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Information Hiding for "Color to Gray and back" with Hartley, Slant and Kekre's wavelet using Normalization

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Abstract: *The paper shows performance comparison of three proposed methods with orthogonal wavelet alias Hartley,Slant &Kekre's wavelet using Normalization for 'Color to Gray and Back'. The color information of the image is embedded into its intermediate gray scale version with wavelet using normalization method. Instead of using the original color image for storage and transmission, intermediate gray image (Gray scale version with embedded color information) can be used, resulting into better bandwidth or storage utilization. Among three algorithms considered the second algorithm give better performance as compared to first and third algorithm. In our experimental results second algorithm for Kekre's wavelet using Normalization gives better performance in 'Color to gray and Back' w.r.t all other wavelet transforms in method 1, method 2 and method 3. The intent is to achieve compression of 1/3 and to print color images with black and white printers and to be able to recover the color information.*

Keywords*-Color Embedding, Color-to-Gray Conversion, Transforms, Wavelets,Normalization ,Compression.*

I. INTRODUCTION

Digital images can be classified roughly to 24 bit color images and 8bit gray images. We have come to tend to treat colorful images by the development of various kinds of devices. However, there is still much demand to treat color images as gray images from the viewpoint of running cost, data quantity, etc. We can convert a color image into a gray image by linear combination of RGB color elements uniquely. Meanwhile, the inverse problem to find an RGB vector from a luminance value is an ill-posed problem. Therefore, it is impossible theoretically to completely restore a color image from a gray image. For this problem, recently, colorization techniques have been proposed [1]-[4]. Those methods can re-store a color image from a gray image by giving color hints. However, the color of the restored image strongly depends on the color hints given by a user as an initial condition subjectively.

In recent years, there is increase in the size of databases because of color images. There is needto reduce the size of data. To reduce the size of color images, information from all individual color components (color planes) is embedded into a single plane by which intermediate gray image is obtained [5][6][7][8]. This also reduces the bandwidth required to transmit the image over the network.Gray image, which is obtained from color image, can be printed using a black-and-white printer or transmitted using a conventional fax machine [6]. This gray image then can be used to retrieve its original color image.

In this paper, we propose three different methods of color-to-gray mapping technique with wavelet transforms using normalization [8][9], that is, our method can recover color images from color embedded gray images with having almost original color images. In method 1 the color information in normalized form is hidden in LH and HL area of first component as in figure 3. And in method 2 the color information in normalize form is hidden in HL and HH area of first component as in figure 3and in method 3 the color information in normalize form is hidden in LH and HH area of first component as in figure 3. Normalization is the process where each pixel value is divided by 256 to minimize the embedding error [9].

The paper is organized as follows. Section 2 describes transforms and wavelet generation. Section 3 presents the proposed system for "Color to Gray and back" using wavelets. Section 4 describes experimental results and finally the concluding remarks are given in section 5.

II. TRANSFORMS AND WAVELET GENERATION

2.1 Hartley Transform [10]

The Discrete Cosine Transform(DCT) utilizes cosine basis functions, while Discrete Sine Transform(DST) uses sine basis function. The Hartley transform utilizes both sine and cosine basis functions. The discrete 2-dimensional Hartley Transform is defined as[7]

F(u, v)= $\frac{1}{N}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)Cas\left\{\frac{2\pi}{N}(ux+vy)\right\}$ ------(1)

Inverse discrete 2-dimensional Hartley Transform is,

f(x, y)= $\frac{1}{N}\sum_{u=0}^{N-1}\sum_{v=0}^{N-1} F(u,v)Cas\left\{\frac{2\pi}{N}(ux+vy)\right\}$ ------(2)

where, $Cas\theta = \cos\theta + \sin\theta$

2.2 Slant Transform [11]

The Slant transform is a member of the orthogonal transforms. It has a constant function for the first row, and has a second row which is a linear (slant) function of the column index. The matrices are formed by an iterative construction that exhibits the matrices as products of sparse matrices, which in turn leads to a fast transform algorithm[11]

