Image Reconstruction using Fast Inverse Half tone and Huffman Coding Technique

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ABSTRACT
Transmission of audio-video data over internet applications like Multimedia is increasing with fast pace. Biometric, Content Based Image Retrieval (CBIR), CCTV footage applications require huge storage of images in database. For such applications this combination of half tone with Huffman coding is useful. Half toning is lossy technique used in printing industry where binary image is required. Objective of achieving higher Compression Ratio by combining lossy half tone and lossless Modified Huffman coding techniques is used. Apart from standard operator like Floyd-Steinberg and Jarvis operators, Small and South-East operator are used. Halftone and Huffman coding technique is implemented on 10 different color images of size 512x512. For measurement of image quality, Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR) and Structure Similarity Index (SSIM) are used. This hybrid technique can use for low bit rate video data transmission and mass image storage.

Keywords
Halftone, error diffusion, gradient estimation, concatenation, Structure Similarity Index (SSIM), Huffman coding

1. INTRODUCTION
For reconstruction of image Fast Inverse half toning algorithm is used [1], [2], [3] and [4]. For reconstruction of image, many iterations are required that increases computational complexity and memory space [2], [3] and [4]. In this paper, Fast Inverse half toning algorithm in which 7X7 matrix is used as multi-scale gradient estimation for edge detection while other technique requires heavy use of floating point operations. This algorithm takes single pass along both the axes for filtration instead of multiple iterations. In this algorithm, most of the processes require integer additions and seven rows are kept in memory at a time. After half toning process quantization process is applied to get binary image in which error diffusion introduces noise. Reconstruction of image from such half tone image without loss is impossible. Inverse image is blurred image because of Finite Impulse Response (FIR) Low pass Filter. Halftone technique is used in printing media where image is in binary form. Halftone technique converts continuous tone image into half tone image. Floyd-Steinberg and Jarvis half toning operators preserve the artifacts in the image [3], [5]. Various halftone operators are explained in [5] and [6]. For further compression of image data, lossless Run Length Encoding [7], Huffman coding technique with different approaches is used in paper [8] to [12**].**

In this paper, section 2 is the implementation of Halftone and Huffman coding Algorithm. Section 3 gives the implementation of Fast Inverse Half toning algorithm. In section 4 introduces Structure Similarity Index (SSIM), the measuring parameter for quality measurement between reconstructed and original image. Section 5 gives the discussion about various half toning operators and significance of measuring parameters. Section 6 shows the experimental results in the form of images and measuring parameters like Mean Square Error (MSE), SSIM and Peak Signal-to-Noise Ratio (PSNR) are given in Table-1. Same section gives parameter comparison in graphical format and brief discussion about the same. Conclusion and future scope of the paper is explained in section 7. Section 8 is the paper references. This is the extension of paper [1] in which reconstruction of image using Fast Inverse Half toning algorithm is explained.

2. HALF TONE AND HUFFMAN CODING

0	**0**	**0**
0	**X**	**1**
0	**1**	**3**

Fig 1.a): Small Operator

0	**0**	**0**
0	**X**	**7**
3	**5**	**1**

Fig 1.b): Floyd-Steinberg Operator

0	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**
0	**0**	**X**	**7**	**5**
3	**5**	**7**	**5**	**3**
1	**3**	**5**	**3**	**1**

Fig 1.c): Jarvis Operator

0	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**
0	**0**	**X**	**1**	**9**
23	**7**	**5**	**3**	**11**
21	**19**	**17**	**15**	**13**

Fig 1. d): South-East Operator

Each plane of continuous tone image is having 0 to 255 gray levels. This entire range is converted into binary values i.e. 0 and 1, hence this is lossy technique. Huffman coding has unique codes, from which image can be decoded without loss.

