Image reconstruction using Half tone and Kekre's Fast Codebook Generation Vector Quantization technique

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ABSTRACT
Now a day's transmission of image and video data is gradually increasing. Compression of image data with acceptable image quality is the objective of this paper. To achieve higher Compression Ratio combination of halftone and Kekre's Fast Codebook Generation (KFCG) Vector Quantization algorithm is used. For Vector Quantization KFCG algorithm is used to reduce time and memory space. Half toning technique is used in printing industry which is lossy and gives one bit image, hence to achieve higher Compression Ratio 8:1. To reduce the computational complexity Small half toning operator is used. Codebook of different sizes 8, 16, 32, 64, 128 and 256 and pixel group of 2X2 size is used in this paper. Different bit map images of size 512x512 are used. For reconstruction of image Fast Inverse Half toning algorithm is used. To measure image quality measuring parameters like Mean Square Error (MSE), Peak Signal-to-Noise ratio (PSNR) and Structure Similarity Index (SSIM) are used. This is the proposed combination of compression technique to fulfill the objectives of video data streaming with low bit rate transmission which is the major constraint as well as to store of large number of half tone images for printing in encoded form.

Keywords
Halftone, Code Vector, Codebook, Quantization, Kekre's Fast Codebook Generation (KFCG), Index, Structure Similarity Index (SSIM)

1. INTRODUCTION
Different half toning operators are explained [1] in which almost all are error diffusion type operators. Floyd-Steinberg and Jarvis half toning operators preserve the artifacts in the image [2], [5]. Few operators are presented and compared their results with Floyd-Steinberg and Jarvis half toning operators [6]. Floyd-Steinberg operator preserves the artifacts and maximum details in the image. Jarvis operator has 12-coefficient error filter. The Jarvis halftone is substantially sharper. Jarvis halftone technique linearizes error diffusion algorithms by modeling the quantized as a linear gain plus additive noise. Edge sharpening is proportional to the linear gain, and a formula is given to estimate the gain from a given error filter. Vector Quantization algorithms are expressed in [10] and [15].Time complexity of Euclidian distance for codebook generation is presented in [15] and [16]. Kekre's Fast Code Book Generation (KFCG) algorithm is used to reduce time and computational complexity. Like this other compression techniques Run Length Encoding with half tone [5] and Huffman Encoding with halftone are presented [7].

In this paper, section 2 and section 3 is the implementation of Halftone method and KFCG Algorithm. Section 4 gives the implementation of Fast Inverse Half toning algorithm. In section 5 introduces Structure Similarity Index (SSIM), the measuring parameter for quality measurement between reconstructed and original image. Section 6 shows the experimental results in the form of images and measuring parameters like Mean Square Error (MSE) and SSIM and 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 8. Section 9 is the paper references. This is the extension of paper [6] in which reconstruction of image using Fast Inverse Half toning algorithm is explained.

2. HALF TONING METOHD
Printing understands whether to put dot on paper op not to dot. It means binary data like 1 and 0 is the input for Printer. All the advertising boards, Flex board, News papers are not painted like brush painting, all are printed with dots. That is why half toning is nothing but conversion of continuous to dot form. Human being can integrates the whole image and understand it fully. In color image each pixel is represented by 24- bits. Neighborhood processing is applied on each plane. 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. The blue noise is introduced during half toning process is called as quantization error [5]-[6]. Other half toning operator's performance is compared with small operator in terms of computational complexity and memory [6]-[9]. Small half toning operator is shown in figure 1 where **X** indicates the central pixel. It takes 3-tap effectively 1-tap operation. This is one of the great advantages over Floyd-Steinberg and Jarvis half toning operators along with almost same PSNR and image quality.

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

Figure 1. Small half toning operator

3. KEKRE'S FAST CODEBOOK GENRATION (KFCG) ALGORITHM

Kekre's Fast Codebook Generation algorithm requires less number of computations, hence reduces the processing time [21]. The overall algorithm is explained in [20].Concatenated half tone image is treated as input to KFCG for further image data compression. Different approaches for Vector Quantization [8], [11], [12], [13].