The Slant transform matrix of order two is given by

$$S_2 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ -1 & 1 \end{bmatrix} \qquad \text{-----(3)}$$

$$S_N = \frac{1}{2^{1/2}}\begin{bmatrix} 1 & 0 & \vdots & & \vdots & 1 & 0 & \vdots & \\ a_N & b_N & \vdots & 0 & \vdots & -a_N & b_N & \vdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ & 0 & \vdots & I_{(n/2)-2} & \vdots & & 0 & \vdots & I_{(n/2)-2} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 1 & \vdots & & \vdots & 0 & -1 & \vdots & \\ -b_N & a_N & \vdots & 0 & \vdots & b_N & a_N & \vdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ & 0 & \vdots & I_{(n/2)-2} & \vdots & & 0 & \vdots & -I_{(n/2)-2} \end{bmatrix}\begin{bmatrix} & \vdots & \\ S_{N/2} & \vdots & 0 \\ & \vdots & \\ & \vdots & \\ \cdots & \vdots & \cdots \\ & \vdots & \\ & \vdots & \\ 0 & \vdots & S_{N/2} \\ & \vdots & \end{bmatrix} \qquad \text{-----(4)}$$

The matrix $I_{(n/2)-2}$ is the identity matrix of dimension (N/2)-2. The constants a_N, $b_N$may be computed by the formulas

$$a_{2N} = \left(\frac{3N^2}{4N^2-1}\right)^{(1/2)}, \qquad b_{2N} = \left(\frac{N^2-1}{4N^2-1}\right)^{1/2}$$

2.3 Kekre Transform [12]

Kekre Transform matrix can be of any size NxN, which need not have to be in powers of. All upper diagonal and diagonal values of Kekre's transform matrix are one, while the lower diagonal part except the values just below diagonal is zero. Generalized NxNKekre Transform matrix can be given as [10]

$$K_{NxN} = \begin{bmatrix} 1 & 1 & 1 & .. & 1 & 1 \\ -N+1 & 1 & 1 & .. & 1 & 1 \\ 0 & -N+2 & 1 & .. & : & : \\ : & 0 & .. & .. & 1 & 1 \\ 0 & 0 & 0 & .. & -N+(N-1) & 1 \end{bmatrix} \qquad \text{------(5)}$$

The formula for generating the term Kx,y of Kekre Transform matrix is

$$K_{x,y} = \begin{cases} 1 & ,x \le y \\ -N+(x+1) & ,x = y+1 \\ 0 & ,x > y+1 \end{cases} \qquad \text{------(6)}$$

2.4 Wavelets [13]

The first step is to select the transform for which the wavelet need to be generated i.e. let's assume "4 x 4 Walsh transform as shown in Figure 1". The procedure of generating 16x16 Walsh wavelet transform from 4x4 Walsh transform is illustrated in Figure 2.

1	1	1	1
1	1	-1	-1
1	-1	-1	1
1	-1	1	-1

Figure 1: 4x4 Walsh Transform Matrix Figure

	1st column of W4 Repeated N=4 times				2nd column of W4 Repeated N=4 times				3rd column of W4 Repeated N=4 times				4th column of W4 Repeated N=4 times			
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1 to 4 rows	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1
	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1
	1	1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0
5 to 8 rows	0	0	0	0	1	1	-1	-1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	1	1	-1	-1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	1	1	-1	-1
	1	-1	-1	1	0	0	0	0	0	0	0	0	0	0	0	0
9 to 12 rows	0	0	0	0	1	-1	-1	1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	1	-1	-1	1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	-1	1
	1	-1	1	-1	0	0	0	0	0	0	0	0	0	0	0	0
13 to16rows	0	0	0	0	1	-1	1	-1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	1	-1	1	-1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	1	-1

Figure 2: Generation of 16x16 Walsh wavelet transform from 4x4 Walsh transform

Wavelets for other transforms can also be generated using the same procedure.