Fig1. a) - fig1. d) Shows different half toning operators. These operators are used and obtained satisfactory experimental results. **X** shown in all operators is the central pixel. The half toning operator is convolved with the original image and quantization process is applied so as to get half tone single bit image [1], [7]. Floyd-Steinberg and Jarvis half toning are the standard operators and the Small and South-East operator are presented in paper [7]. During neighborhood processing Small, Floyd-Steinberg, Jarvis and South-East half toning operators require 3 tap, 4 tap, 12 tap and 12 tap effectively 1 tap, 3 tap, 10 tap and 11 tap operation respectively. Half toning process converts 8-bit gray scale image into 1-bit image and gives 8:1 compression ratio, hence it is a lossy technique. During quantization process quantization error is introduced is called as blue noise [1], [7]. As shown in fig2 color image is split into three primary colors R-G-B individual plane. After the half tone process, sampling and quantization process is applied on each individual plane and pixel will be represented by single bit instead of 8 bit per pixel.

Modified Huffman coding is used for higher compression ratio [7] where less than one bit per pixel is required. The compression ratio between half tone image and Huffman coded image is 2.99 irrespective of the input image. The coded sequence of the halftone image data has been considered in group of 16 bits in size to minimize the network resources and storage required. Each of the 16 bits groups is converted into their decimal equivalent on which Huffman coding is applied.

3. FAST INVERSE HALFTONING ALGORITHM

Different types of error diffusion half tone operators as well as block diagram for image reconstruction are expressed in paper [1] and [2]. With the help of multi-scale gradient estimation both edges are traced. As it require minimum multiplication, division and negligible floating point operations that lowest computational complexity and memory usage [1].

Fig 2 shows the block diagram for reconstruction of image from Huffman decoded image. Huffman coding is the lossless technique; hence it is the color half tone image and is split into three primary R-G-B colors. From each plane vertical and horizontal edges are traces using gradient estimation. Control function is defined in [1] that calculates the cut-off frequency for FIR separable Low Pass filter. Because of Low Pass filter image looks little bit blurry. Color 24-bit image is reproduced using concatenation technique.

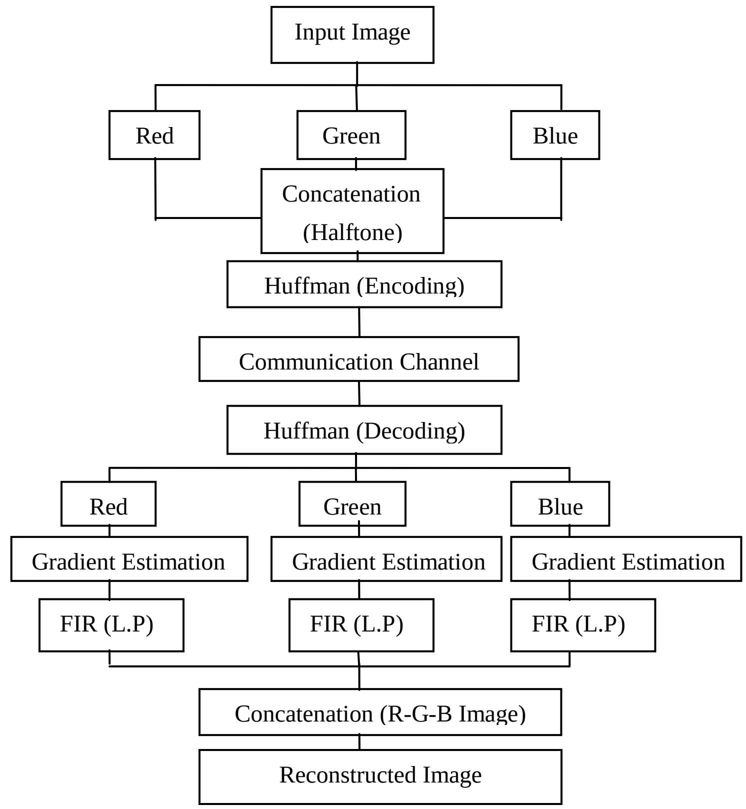

Fig 2: Block diagram

4. Structure Similarity Index (SSIM)

The Structural Similarity (SSIM) index is a measuring parameter between original image and its processed image. As shown in equation (1), image x is considered as input image and image y is inverse image. This measuring parameter gives structure wise similarity between two images. Block of size 8×8 is considered for both image x and image y. SSIM is the quality measure on the degradation of structural information and for calculation of Structural Similarity Index the measurement system is presented in [13]. Some quality measuring approaches are presented in [14]-[15].

