Improved Performance for "Color to Gray and Back" For Orthogonal transforms using Normalization

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ABSTRACT:

The paper shows performance comparison of two proposed methods with Image transforms alias Cosine, Sine, Haar & Walsh using Normalization for 'Color to Gray and Back'. The color information of the image is embedded into its gray scale version using transform 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 two algorithms considered the first algorithm give better performance as compared to the second algorithm. In our experimental results first algorithm for Discreet Cosine Transform (DCT) using Normalization gives better performance in 'Color to gray and Back' w.r.t all other transforms in method 1 and method 2. 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 afterwards.

Key Words: *Color Embedding; Color-to-Gray Conversion; Transforms; 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 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][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 two different methods of color-to-gray mapping technique using transforms 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 HL and HH area of first component as in figure 1. And in method 2 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 256 to minimize the embedding error [9].

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

II. TRANSFORMS

2.1 DCT (Discrete Cosine Transform) [9][12]

The NxN cosine transform matrix C={c(k,n)},also called the Discrete Cosine Transform(DCT),is defined as

$$c(k,n) = \begin{cases} \frac{1}{\sqrt{N}} & k = 0, 0 \le n \le N-1 \\ \sqrt{\frac{2}{N}} \cos \frac{\Pi(2n+1)k}{2N} & 1 \le k \le N-1, 0 \le n \le N-1 \end{cases} \quad \text{-----(1)}$$

The one-dimensional DCT of a sequence $\{u(n), 0 \le n \le N-1\}$ is defined as

$$v(k) = \alpha(k) \sum_{n=0}^{N-1} u(n) \cos\left[\frac{\Pi(2n+1)k}{2N}\right] \quad 0 \le k \le N-1 \quad \text{-----(2)}$$

Where $\alpha(0) = \frac{1}{\sqrt{N}}, \alpha(k) = \sqrt{\frac{2}{N}}$ *for* $1 \le k \le N-1$

The inverse transformation is given by

$$u(n) = \sum_{k=0}^{N-1} \alpha(k) v(k) \cos\left[\frac{\Pi(2n+1)k}{2N}\right], 0 \le n \le N-1 \quad \text{-----(3)}$$

2.2 DST (Discrete Sine Transform) [9]

The NxN sine transform matrix $\psi = \{\Psi(k,n)\}$, also called the Discrete Sine Transform (DST), is defined as

$$\Psi(k,n) = \sqrt{\frac{2}{N+1}} \sin \frac{\Pi(k+1)(n+1)}{N+1} \quad \text{-----(4)}$$

$0 \le k, n \le N-1$

The sine transform pair of one-dimensional sequences is defined as

$$v(k) = \sqrt{\frac{2}{N+1}} \sum_{n=0}^{N-1} u(n) \sin \frac{\Pi(k+1)(n+1)}{N+1} \quad 0 \le k \le N-1 \quad \text{-----(5)}$$

The inverse transformation is given by

$$u(n) = \sqrt{\frac{2}{N+1}} \sum_{n=0}^{N-1} v(k) \sin \frac{\Pi(k+1)(n+1)}{N+1} \quad 0 \le n \le N-1 \quad \text{-----(6)}$$

2.3 Haar Transfrom [9][10]

The Haar wavelet's mother wavelet function φ (t) can be described as

$$\varphi(t) = \begin{cases} 1 & , 0 \le t \le \frac{1}{2} \\ -1 & , \frac{1}{2} \le t \le 1 \\ 0 & , Otherwise \end{cases} \quad \text{-----(7)}$$

And its scaling function $\varphi(t)$ can be described as,

$$\varphi(t) = \begin{cases} 1 & , 0 \le t \le 1 \\ 0 & , Otherwise \end{cases} \quad \text{-----(8)}$$

2.4 Walsh Transform [9][11][12]

Walsh transform matrix is defined as a set of N rows, denoted Wj, for j = 0, 1, ..., N - 1, which have the following properties[9]

1) Wj takes on the values +1 and -1.
2) Wj[0] = 1 for all j.
3) Wj xWkT =0, for $j \neq k$ and Wj xWKT, Wj has exactly j zero crossings, for j = 0, 1, ...N-1.
4) Each row Wj is even or odd with respect to its midpoint.
5) Transform matrix is defined using a Hadamard matrix of order N. The Walsh transform matrix row is the row of the Hadamard matrix specified by the Walsh code index, which must be an integer in the
6) range [0... N-1]. For the Walsh code index equal to an integer j, the respective Hadamard output code has exactly j zero crossings, for j = 0, 1... N - 1.

III. PROPOSED SYSTEM

In this section, we propose a two new 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. Transform i.e. DCT, DST, Haar or Walsh 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 replace by normalized third color component.
6. Inverse 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. Transform to be applied on Gray image of size N x N to obtain four subbands as LL, LH, HL and HH.
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.
3. De-normalize Second & Third color component by multiplying it by 256.
4. Resize Second & Third color component to NxN.
5. Inverse 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. Transform i.e. DCT, DST, Haar or Walsh 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 replace by normalized third color component.
6. Inverse Transform to be applied to obtain Gray image of size N x N.