III. PROPOSED SYSTEM

In this section, we propose three new wavelet based color-to-gray mapping algorithm and color recovery method.

3.1 Method 1 [6][7][8]

The 'Color to Gray and Back' has two steps as Conversion of Color to Matted Gray Image with color embedding into gray image & Recovery of Color image back.

3.1.1 Color-to-gray Step

1. First color component (R-plane) of size NxN is kept as it is and second (G-plane) & third (B-plane) color component are resized to N/2 x N/2.
2. Second & Third color component are normalized to minimize the embedding error.
3. Wavelet i.e. Hartley, Slant or Kekre's wavelet to be applied to first color components of image.
4. First component to be divided into four subbands as shown in figure1 corresponding to the low pass [LL], vertical [LH], horizontal [HL], and diagonal [HH] subbands, respectively.
5. LH to be replaced by normalized second color component, HL to be replace by normalized third color component.
6. Inverse wavelet transform to be applied to obtain Gray image of size N x N.

LL	**LH**
HL	**HH**

Figure 1: Sub-band in Transform domain

3.1.2 Recovery Step

1. Wavelet to be applied on Gray image of size N x N to obtain four sub-bands as LL, LH, HL and HH.
2. Retrieve LHas second color component and HL as third color component of size N/2 x N/2 and the the remaining as first color component of size NxN.
3. De-normalize Second & Third color component by multiplying it by 256.
4. Resize Second & Third color component to NxN.
5. Inverse Wavelet transform to be applied on first color component.
6. All three color component are merged to obtain Recovered Color Image.

3.2 Method 2 [6][7][8][9]

3.2.1 Color-to-gray Step

1. First color component (R-plane) of size NxN is kept as it is and second (G-plane) & third (B-plane) color component are resized to N/2 x N/2.
2. Second & Third color component are normalized to minimize the embedding error.
3. Wavelet i.e. Hartley, Slant or Kekre's wavelet to be applied to first color components of image.
4. First component to be divided into four subbands as shown in figure1 corresponding to the low pass [LL], vertical [LH], horizontal [HL], and diagonal [HH] subbands, respectively.
5. HL to be replaced by normalized second color component, HH to be replace by normalized third color component.
6. Inverse Wavelet transform to be applied to obtain Gray image of size N x N.

3.2.2 Recovery Step

1. Wavelet to be applied on Gray image of size N x N to obtain four sub-bands as LL, LH, HL and HH.
2. Retrieve HLas second color component and HH as third color component of size N/2 x N/2 and the the remaining as first color component of size NxN.
3. De-normalize Second & Third color component by multiplying it by 256.
4. Resize Second & Third color component to NxN.
5. Inverse Wavelet transform to be applied on first color component.
6. All three color component are merged to obtain Recovered Color Image.

3.3 Method 3 [6][7][8][9]

3.3.1 Color-to-gray Step

1. First color component (R-plane) of size NxN is kept as it is and second (G-plane) & third (B-plane) color component are resized to N/2 x N/2.
2. Second & Third color component are normalized to minimize the embedding error.
3. Wavelet i.e. Hartley, Slant or Kekre's wavelet to be applied to first color components of image.
4. First component to be divided into four subbands as shown in figure1 corresponding to the low pass [LL], vertical [LH], horizontal [HL], and diagonal [HH] subbands, respectively.
5. LH to be replaced by normalized second color component, HH to be replace by normalized third color component.
6. Inverse Wavelet transform to be applied to obtain Gray image of size N x N.

3.3.2 Recovery Step

1. Wavelet to be applied on Gray image of size N x N to obtain four sub-bands as LL, LH, HL and HH.
2. Retrieve LHas second color component and HH as third color component of size N/2 x N/2 and the the remaining as first color component of size NxN.
3. De-normalize Second & Third color component by multiplying it by 256.
4. Resize Second & Third color component to NxN.
5. Inverse Wavelet transform to be applied on first color component.
6. All three color component are merged to obtain Recovered Color Image.