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c1)(2\text{cov}_{xy} + c2)}{(\mu_{x2} + \mu_{y2} + c1)(\sigma_x^{\ 2} + \mu_y^{\ 2} + c2)} \quad (1)$$

Where, 1) $\mathbf{\mu_x}$ is the average of image x.

2) $\mathbf{\mu_y}$ is the average of image y.

3) $\mathbf{\sigma_x^2}$ is the variance of image x.

4) $\mathbf{\sigma_y^2}$ is the variance of image y

5) $\mathbf{cov_{xy}}$ is the co-variance between two images x and y.

6) $C_1 = (\mathbf{k_1.L})^2$ and $C_2 = (\mathbf{k_2.L})^2$ are the two variables to stabilize the division with small value denominator, where L is the dynamic range of pixel values i.e. $\mathbf{2^n}$.

7) $\mathbf{k_1 = 0.01}$ and $\mathbf{k_2 = 0.03}$ by default

The range for SSIM is -1 to +1. For both the identical images SSIM is +1 and SSIM is -1 for worse output image as compared to input image. Structural dissimilarity (DSSIM) is a distance metric derived from SSIM.

$$DSSIM(x,y) = \frac{1}{1 - SSIM(x,y)} \qquad (2)$$

5. DISCUSSION

The overall objective of this paper is to achieve higher compression ratio to real-time video data streaming. As mentioned in section2 effective number of taps determines the computational complexity. So, Small operator gives the single tap operation with acceptable image quality. SSIM is designed to improve on traditional methods like Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE), which have proved to be inconsistent with human eye perception. Even though MSE is same in two different cases but appearance point of view both images are quite different. From human visual system point of view SSIM gives the accurate result. Typically it is calculated on window sizes of 8×8. Window size can be changed to reduce the complexity.

Image shown in fig 3.a) is the sample image of Rohit as an original image. Small half toning operator is used to convert original image into halftone image shown in fig 3.b), fig 3.c), and fig 3.d) are the Huffman decoded image and inverse image respectively. In the same way each code is unique and this helps in decoding the coded sequence easily. The decoded sequence is then arranged in a matrix of the size of the original image and thus the Huffman decoded image is obtained, which is identical to that of halftone image. Huffman coding technique is lossless but useful for higher compression.

6. EXPERIMENTAL RESULTS

The algorithm discussed above is implemented using MATLAB 2008b on P8600 @ 2.40GHz, 2.92 GB RAM. To test the performance of this algorithm four color images belonging to different classes of size 512x512x3 are used.

Table-1 shows the result of 10 sample images of different categories. Fig 4.a), 4.b) and 4.c) are the graphical presentation of sample images with respect to MSE, SSIM, and PSNR respectively. Fig 4.a) shows that MSE is almost same for all half toning operators. Appearance point of view quality of inverse image from Floyd-Steinberg and Jarvis half toning operators is better. With single tap operation i.e. lowest computation inverse image generated from Small operator is also with acceptable quality. Half tone image produced by Floyd-Steinberg is very good retains pictorial details as compared to other half tone operators. Jarvis half toning operator preserves edges and artifacts. Whereas the inverse image of South-East half tone operator looks patchy with some shadow effects. Fig 3 b) is the half tone image from Small operator and fig 3 c) is the Huffman decoded image from it. Fig 3 e) is the half tone image from Floyd-Steinberg operator and fig 3 f) is the Huffman decoded image from it. Fig 3 h) is the half tone image from Jarvis operator and fig 3 i) show the Huffman decoded image from it. Fig 3 k) is the half tone image from South-East operator and fig 3 l) show the Huffman decoded image from it. Fig 3 g), and fig 3j) are the reconstructed images from Floyd-Steinberg and Jarvis operator are of fine image quality as compared to fig 3 d) and fig 3 m) of Small and South-East operator. Fig 3 d) is little-bit course and fig 3 m) looks quite patchy image. From computation point of view Small operator require lowest number of computations as explained in section 2. Table 1 shows SSIM value approaches to zero means from structure point of view reconstructed image is moderate with respect to input image.

