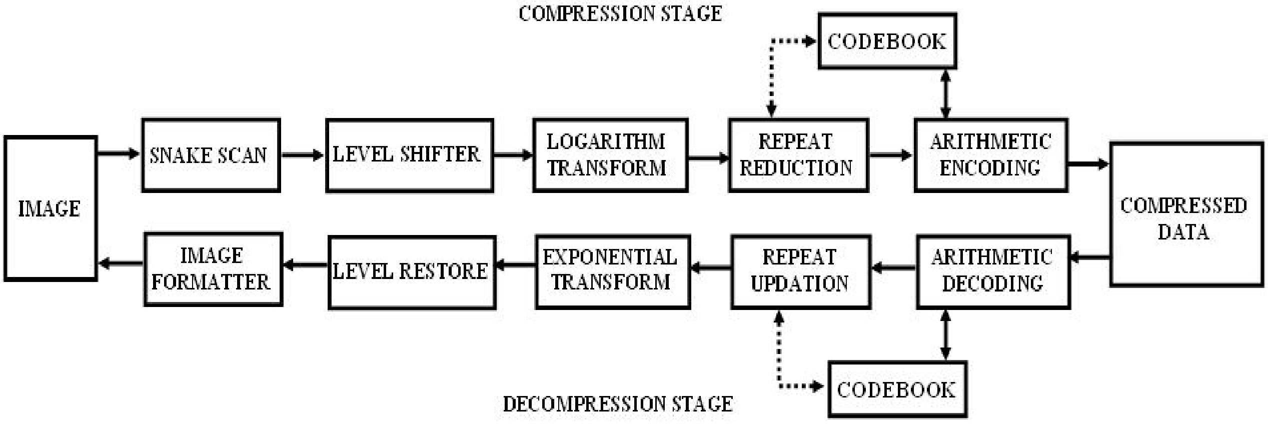


Fig. 1 Proposed LOG-EXP Image Compression – Decompression System.

6. An x_i value occurring y_i times consecutively in log transformed image of step 3 is replaced by the corresponding codebook index.
7. These index values are then arithmetic coded [4], [5] by considering 8 indices per message using the probability information, p_i, in the codebook.

Reverse procedure is used to reconstruct the image pixels. The quality of the reconstructed image is controlled by the choice of number of decimal digits in the fractional part of the log values.

3. Performance Evaluation

For the purpose of comparison, three grayscale images, namely, Lena, Pepper and Mandrill shown in Figs. 2(a), 3(a) and 4(a) respectively, are considered. Each image is of size 512 x 512 with 8 bit resolution. The MATLAB simulation of the proposed algorithm was performed on an Intel Pentium 4 Processor PC operating at 3.2 GHz, running Windows XP Professional and having 1 GB RAM.

The performance of the proposed algorithm is compared with that of algorithm of [1] and JPEG standard [2] on the basis of PSNR, CR, subjective quality and execution time. The results for JPEG standard are obtained using Adobe Photoshop.

Tables 1, 2 and 3 show the values of PSNR, CR and execution times of the algorithm of [1] and the proposed algorithm for Lena, Pepper and Mandrill images respectively.

Table 4 shows the values of PSNR and CR obtained using JPEG in Adobe Photoshop for Lena, Pepper and Mandrill images for similar PSNR values as in Tables 1, 2 and 3.

Table 1: Results for Lena Image

PSNR (dB)	Algorithm of [1]		Proposed Algorithm	
	CR	Execution Time (s)	CR	Execution Time (s)
29.89	14.77	180.51	14.85	18.20
42.36	8.95	312.23	9.01	29.67
50.68	6.52	592.12	6.54	39.88
62.19	5.95	692.62	5.96	43.64

Table 2: Results for Pepper Image

PSNR (dB)	Algorithm of [1]		Proposed Algorithm	
	CR	Execution Time (s)	CR	Execution Time (s)
29.71	13.78	237.34	13.86	19.33
42.31	8.44	386.36	8.47	31.67
50.95	6.24	735.97	6.26	41.81
61.91	5.77	825.08	5.79	44.69

Table 3: Results for Mandrill Image

PSNR (dB)	Algorithm of [1]		Proposed Algorithm	
	CR	Execution Time (s)	CR	Execution Time (s)
29.65	12.37	220.29	12.43	2.04
42.30	8.38	392.17	8.42	31.99
50.93	6.47	766.44	6.49	40.76
63.55	5.91	847.29	5.93	43.80

Table 4: JPEG Results

	PSNR (dB)	CR
Lena	42.67	4.39
	49.54	2.07
	56.42	1.64
Pepper	42.19	3.31
	48.93	1.90
	56.40	1.56
Mandrill	43.83	2.99
	52.76	1.73
	58.19	1.47

From the Tables 1, 2 and 3, it can be seen that the proposed algorithm is quite faster compared to that of algorithm of [1] for same PSNR values. Also, it can be seen from these Tables that the CR values obtained using the proposed algorithm are almost the same as those of algorithm of [1]. Also, it can be seen from the Tables 1 to 4 that the CR values obtained using the proposed algorithm and the algorithm of [1] are far better than those obtained using JPEG standard.