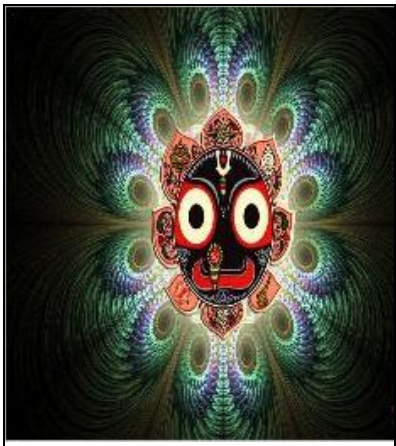
IV. RESULTS & DISCUSSION

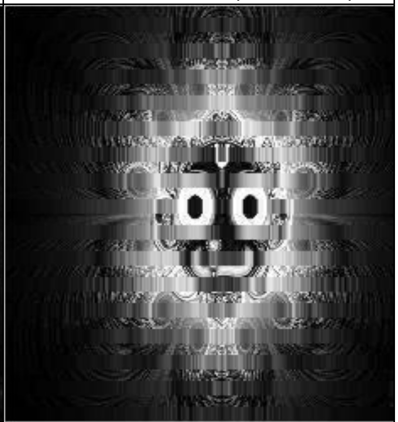
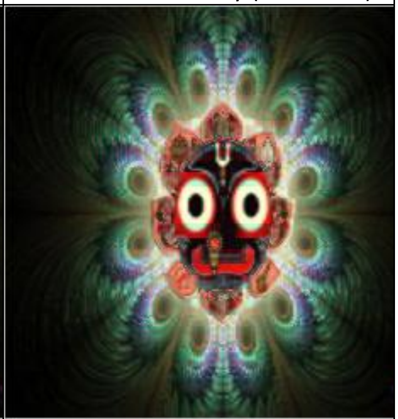
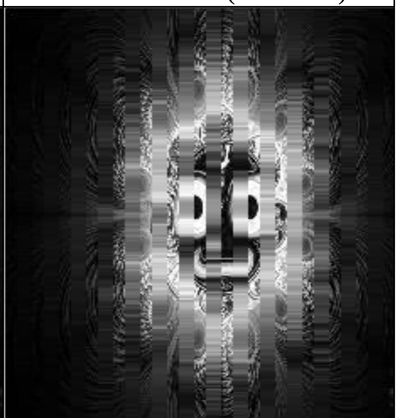
These are the experimental results of the images shown in figure 2 which were carried out on DELL N5110 with below Hardware and Software configuration.
Hardware Configuration:
1. Processor: Intel(R) Core(TM) i3-2310M CPU@ 2.10 GHz.
2. RAM: 4 GB DDR3.
3. System Type: 64 bit Operating System.

Software Configuration:
1. Operating System: Windows 7 Ultimate [64 bit].
2. Software: Matlab 7.0.0.783 (R2012b) [64 bit].

The quality of 'Color to Gray and Back' is measured using Mean Squared Error (MSE) of original color image with that of recovered color image, also the difference between original gray image and reconstructed gray image (where color information is embedded) gives an important insight through user acceptance of the methodology. This is the experimental result taken on 10 different images of different category as shown in Figure 4. Figure 5shows the sample original color image, original gray image and its gray equivalent having colors information embedded into it, and recovered color image using method 1, method 2 and method 3 for Hartley, Slant or Kekre's wavelet transform.

Figure 4: Test bed of Image used for experimentation.

		
Original Color		Original Gray
Hartley Wavelet	Slant Wavelet	Kekre's Wavelet
		
Reconstructed Gray (Method 1)	Reconstructed Gray (Method 1)	Reconstructed Gray (Method 1)

		
Recovered Color (Method 1)	Recovered Color (Method 1)	Recovered Color (Method 1)
		
Reconstructed Gray (Method 2)	Reconstructed Gray (Method 2)	Reconstructed Gray (Method 2)
		
Recoverd Color (Method 2)	Recoverd Color (Method 2)	Recoverd Color (Method 2)
		