7. CONCLUSION AND FUTURE SCOPE

In this paper, we have used standard half toning operates along with proposed Small and South-East operators. Small and South-East operator's give almost same result as compared Floyd-Steinberg and Jarvis operator in terms of measuring parameter. It means reconstructed image quality matches with input image considerably. In Fast Inverse half tone algorithm FIR Low Pass filter is used. The scope to this paper is to develop half toning operators and design of filter to minimize the blurring effect. In printing media it is required to store huge number of images as well as transmission of images, videos worldwide. In such kind of applications this hybrid technique can be utilized. From result the image quality is acceptable and can be used for low bit rate video data transmission, the same work is under process. The same technique can be used for storage of CCTV footage in hybrid encoded form. Stream of video can be cut into number of frames using Virtual –dub or Frame-Shot software. For video conferencing high speed communication is required and that can be achieved by skipping some of the frames based on threshold.

Fig 3.a): Original Image: Rohit

Fig 3.b): Small Half tone Image

Fig 3.c): Small - Huffman Decoded Image

Fig 3.d): Reconstructed image

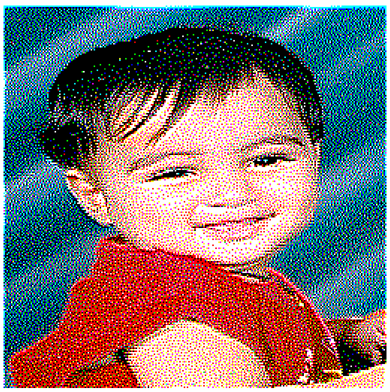

Fig 3.e): Floyd-Steinberg Half tone Image

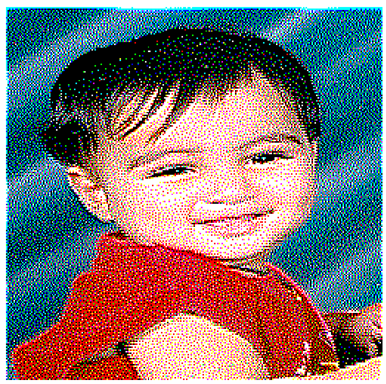

Fig 3.f): Floyd-Steinberg- Huffman Decoded Image

Fig 3.g): Reconstructed image

Fig 3.h): Jarvis Half tone Image

Fig 3.i): Jarvis - Huffman Decoded Image

Fig 3.j): Reconstructed image

Fig 3.k): South-East Half tone Image

Fig 3.l): South-East - Huffman Decoded Image

Fig 3.m): Reconstructed image

Table1. Measuring parameters like Mean Square Error (MSE), PSNR and Structure Similarity Index (SSIM) used for different images and half tone operators.