Figures 2(b) – 2(d), 3(b) – 3(d) and 4(b) – 4(d) show the reconstructed images obtained using the JPEG algorithm [2] for Lena, Pepper and Mandrill images respectively. Figures 2(e) – 2(h), 3(e) – 3(h) and 4(e) – 4(h) show the reconstructed images obtained using the original LOG – EXP algorithm [1] for Lena, Pepper and Mandrill images respectively. Figures 2(i) – 2(l), 3(i) – 3(l) and 4(i) – 4(l) show the reconstructed images obtained using the proposed LOG – EXP algorithm for Lena, Pepper and Mandrill images respectively.

Fig. 2(a) Original 512 x 512 Lena Image.

Fig. 3(a) Original 512 x 512 Pepper Image.

Fig. 4(a) Original 512 x 512 Mandrill Image.

PSNR = 42.67 dB,
CR = 4.39
Fig. 2(b)

PSNR = 49.54 dB,
CR = 2.07
Fig. 2(c)

PSNR = 56.42 dB, CR = 1.64
Fig. 2(d)

Fig. 2(b) – 2(d) Reconstructed 512 x 512 Lena Image using JPEG Algorithm.

PSNR = 29.89 dB,
CR = 14.77
Fig. 2(e)

PSNR = 42.36 dB,
CR = 8.95
Fig. 2(f)

PSNR = 50.68 dB,
CR = 6.52
Fig. 2(g)

PSNR = 62.19 dB,
CR = 5.95
Fig. 2(h)

Fig. 2(e) – 2(h) Reconstructed 512 x 512 Lena Image using Original LOG-EXP Algorithm.

PSNR = 29.89 dB,
CR = 14.85
Fig. 2(i)

PSNR = 42.36 dB,
CR = 9.01
Fig. 2(j)

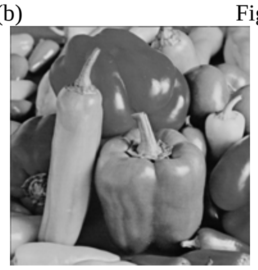
PSNR = 50.68 dB,
CR = 6.54
Fig. 2(k)

PSNR = 62.19 dB,
CR = 5.96
Fig. 2(l)

Fig. 2(i) – 2(l) Reconstructed 512 x 512 Lena Image using Proposed LOG-EXP Algorithm.

PSNR = 42.19 dB,
CR = 3.31
Fig. 3(b)

PSNR = 48.93 dB,
CR = 1.90
Fig. 3(c)

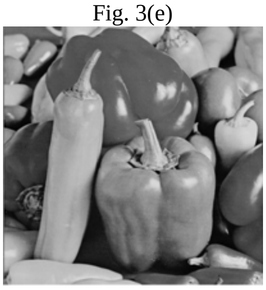


PSNR = 56.40 dB, CR = 1.56
Fig. 3(d)

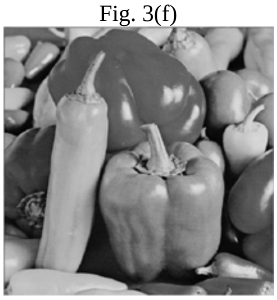
Fig. 3(b) – 3(d) Reconstructed 512 x 512 Pepper Image using JPEG Algorithm.

PSNR = 29.71 dB, CR = 13.78
Fig. 3(e)

PSNR = 42.31 dB, CR = 8.44
Fig. 3(f)



PSNR = 50.95 dB, CR = 6.24
Fig. 3(g)

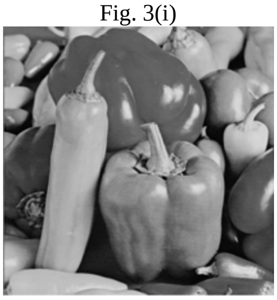


PSNR = 61.91 dB, CR = 5.77
Fig. 3(h)

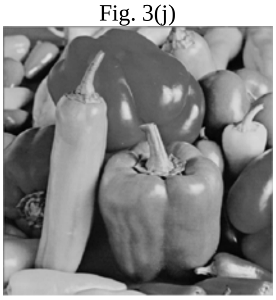
Fig. 3(e) – 3(h) Reconstructed 512 x 512 Pepper Image using Original LOG-EXP Algorithm.