Reconstructed Gray (Method 3)	Reconstructed Gray (Method 3)	Reconstructed Gray (Method 3)

Recoverd Color (Method 3)	Recoverd Color (Method 3)	Recoverd Color (Method 3)

Figure 5: Color to gray and Back of sample image using Method 1, Method 2 and Method 3

Table 1: MSE between Original Gray-Reconstructed Gray Image

	Hartley			Slant			Kekre		
	Method 1	Method 2	Method 3	Method 1	Method 2	Method 3	Method 1	Method 2	Method 3
Img 1	7386.90	7717.10	7549.30	7398.30	7714.80	7479.60	7465.80	7782.40	7586.30
Img 2	15899.00	15975.00	15944.00	15913.00	15978.00	15935.00	15926.00	15996.00	15959.00
Img 3	4598.70	4796.70	4709.90	4602.50	4767.40	4708.20	4675.60	4816.00	4772.50
Img 4	15067.00	15119.00	15276.00	15128.00	15170.00	15281.00	15102.00	15147.00	15288.00
Img 5	4894.40	5082.10	4951.20	4965.50	5125.10	4988.90	4960.50	5100.80	5006.80
Img 6	2154.90	2196.40	2193.60	2164.60	2193.50	2199.80	2171.40	2203.00	2207.90
Img 7	21688.00	21712.00	21723.00	21703.00	21724.00	21728.00	21694.00	21712.00	21727.00
Img 8	26716.00	26758.00	26730.00	26731.00	26764.00	26732.00	26718.00	26758.00	26731.00
Img 9	4673.50	4695.70	4697.10	4682.10	4700.20	4699.70	4682.60	4705.00	4703.90
Img 10	3414.70	3511.90	3452.30	3407.00	3519.10	3416.10	3422.30	3526.20	3451.10
Average	**10649.31**	**10756.39**	**10722.64**	**10669.50**	**10765.61**	**10716.83**	**10681.82**	**10774.64**	**10743.35**

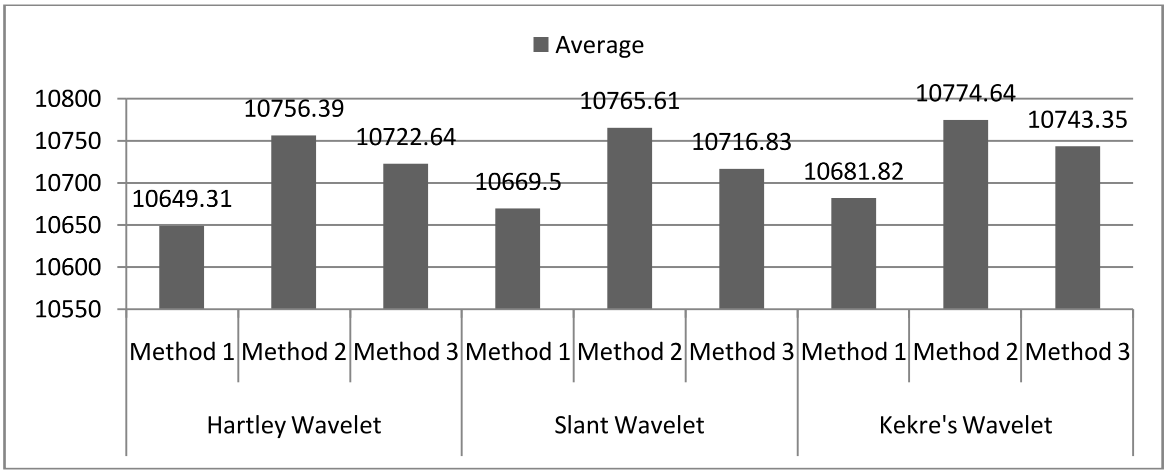


Figure 6: Average MSE of Original Gray w.r.t Reconstructed Gray for Method 1 & Method 2