Image	Parameter	Floyd-Stenberg Operator	Jarvis Operator	Small Operator	South-East Operator
Baboon	SSIM	8.8218e-005	8.5575e-005	8.6894e-005	8.7714e-005
	MSE	17715	17719	17717	17718
	PSNR	42.4834	42.4843	42.4839	42.4842
Cloud	SSIM	7.2531e-005	6.7736e-005	7.0133e-005	7.8740e-005
	MSE	15027	15032	15029	15023
	PSNR	41.7686	41.7701	41.7694	41.7675
Lata	SSIM	8.2293e-005	8.2293e-005	8.0988e-005	8.2793e-005
	MSE	16461	16461	16462	16460
	PSNR	42.1646	42.1646	42.1648	42.1644
LenaColor	SSIM	7.8322e-005	8.0062e-005	7.8723e-005	8.2200e-005
	MSE	18897	18899	18898	18898
	PSNR	42.7639	42.7643	42.7642	42.7642
Pepper	SSIM	6.6770e-005	6.8110e-005	6.7159e-005	6.9335e-005
	MSE	29247	29244	29246	29242
	PSNR	44.6608	44.6604	44.6607	44.6601
Rock	SSIM	8.1580e-005	8.5367e-005	8.3284e-005	9.1342e-005
	MSE	9690	9688	9689	9685
	PSNR	39.8633	39.8627	39.8629	39.8613
Rohit4	SSIM	6.7379e-005	6.8466e-005	6.5358e-005	6.9780e-005
	MSE	22950	22949	22953	22947
	PSNR	43.6078	43.6076	43.6084	43.6073
Rohit11	SSIM	6.9905e-005	7.0903e-005	6.9487e-005	6.7828e-005
	MSE	23734	23733	23735	23739
	PSNR	43.7538	43.7536	43.7539	43.7545
RohitKrishna	SSIM	6.4643e-005	6.6545e-005	6.4804e-005	6.7976e-005
	MSE	23500	23499	23501	23498
	PSNR	43.7107	43.7105	43.7108	43.7103
RohitSmile	SSIM	7.5209e-005	7.5234e-005	7.4972e-005	7.4494e-005
	MSE	17830	17831	17831	17833
	PSNR	42.5116	42.5118	42.5118	42.5121

