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Improved Performance for "Color to Gray and Back" using DCT-Haar, DST-Haar, Walsh-Haar, Hartley-Haar, Slant-Haar, Kekre-Haar Hybrid Wavelet Transforms

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Abstract

The paper shows performance comparison of DCT-Haar, DST-Haar, Walsh-Haar, Hartley-Haar, Slant-Haar and Kekre-Haar Hybrid Wavelet Transforms using Normalization for 'Color to Gray and Back'. The color information of the image is embedded into its gray scale version using hybrid wavelet transform [HWT] and normalization method. Instead of using the original color image for storage and transmission, gray image (Gray scale version with embedded color information) can be used, resulting into better bandwidth or storage utilization. Among the three algorithms considered the second algorithm give better performance as compared to first and third algorithm. In our experimental results second algorithm for DCT-Haar HWT using Normalization gives better performance in 'Color to gray and Back' w.r.t all other transforms in method 1, method 2 and method 3. The intent is to achieve compression of 1/3 and to store and send color images as gray image and to be able to recover the color information afterwards.

Keywords

Color Embedding, Color-to-Gray Conversion, Transforms, Hybrid Wavelet Transforms, Normalization, Compression.

1. 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.

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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 need to 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 gray image is obtained [5]-[12]. 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 using DCT-Haar, DST-Haar, Walsh-Haar, Hartley-Haar, Slant-Haar and Kekre-Haar HWT and 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 1. In method 2 the color information in normalize form is hidden in HL and HH area of first component as in figure 1 and in method 3 the color information in normalize form is hidden in LH and HH area of first component as in figure 1. Normalization is the process where each pixel value is divided by maximum pixel value to minimize the embedding error [13].

The paper is organized as follows. Section 2 describes hybrid wavelet transform generation. Section 3 presents the proposed system for "Color to Gray and Back". Section 4 describes experimental results and finally the concluding remarks and future work are given in section 5.

LL	LH
HL	HH

Figure 1: Sub-band in Transform domain

2. Hybrid Wavelet Transform

Kronecker product is also known as tensor product. Kronecker product is represented by a sign $\otimes$. The Kronecker product of 2 matrices (say A and B) is computed by multiplying each element of the 1st matrix(A) by the entire 2nd matrix(B) as in equation 1:

$$\begin{bmatrix} a1 & a2 \\ a3 & a4 \end{bmatrix} \otimes \begin{bmatrix} b1 & b2 \\ b3 & b4 \end{bmatrix} =$$

$$\begin{bmatrix} a1\begin{bmatrix} b1 & b2 \\ b3 & b4 \end{bmatrix} & a2\begin{bmatrix} b1 & b2 \\ b3 & b4 \end{bmatrix} \\ a3\begin{bmatrix} b1 & b2 \\ b3 & b4 \end{bmatrix} & a4\begin{bmatrix} b1 & b2 \\ b3 & b4 \end{bmatrix} \end{bmatrix}$$

$$= \begin{bmatrix} a1b1 & a1b2 & a2b1 & a2b2 \\ a1b3 & a1b4 & a2b3 & a2b4 \\ a3b1 & a3b2 & a4b1 & a4b2 \\ a3b3 & a3b4 & a4b3 & a4b4 \end{bmatrix} \quad \text{----(1)}$$

The hybrid wavelet [14] transform matrix of size NxN (say 'T_{CD}') can be generated from two orthogonal transform matrices (say C and D respectively with sizes pxp and qxq, where N=p*q=pq) as given by equations 2.

$$C=\begin{bmatrix} c11 & c12 & \dots & c1p \\ c21 & c22 & \dots & c2p \\ \vdots & \vdots & \vdots & \vdots \\ cp1 & cp2 & \dots & cpp \end{bmatrix} \begin{matrix} C1 \\ C2 \\ C3 \\ CP \end{matrix}$$

$$D=\begin{bmatrix} d11 & d12 & \dots & d1q \\ d21 & d22 & \dots & d2q \\ \vdots & \vdots & \vdots & \vdots \\ dq1 & dq2 & \dots & dqq \end{bmatrix}$$