Following steps are required to implementation of Kekre's Fast Codebook Generation.

1] Divide the complete image (NxN) into 2x2 non-overlapping blocks.

2] Form 12-byte input vector as a row in matrix so as to get V1, V2,….,Vm number of input vectors.

3] This matrix is called as Training set or Cluster1.

4] Centriod or code vector can be calculated by taking column wise average.

5] Compare first byte of centroid with each co-efficient of input vector and split Clustor1 into Clustor1 and Clustor2 [6], [10], [15]-[18].

6] To generate codebook step 5 is repeated till to get the desired codebook size [6].

7] Total number of code vectors generated is 2^n, where n is the number of bits used as a code vector index.

8] Do the indexing and instead of sending code vector only its index will be sent.

4. FAST INVERSE HALFTONING ALGORITHM

Following steps are performed to reconstruct image from halftone image as shown in figure2.

1] Input color image is split into primary three R-G-B colors as 8-bit individual plane.

2] Each plane is processed separately to convert individual plane into halftone image.

3] All the three plane concatenated so as to obtain color 24-bit halftone image.

4] Vector quantization is done using KFCG algorithm. Each code vector is then represented with minimum number of bits as index. In this way entire image is encoded to achieve higher compression ratio.

5] With the help of indices from code book entire image is decoded as a halftone image.

6] For reconstruction of image from halftone image Fast Inverse Half toning algorithm is used. For that KFCG-VQ decoded image split into three components.

7] Gradient Estimation is performed using 7x7 mask in x-direction and y-directions so that vertical and horizontal edges can be traced respectively [5].

8] To obtain inverse image separable FIR Low Pass filter is applied.

9] Reconstruction of image is done by concatenation process.

Along both the axis FIR Low Pass filter is applied because of which image blurring effect occurs.

Kernel estimation, Bayes and Wavelet inverse algorithm has $8N^2$, $8N^2$ and $36N^2$ has computational complexity [3] as it requires iterative operation. These entire algorithms require large amount of calculation, floating point operation, time and memory space. Fast Inverse half toning algorithm single operation with window size 7x7 with negligible floating point operation, hence computational complexity for this algorithm is 7N.

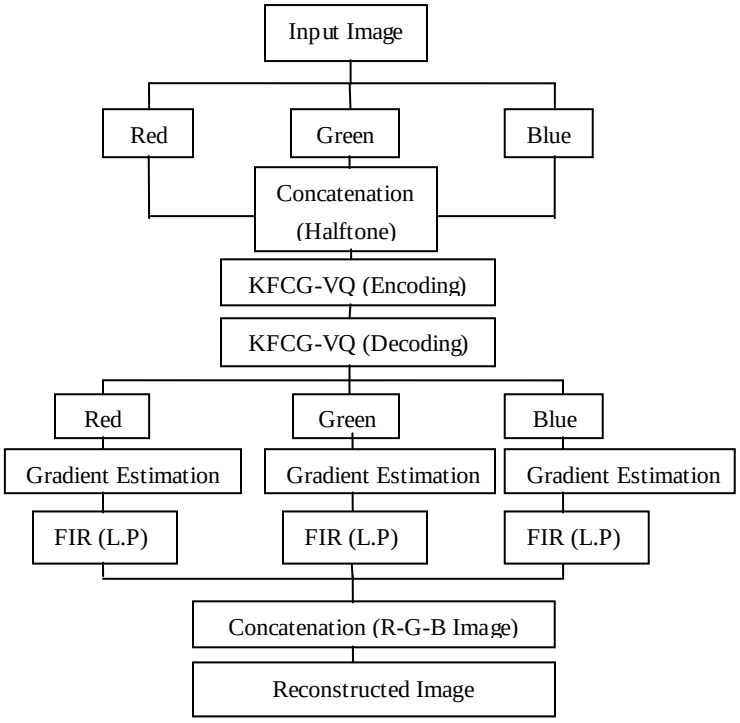

Figure 2. Block diagram

Fast inverse half toning algorithm expression Type equation here.and explanation along with computational complexity is given in detail in paper [9].