Table 2: MSE between Original Color-Recovered Color Image

	Hartley Wavelet			Slant Wavelet			Kekre's Wavelet		
	Method 1	Method 2	Method 3	Method 1	Method 2	Method 3	Method 1	Method 2	Method 3
Img 1	892.1496	603.8079	680.3915	890.4221	599.5275	701.884	839.4608	564.9742	667.416
Img 2	249.2582	159.7434	185.4235	245.2057	153.6809	191.489	227.541	149.1171	170.119
Img 3	514.9844	334.423	393.6213	522.0832	339.024	404.1587	473.7449	323.3183	360.951
Img 4	277.0018	210.9004	153.0065	259.2094	203.3963	144.1533	248.1132	193.0011	141.4685
Img 5	229.9677	92.206	168.744	177.7682	64.8229	143.2	180.51	72.746	136.7483
Img 6	144.9556	102.1086	105.1292	143.0372	105.4735	102.7064	136.3717	100.799	97.8116
Img 7	336.6507	271.0535	282.4399	321.9532	265.8382	275.072	328.8107	267.1472	278.7444
Img 8	132.5979	87.5349	108.5049	128.1068	84.364	108.4743	130.4926	85.9009	108.6994
Img 9	179.1137	131.087	124.4476	180.4896	135.0845	125.2378	165.715	123.5483	116.483
Img 10	510.0717	399.2871	431.1616	512.0223	398.462	438.1092	499.31	393.741	427.2105
Average	**346.6751**	**239.2152**	**263.287**	**338.0298**	**234.9674**	**263.4485**	**323.007**	**227.4293**	**250.5652**

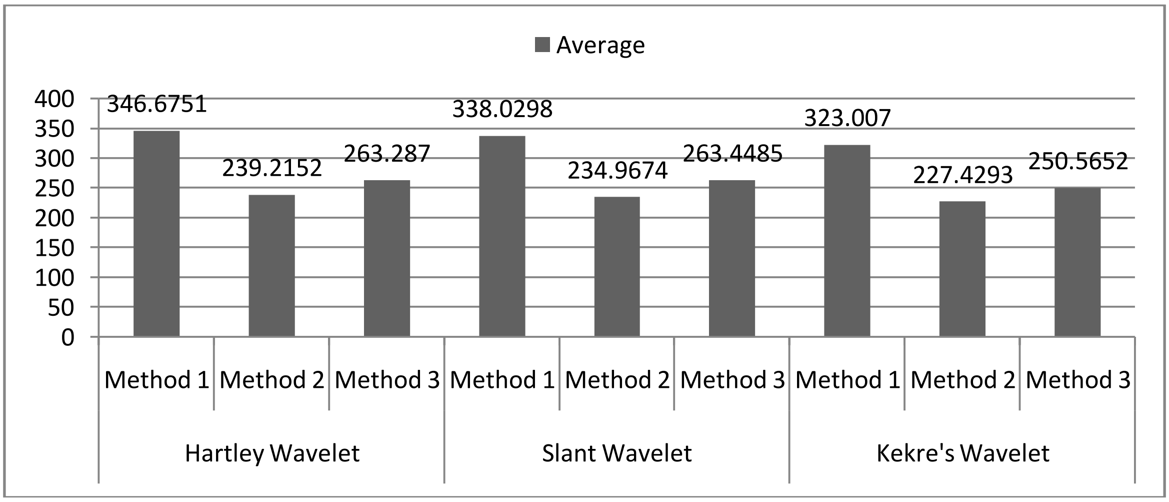


Figure 7: Average MSE of Original Color w.r.t Recovered Color for Method 1, Method 2 and Method 3

It is observed in Table 2 and Figure 7 that Kekre's waveletusing method 2 gives least MSE between Original Color Image and the Recovered Color Image. Among all considered wavelet transforms, Kekre'swavelet using method 2 gives best results. And in Table 1 and Figure 6 it is observed that Hartley wavelet using method 1 gives least MSE between Original Gray Image and the Reconstructed Gray Image. Among all considered wavelet transforms, less distortion in Gray Scale image after information embedding is observed for Hartley wavelet transform using method 1. The quality of the matted gray is not an issue, just the quality of the recovered color image matters. This can be observed that when Kekre'swavelet using method 1 is applied the recovered color image is of best quality as compared to other image transforms used in method 1, method 2 and method 3.