----(2)

Here first 'q' rows of the hybrid wavelet transform matrix are calculated as Kronecker product of D and C1 which is given as:

For next 'q' rows of hybrid wavelet transform matrix Kronecker product of identity matrix I_q and C2 is taken which is given by equation 4:

$$I_q \otimes C2 = \begin{bmatrix} c21 & c22 & \dots & c2p & 0 & 0 & \dots & 0 & \dots & 0 & 0 & \dots & 0 \\ 0 & 0 & \dots & 0 & c21 & c22 & \dots & c2p & \dots & 0 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & c21 & c22 & \dots & c2p \end{bmatrix}$$

----(4)

Similarly the other rows of hybrid wavelet transform matrix are generated as $I_q \otimes C3$, $I_q \otimes C4$, $I_q \otimes C3$ ….. and the last 'q' row are generated as equation 5:

$$I_q \otimes CP = \begin{bmatrix} cp1 & cp2 & \dots & cpp & 0 & 0 & \dots & 0 & \dots & 0 & 0 & \dots & 0 \\ 0 & 0 & \dots & 0 & cp1 & cp2 & \dots & cpp & \dots & 0 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & \dots & cp1 & cp2 & \dots & cpp \end{bmatrix}$$

----(5)

and the final hybrid wavelet transform matrix is given by equation 6:

$$T_{cd}= \begin{bmatrix} d11c11 & d11c12 & \dots & d11c1p & d12c11 & d12c12 & \dots & d12c1p & \dots & d1qc11 & d1qc12 & \dots & d1qc1p \\ d21c11 & d21c12 & \dots & d21c1p & d22c11 & d22c12 & \dots & d22c1p & \dots & d2qc11 & d2qc12 & & d2qc1p \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & & \vdots & \vdots & \vdots & \vdots \\ dq1c11 & dq1c12 & \dots & dq1c1p & dq2c11 & dq2c12 & \dots & dq2c1p & \dots & dqqc11 & dqqc12 & \dots & dqqc1p \\ c21 & c22 & \dots & c2p & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & c21 & c22 & \dots & c2p & \dots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \dots & c21 & c22 & \dots & c2p \\ c31 & c32 & \dots & c3p & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & c31 & c32 & \dots & c3p & \dots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \dots & c31 & c32 & \dots & c3p \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ cp1 & cp2 & \dots & cpp & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & cp1 & cp2 & \dots & cpp & \dots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \dots & cp1 & cp2 & \dots & cpp \end{bmatrix}$$

----(6)

3. Proposed System

In this section, we propose a two new color-to-gray mapping algorithm and color recovery method. The 'Color to Gray and Back' has two steps as Conversion of Color to Gray Image with color embedding into gray image & Recovery of Color image back.

Color-to-gray Step

i. 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.

ii. Second & Third color component are normalized to minimize the embedding error.
iii. Hybrid wavelet transform applied to first color components of image.
iv. 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.
v. ***Method 1:*** LH to be replaced by normalized second color component, HL to be replace by normalized third color component.
Method 2: HL to be replaced by normalized second color component, HH to replace by normalized third color component.
Method 3: LH to be replaced by normalized second color component, HH to replace by normalized third color component.
vi. Inverse hybrid wavelet transform to be applied to obtain Gray image of size N x N.

Recovery Step

i. Hybrid wavelet transform to be applied on Gray image of size N x N to obtain four sub-bands as LL, LH, HL and HH.
ii. ***Method 1:*** Retrieve LH as 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.
Method 2: Retrieve HL as 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.
Method 3: Retrieve LH as 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.
iii. De-normalize Second & Third color component by multiplying it by 255.
iv. Resize Second & Third color component to NxN.
v. Inverse Hybrid wavelet transform to be applied on first color component.
vi. All three color component are merged to obtain Recovered Color Image.

4. Results and 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. This is the experimental result taken on 10 different images of different category as shown in Figure 2. Figure 3 shows the sample original color image, original gray image and its gray equivalent having colors information embedded into it, and recovered color image using method 2 for DCT-Haar HWT. As it can be observed that the gray images obtained from these methods appears almost like the original gray image, which is due to the normalizing as it reduces the embedding error.