PSNR = 29.71 dB,
CR = 13.86
Fig. 3(i)

PSNR = 42.31 dB,
CR = 8.47
Fig. 3(j)



PSNR = 50.95 dB,
CR = 6.26
Fig. 3(k)

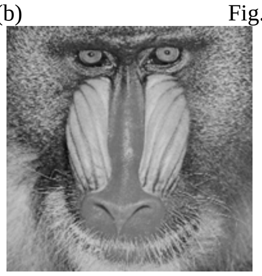


PSNR = 61.91 dB,
CR = 5.79
Fig. 3(l)

Fig. 3(i) – 3(l) Reconstructed 512 x 512 Pepper Image using Proposed LOG-EXP Algorithm.

PSNR = 43.83 dB,
CR = 2.99
Fig. 4(b)

PSNR = 52.76 dB,
CR = 1.73
Fig. 4(c)

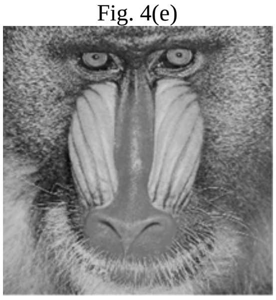


PSNR = 58.19 dB, CR = 1.47
Fig. 4(d)

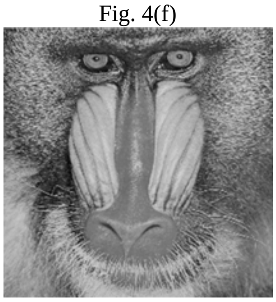
Fig. 4(b) – 4(d) Reconstructed 512 x 512 Mandrill Image using JPEG Algorithm.

PSNR = 29.65 dB,
CR = 12.37
Fig. 4(e)

PSNR = 42.30 dB,
CR = 8.38
Fig. 4(f)



PSNR = 50.93 dB,
CR = 6.47
Fig. 4(g)

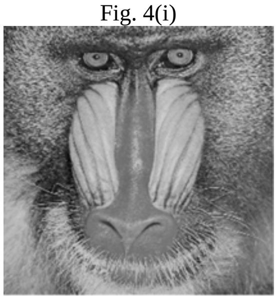


PSNR = 63.55 dB,
CR = 5.91
Fig. 4(h)

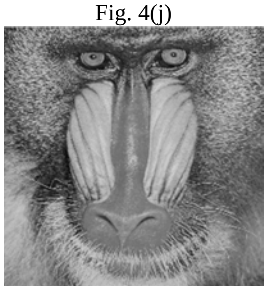
Fig. 4(e) – 4(h) Reconstructed 512 x 512 Mandrill Image using Original LOG-EXP Algorithm.

PSNR = 29.65 dB,
CR = 12.43
Fig. 4(i)

PSNR = 42.30 dB,
CR = 8.42
Fig. 4(j)



PSNR = 50.93 dB,
CR = 6.49
Fig. 4(k)



PSNR = 63.55 dB,
CR = 5.93
Fig. 4(l)

Fig. 4(i) – 4(l) Reconstructed 512 x 512 Mandrill Image using Proposed LOG-EXP Algorithm.

From these figures, it can be seen that the subjective quality of the reconstructed images is same as those obtained using the original LOG – EXP algorithm.

4. FPGA Implementation

The proposed algorithm is implemented on Xilinx Spartan 3E FPGA and the synthesis report is as shown in Table 5.

Table 5: FPGA Synthesis Report

Parameter	Value
Selected Device	3S250EPQ208-5
No. of Slices (out of 2448)	985 (40 %)
No. of 4 I/P LUTs (out of 4896)	2545 (52 %)
No. of bonded I/Os (out of 158)	45 (29 %)
Clock Speed	96 MHz

A modified LOG-EXP based algorithm is proposed in this paper. The advantage of the proposed algorithm is that the computation time is about 10 times smaller than that of the original algorithm. The CR achieved with the proposed algorithm is slightly greater than that of algorithm of [1] for any given PSNR value. Also, the subjective quality of the reconstructed images obtained using the proposed algorithm is the same as that obtained using the algorithm of [1]. The proposed algorithm is implemented on Xilinx Spartan 3E 250K FPGA. The architecture can be operated with a clock speed of 96 MHz with a resource utilization of 52%.

5. Conclusion

LOG-EXP based image compression technique known to yield reconstructed images with better subjective quality than that obtained using JPEG standard is modified in this paper by using arithmetic coding in place of Huffman coding. It is found that this improves the speed of execution of the LOG-EXP based image compression algorithm without altering the PSNR, CR and subjective quality characteristics of the original LOG-EXP based image compression algorithm of [1]. The proposed algorithm implemented on Xilinx Spartan 3E 250K FPGA can be operated with a clock speed of 96 MHz. The resource utilization is found to be 52%.

Acknowledgment

This work was supported by CSIR (Council for Scientific and Industrial Research), Government of India, under Senior Research Fellowship (SRF).

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