5. Structural Similarity Index (SSIM)

In digital image processing image gets degraded operations like compression, storage, transmission and reconstruction. Human visual perception is highly adapted for extracting the structural information from a scene. SSIM is the quality measure on the degradation of structural information [22]. Some quality

measuring approaches are presented in [23]-[24].For calculation of Structural Similarity Index the measurement system is presented in [22].Consider x is the original image having perfect quality and y is the processed degraded image. Luminance on both images is compared and it is estimated as mean intensity-

$$\mu_x = \frac{1}{N}\sum_{i=1}^{N} x_i \quad (1)$$

Luminance function *l(x, y)* is comparison function on μ_x and μ_y.

Another contrast comparison *c(x, y)* is then the comparison of σ_x and σ_y.

$$\sigma_x = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \mu_x) \quad (2)$$

The third function *s(x,y)* for normalization by its own standard deviation.

The overall measure of SSIM is the combination of three functions.

$$S(x,y) = f(l(x,y), c(x,y), s(x,y)) \quad (3)$$

The complete expression is explained in [22] as-

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C1)(2cov_{xy} + C2)}{(\mu_x^2 + \mu_y^2 + C1)(\sigma_x^2 + \sigma_y^2 + C2)} \quad (4)$$

Figure 3.a Original Image (Rohit)

The range for SSIM is from -1 to +1. SSIM is the symmetric measure and is used for similarity measure for comparing two images.

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.
The image is divided from codebook 8 to codebook size 256. Measuring parameters like Mean Square Error (MSE), PSNR and Structure Similarity Index (SSIM) are the measuring parameters for quality measurement on various images with different codebook size are used.

Image shown in figure 3.a is the sample image of Rohit as an original image. Small half toning operator is used to convert into halftone image shown in figure 3.b. Figure 3c, e, g, i, k, m are the half tone images for codebook size 8, 16, 32, 64, 128, 256 and figure 3 d, f, h, j, l, n are the inverse images respectively. Table1 shows the results for different images for codebook size 8, 16, 32, 64, 128, 256 in terms of MSE, PSNR and SSIM. The same results are presented graphically Codebook Vs MSE, Codebook Vs PSNR, Codebook Vs SSIM in figures figure 4.a, figure 4.b and figure 4.c respectively.

It is clear that as the codebook size increases the quality of the image improves with decrease in MSE and increase in SSIM. As the codebook size increases further the computation and number of bits in index will increase with improvement in image quality.