The quality of the matted gray is not an issue, just the quality of the recovered color image matters. So, It is observed from Table 1 and Figure 4 that among all the hybrid wavelet transform tested for method 1 DCT-Haar HWT gives least MSE between Original Color Image and the Recovered Color Image.

Table 2 and Figure 5 shows that among all the hybrid wavelet transform tested for method 2 DCT-Haar HWT gives least MSE between Original Color Image and the Recovered Color Image.

And similarly from Table 3 and Figure 6 it is observed that among all the hybrid wavelet transform tested for method 3 DCT-Haar HWT gives least MSE between Original Color Image and the Recovered Color Image.

From Figure 4, Figure 5 and Figure 6 for Method 1, Method 2 and Method 3 we can observe that for DCT-Haar HWT we get the best results. To evaluate the best performance among all the three methods, the best results of all the three methods are compared with each other as in Figure 7.

From Figure 7 it can be observed that by comparing best results of Method 1, Method 2 and Method 3.

DCT-Haar HWT using Method 2 gives best results by obtaining better quality of recovered color image.

Figure 2: Test bed of Image used for experimentation.

Original Color Original Gray

Reconstructed Color Reconstructed Gray

DCT-Haar Hybrid Wavelet Transform

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

Table 1: MSE of Original Color w.r.t Recovered Color Image (Method 1)

	Hybrid Wavelet Transform					
	DCT-Haar	DST-Haar	Walsh-Haar	Hartley-Haar	Slant-Haar	Kekre-Haar
Img 1	414.157	480.937	493.514	892.150	890.423	839.461
Img 2	92.825	259.790	121.334	249.258	245.206	227.541
Img 3	231.707	297.064	280.605	514.984	522.083	473.745
Img 4	93.141	200.541	116.585	277.002	259.209	248.113
Img 5	25.574	119.680	41.930	229.968	177.768	180.510
Img 6	64.558	89.562	77.685	144.956	143.037	136.372
Img 7	271.253	491.248	278.649	336.651	321.953	328.811
Img 8	77.026	239.991	84.220	132.598	128.107	130.493
Img 9	86.345	156.403	99.888	179.114	180.490	165.715
Img10	396.064	432.576	409.920	510.072	512.022	499.310
Avg	175.265	276.779	200.433	346.675	338.030	323.007

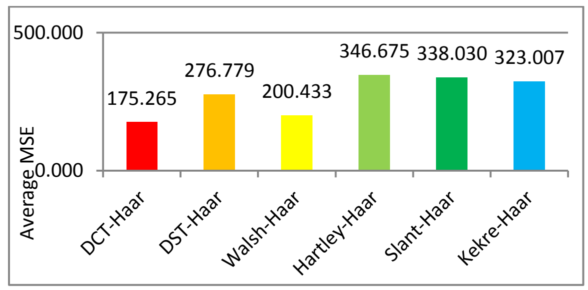

Figure 4: Average MSE of Original Color w.r.t Recovered Color (Method 1)

Table 2: MSE of Original Color w.r.t Recovered Color Image (Method 2)

	Hybrid Wavelet Transform					
	DCT-Haar	DST-Haar	Walsh-Haar	Hartley-Haar	Slant-Haar	Kekre-Haar
Img 1	349.186	385.128	386.818	603.798	599.525	564.973
Img 2	80.149	168.605	94.169	159.734	153.689	149.095
Img 3	195.693	227.849	219.305	334.411	339.004	323.339
Img 4	80.393	132.695	96.508	210.899	203.392	192.967
Img 5	21.017	69.613	25.565	92.201	64.825	72.741
Img 6	55.776	68.185	62.842	102.097	105.469	100.810
Img 7	247.077	361.961	249.004	271.053	265.834	267.120
Img 8	59.631	146.387	62.873	87.532	84.365	85.919
Img 9	75.295	110.339	83.136	131.102	135.079	123.553
Img10	339.331	359.365	347.930	399.283	398.457	393.741
Avg.	150.355	203.013	162.815	239.211	234.964	227.426