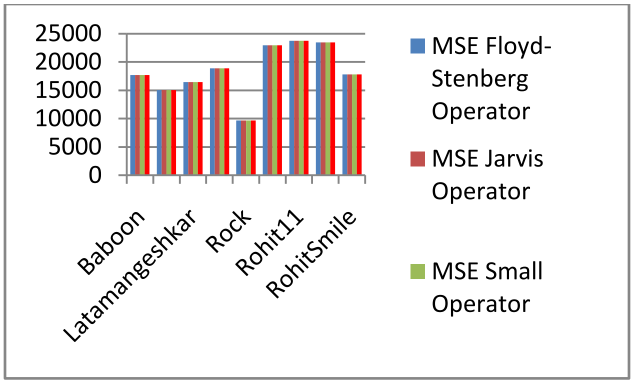

Fig 4.a): Different images versus MSE with different operators

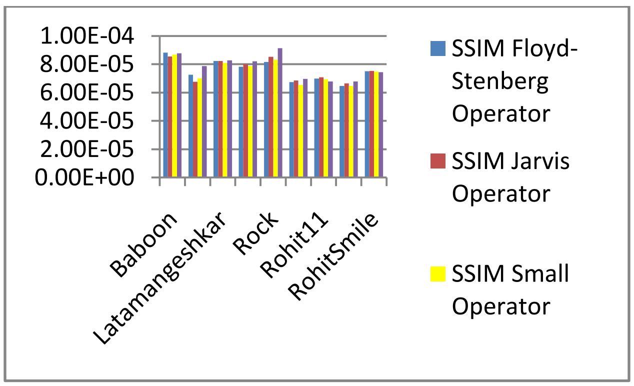

Fig 4.b): Different images versus SSIM with different operators

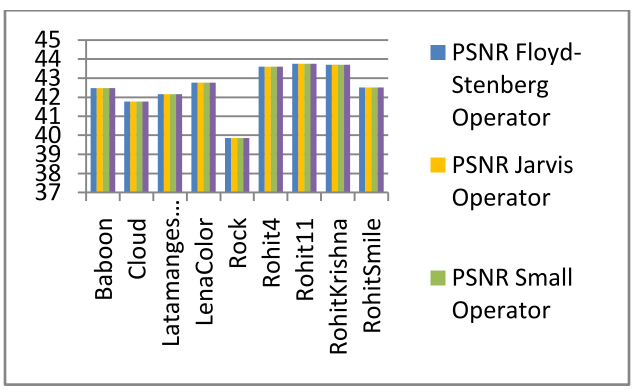

Fig 4.c): Different images versus PSNR with different operators

8. REFERENCES

[1] Sanjay R. Sange, 2009 Restoration of Color Halftone image by using Fast Inverse Half toning Algorithm, in 2009 International Conference on Advances in Recent Technologies in Communication and Computing, 978-0-7695-3845-7/09 $25.00 © 2009 IEEE, DOI 10.1109/ARTCom.2009.36, pg .650—655,Oct.(2009)

[2] Hein, S., Zakhor, A, 1995Halftone to continuous–tone conversion of Error-diffusion coded images, IEEE Trans. Images Processing, vol.4, pp.208--216, Feb. (1995).

[3] Floyd, R. W., Steinberg, 1976, An adaptive algorithm for spatial grayscale, Proc. SID, vol. 17/2, pg. 75--77, (1976)

[4] Wong P., 1995 Inverse half toning and Kernel estimation for error diffusion, IEEE Trans. Image Processing, vol.4, pp.. 486--498, Apr (1995)

[5] Sange, S., 2009 A Survey on, Black and White and Color Half toning Techniques, SVKM's NMIMS University, MPSTME, Journal of science, Engineering & Technology Management, ISSN: 0975-525X Techno-Path" Vol.1 No.2-May (2009), pg. no. 7--17

[6] Kite, T. D., Evans, B. L., Bovik, A. C., 2000 Modeling and Quality Assessment of Half toning by Error Diffusion, IEEE Transaction on Image Processing, vol.9.No.5, May (2000).

[7] Sange, S. R., 2010 Image data compression using new Halftoning operators and Run Length Encoding. In: 1st International Conference Thinkquest2010. Published in Springer Explorer and Springer CS Digital Library, pg-224—230, Feb (2010)

[8] H. B. Kekre, Sanjay R. Sange, Gauri S. Sawant, and Ankit A. Lahoty, 2011, Image Compression Using Half toning and Huffman Coding, ICTSM 2011, CCIS 145, pp.221–226, 2011. © Springer-Verlag Berlin Heidelberg 2011

[9] Pujar, J. H., Kadlaskar, L. M. 2005 – 2010, A New Lossless Method of Image Compression and Decompression using Huffman Coding Techniques, Journal of Theoretical and Applied Information Technology, (2005 – 2010) JATIT.

[10] Saravanan, C. Ponalagusamy, R. 2005 – 2010, Lossless Grey-scale Image Compression using Source Symbols Reduction and Huffman Coding, International Journal of Image Processing (IJIP), Volume (3): Issue (5), (2005 – 2010) JATIT.

[11] Aggarwal M. Narayan A. 2000, An Efficient Huffman Decoding", in (2000) International Conference on Image Processing, IEEE Proceedings, pg.936—939 vol.1

[12] Tehranipour, M. H. Nourani, 2010, Mixed RL-Huffman encoding for power reduction and data compression in scan test, In: Intelligent Information Technology and Security Informatics (IITSI), 2010 Third International Symposium on 2-4 April (2010).

[13] Zhou Wang, Alan Conarad Bovik, Hamid Rahim Sheikh, 2004, Image Quality Assessment: From Error Visibility to Structural Similarity IEEE Transactions on Image Processing, Vol.13, No. 4, April 2004.

[14] Z. Wang, Dec. 2001, Rate scalable Foveated image and video communications, Ph.D. dissertation, Dept. Elect. Comput. Eng., Univ. Texas at Austin, Austin, TX, Dec. 2001.

[15] Zhou Wang, A. C. Bovik,, Mar. 2002, A Universal image quality index, *IEEE Signal Processing Letters*, vol.9, pp. 81-84, Mar. 2002.

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