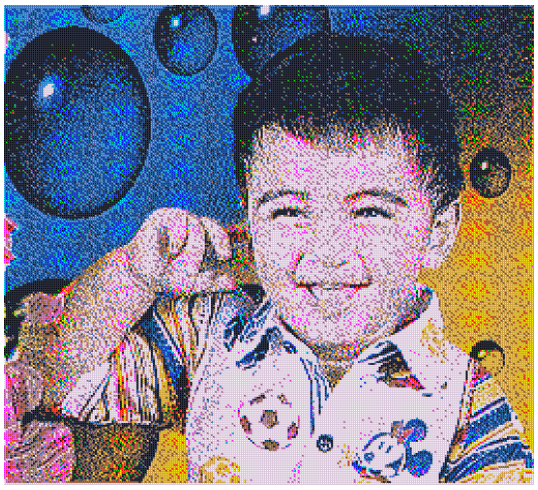

Figure 3.b Half tone Image

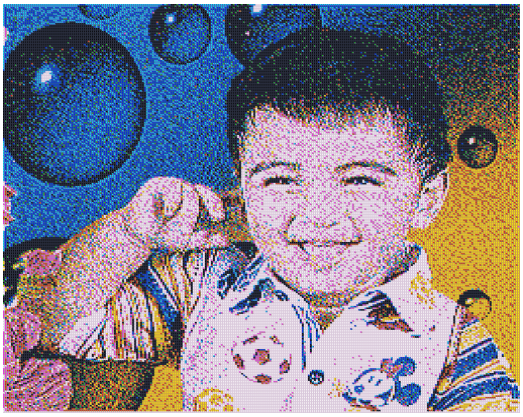

Figure3.c VQ decoded Image: Codebook size 8

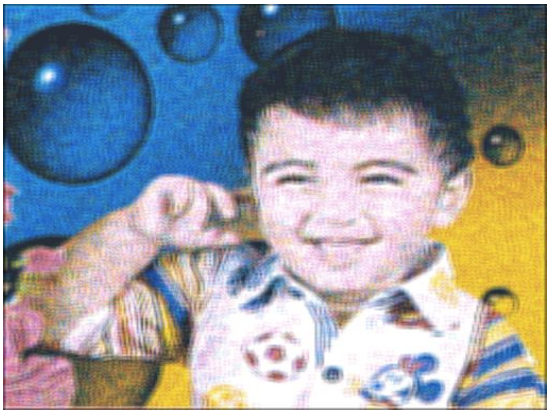

Figure3.d Inverse Image: Codebook size 8

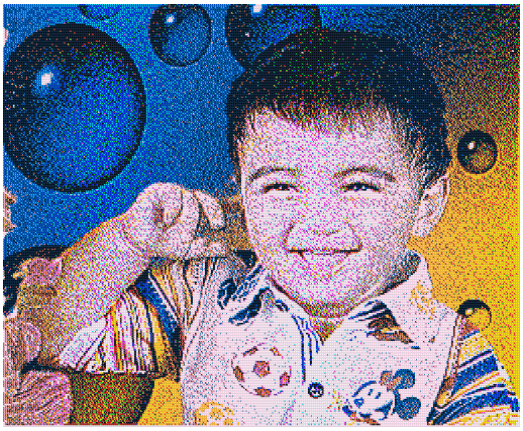

Figure3.e VQ decoded Image: Codebook size 16

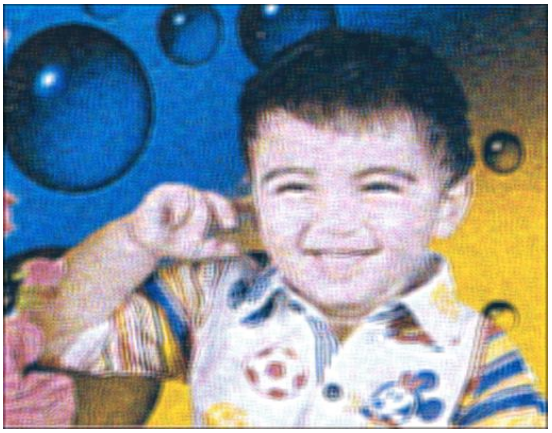

Figure3.f Inverse Image: Codebook size 16

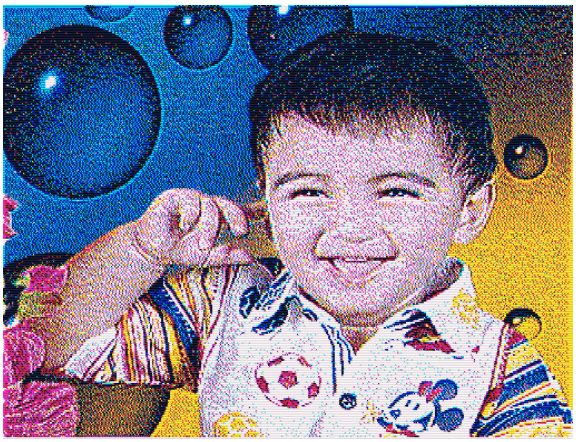

Figure3.g VQ decoded Image: Codebook size 32

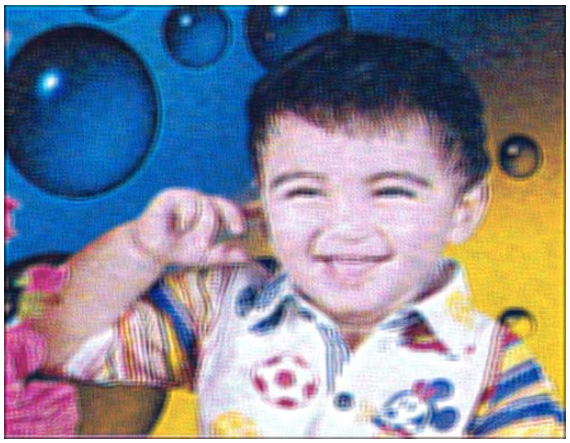

Figure3.h Inverse Image: Codebook size 64

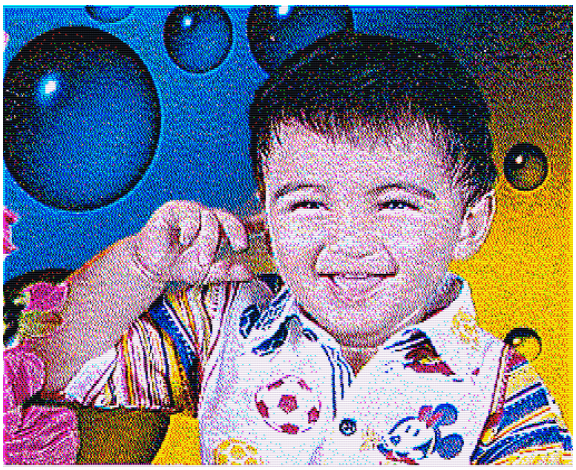