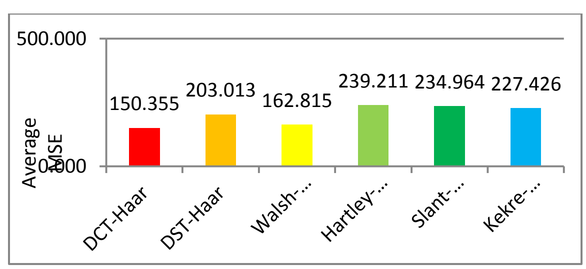

Figure 5: Average MSE of Original Color w.r.t Recovered Color (Method 2)

Table 3: MSE of Original Color w.r.t Recovered Color Image (Method 3)

	Hybrid Wavelet Transform					
	DCT-Haar	DST-Haar	Walsh-Haar	Hartley-Haar	Slant-Haar	Kekre-Haar
Img 1	374.698	406.670	423.348	680.392	701.884	667.416
Img 2	83.508	167.225	99.729	185.424	191.489	170.119
Img 3	208.155	242.064	236.821	393.621	404.162	360.951
Img 4	81.898	140.227	90.456	153.007	144.154	141.469
Img 5	22.909	71.376	35.355	168.744	143.198	136.748
Img 6	57.460	69.970	64.571	105.129	102.706	97.812
Img 7	233.690	349.338	240.045	282.440	275.071	278.744
Img 8	73.380	156.092	78.289	108.505	108.474	108.699
Img 9	75.698	110.971	82.543	124.448	125.239	116.483
Img10	361.205	377.754	368.517	431.162	438.112	427.211
Avg	157.260	209.169	171.967	263.287	263.449	250.565

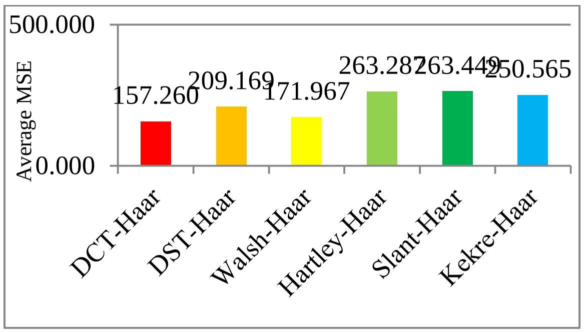

Figure 6: Average MSE of Original Color w.r.t Recovered Color (Method 3)

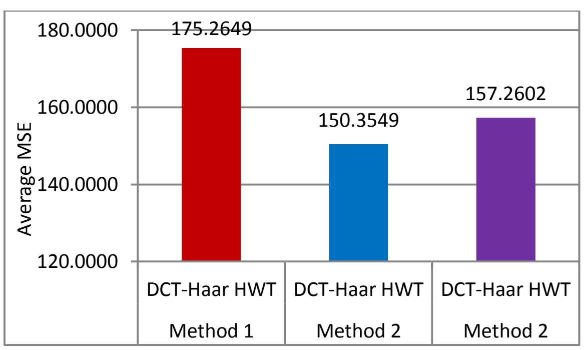

Figure 7: Average MSE comparison for Original Color w.r.t Recovered Color image for the best results of all the 3 methods

5. Conclusion and Future Work

This paper have presented three method to convert color image to gray image with color information embedding into it in two different regions and method of retrieving color information from gray image. These methods allows one to achieve 1/3 compression and to store and send color image as gray image by embedding the color information in a gray image. These methods are based on DCT-Haar, DST-Haar, Walsh-Haar, Hartley-Haar, Slant-Haar and Kekre-Haar Hybrid Wavelet Transforms using Normalization technique. DCT-Haar HWT using method 1, method 2 and method 3 are proved to be the best approach with respect to other hybrid wavelet transforms used in method 1, method 2 and method 3. But among all the methods, method 2 using DCT-Haar HWT gives the best results for 'Color-to-Gray and Back'. Our next research step could be to test other hybrid wavelet transforms for 'Color-to-Gray and Back'.

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