V. CONCLUSION

This paper have presentedthree methods to convert color image to gray image with color informationembedding into it in two different regions andmethod of retrieving color information from gray image. These methods allows one to achieve 1/3 compression and send color imagesthrough regular black and white fax systems, by embedding thecolor information in a gray image. These methods are based on wavelet transforms i.e Hartley, Slant and Kekre's wavelet usingNormalization technique. Kekre's wavelet using method 2 is proved to be the best approach with respect to other wavelet transforms using method 1, method 2 and method 3 for 'Color-to-Gray and Back'. Our next research step couldbe to test other wavelet transforms and hybrid wavelets for 'Color-to-Gray and Back'.

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BIOGRAPHICAL NOTES

H. B. Kekrehas received B.E. (Hons.) in Telecomm. Engineering. From Jabalpur Uiversity in 1958, M.Tech (Industrial Electronics) from IIT Bombay in 1960, M.S.Engg. (Electrical Engg.) from University of Ottawa in 1965 and Ph.D. (System Identification) from IIT Bombay in 1970 He has worked as Faculty of Electrical Engg. and then HOD Computer Science and Engg. at IIT Bombay. For 13 years he was working as a professor and head in the Department of Computer Engg. atThadomalShahani Engineering. College, Mumbai. Now he is Senior Professor at MPSTME, SVKM's NMIMS University. He has guided 17 Ph.Ds, more than 100 M.E./M.Tech and several B.E./B.Tech projects. His areas of interest are Digital Signal processing, Image Processing and Computer Networking. He has more than 450 papers in National / International Conferences and Journals to his credit. He was Senior Member of IEEE. Presently He is Fellow of IETE and Life Member of ISTE. Recently fifteen students working under his guidance have received best paper awards. Eight students under his guidance received Ph. D. From NMIMS University. Currently five students are working for Ph. D. Under his guidance

Sudeep D. Thepadehas Received Ph.D. Computer Engineering from SVKM's NMIMS in 2011, M.E. in Computer Engineering from University of Mumbai in 2008 with Distinction, B.E.(Computer) degree from North Maharashtra University with Distinction in 2003. He has about 10 years of experience in teaching and industry. He was Lecturer in Dept. of Information Technology at ThadomalShahani Engineering College, Bandra(w), Mumbai for nearly 04 years, then worked as Associate Professor and HoD Computer Engineering at Mukesh Patel School of Technology Management and Engineering, SVKM's NMIMS, Vile Parle(w), Mumbai. Currently he is Professor and Dean (R&D), at PimpriChinchwad College of Engineering, Pune. He is member of International Advisory Committee for many International Conferences, acting as reviewer for many referred international journals/transactions including IEEE and IET. His areas of interest are Image Processing and Biometric Identification. He has guided five M.Tech. Projects and several B.Tech projects. He more than 185 papers inInternational Conferences/Journals to his credit with a Best Paper Award at International Conference SSPCCIN-2008, Second Best Paper Award at ThinkQuest-2009, Second Best Research Project Award at Manshodhan 2010, Best Paper Award for paper published in June 2011 issue of International Journal IJCSIS (USA), Editor's Choice Awards for papers published in International Journal IJCA (USA) in 2010 and 2011.

Ratnesh N. Chaturvediis currently pursuing M.Tech. (Computer Engg.) from MPSTME, SVKM's NMIMS University, Mumbai. B.E.(Computer) degree from Mumbai University in 2009. Currently working as T.A in Computer Engineering at Mukesh Patel School of Technology Management and Engineering, SVKM's NMIMS University, VileParle(w), Mumbai, INDIA. He has about 04 years of experience in teaching. He has published papers in several international journals like IJIP, IJCA, IJAET, IJACR etc. His area of interest is Image Colorization & Information Security.