Figure3.i VQ decoded Image: Codebook size 64

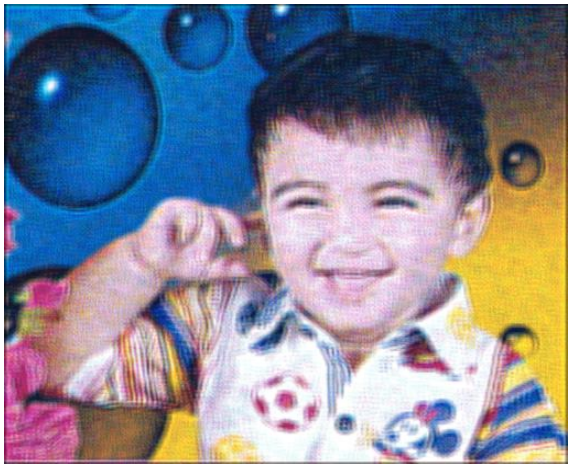

Figure3.j Inverse Image: Codebook size 64

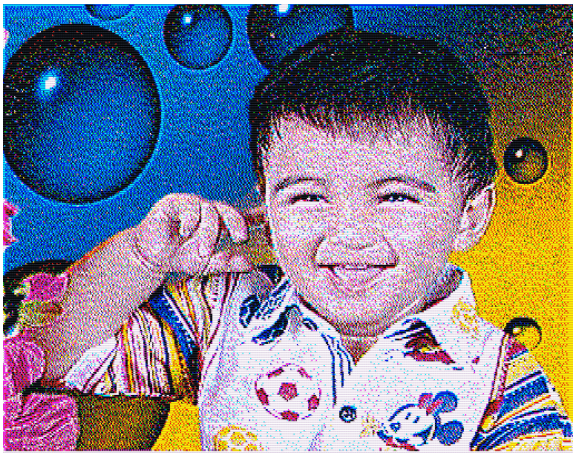

Figure3.k VQ decoded Image: Codebook size 128

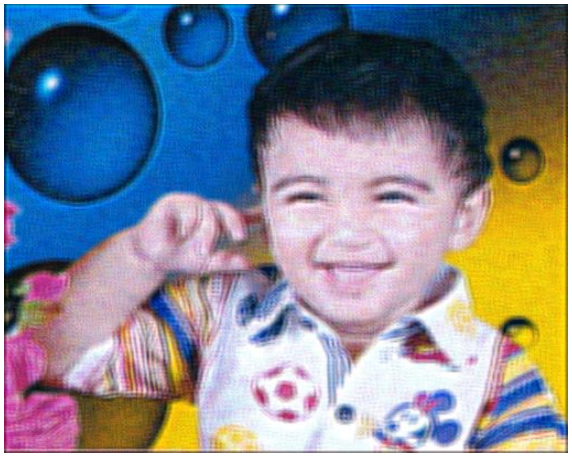

Figure3.l Inverse Image: Codebook size 128

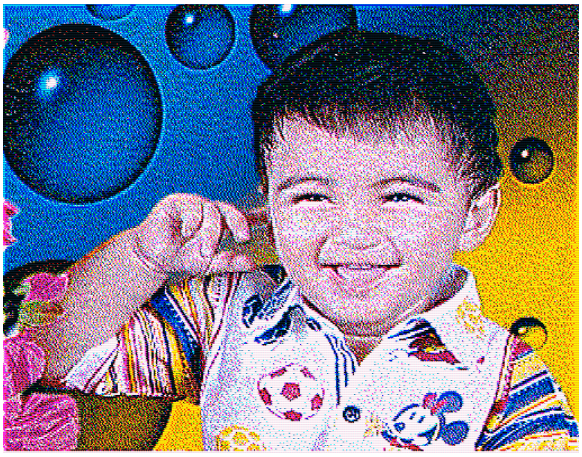

Figure3.m VQ decoded Image: Codebook size 256

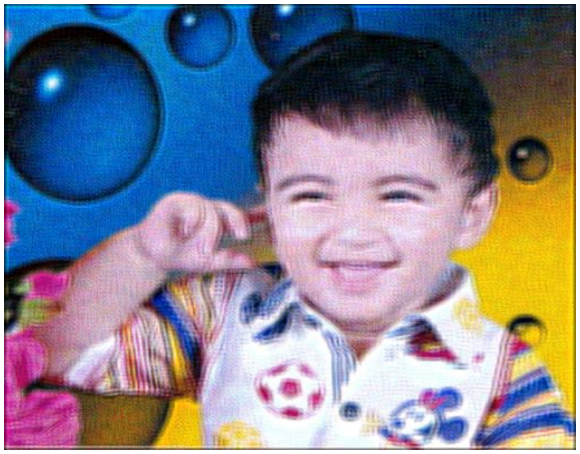

Figure3n Inverse Image: Codebook size 256

Table1. Measuring parameters like Mean Square Error (MSE), PSNR and Structure Similarity Index (SSIM) versus Codebook size

Image	Parameter	CB-8	CB-16	CB-32	CB-64	CB-128	CB-256
Rohit	MSE	22892	22896	22900	22900	22902	22904
	PSNR	43.5968	43.598	43.5983	43.5983	43.5987	43.5991
	SSIM	0.0108	0.0104	0.0101	0.01	0.0098	0.0096
Boat	MSE	18002	18016	18022	18025	18033	18038
	PSNR	42.5532	42.557	42.5579	42.5588	42.5608	42.5618
	SSIM	0.0126	0.0116	0.0112	0.0110	0.0104	0.0101
Lata	MSE	16410	16417	16422	16425	16429	16431
	PSNR	42.1512	42.153	42.1543	42.1551	42.156	42.1567
	SSIM	0.012	0.0113	0.0109	0.0107	0.0103	0.0101
Pepper	MSE	16102	16111	16114	16120	16127	16130
	PSNR	42.0687	42.0713	42.0721	42.0736	42.0756	42.0762
	SSIM	0.0133	0.0126	0.012	0.0114	0.0109	0.0105

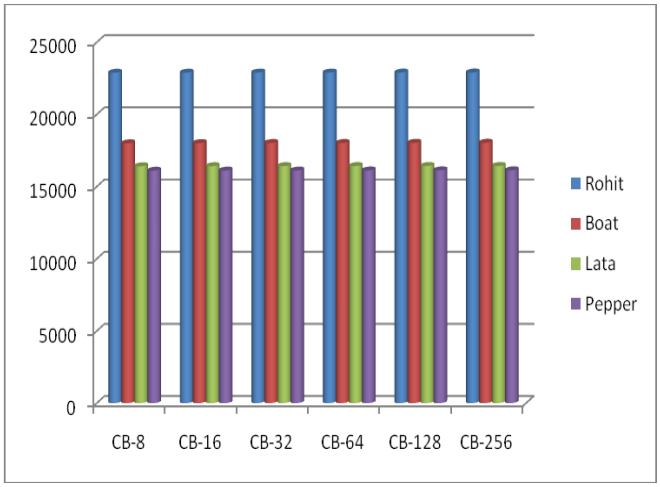

Figure 4.a Codebook Vs MSE

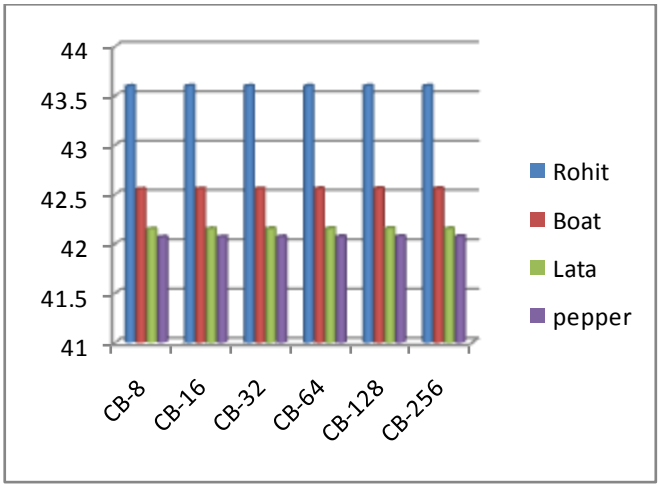

Figure 4.b Codebook Vs PSNR

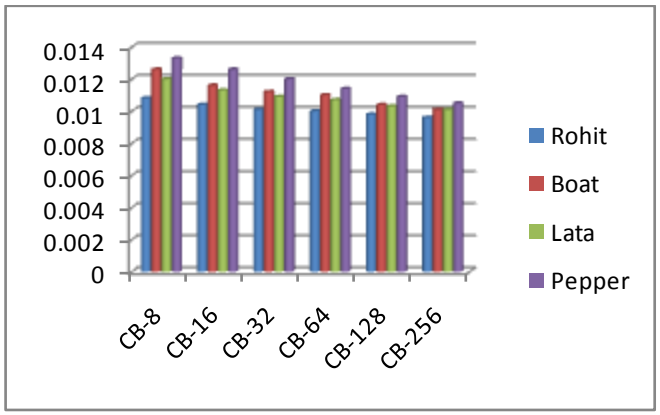

Figure 4.cCodebook Vs SSIM

7. CONCLUSION AND FUTURE SCOPE

In this paper, we have used Small half toning operator that performs one tap operation. For furtherer compression of image data half tone and KFCG techniques are combined. Future scope for this paper is the block size can increase from 2x2 to 3x3, 4x4 and so on as well as the codebook size to 512, 1024 and so on.

If the block size increased then the Compression Ratio will increase but the image will look like patchier. SSIM gives the perceptual image quality that how reconstructed image is structurally close to original image. There is future scope to develop inverse half toning algorithm to reduce blurring effect. In News paper 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.

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