3.2.2 Recovery Step

1. Transform to be applied on Gray image of size N x N to obtain four subbands as LL, LH, HL and HH.
2. 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.
3. De-normalize Second & Third color component by multiplying it by 256.
4. Resize Second & Third color component to NxN.
5. Inverse Transform to be applied on first color component.
6. All three color component are merged to obtain Recovered Color Image.

IV. Results & Discursion

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 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 1 and method 2 for DCT, DST, Haar and Walsh transform. As it can be observed that the gray images obtained from these methods does not have any matting effect it does not give any clue that something is hidden in gray image, which is due to the normalizing as it reduces the embedding error.

Figure 2: Test bed of Image used for experimentation.

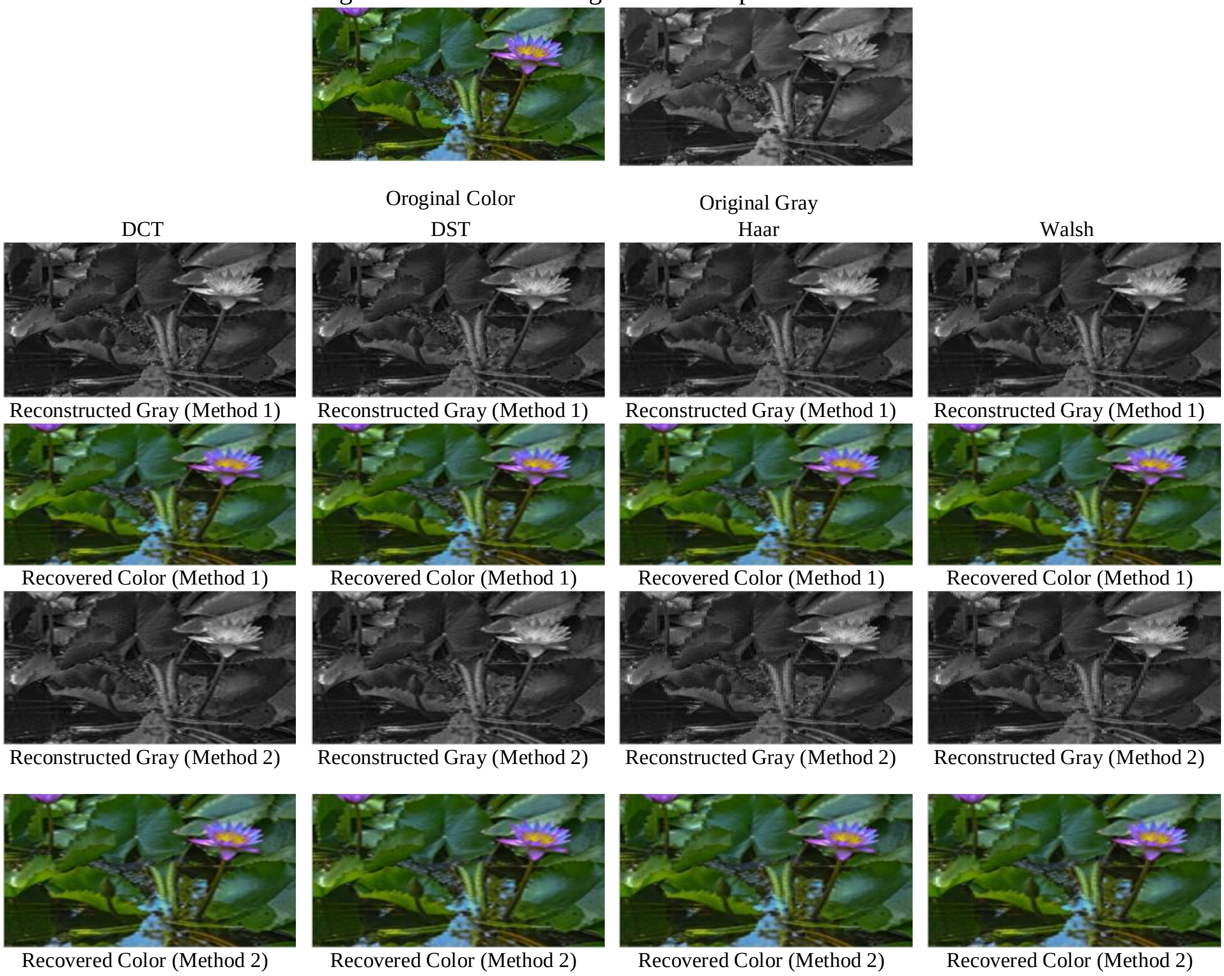

Figure 3: Color to gray and Back of sample image using Method 1 and Method 2

Table 1: MSE between Original Gray-Reconstructed Gray Image

	DCT		DST		Haar		Walsh	
	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
Img 1	8166.1	8121.3	8163.3	8119.9	8094.8	8025	8094.8	8025
Img 2	16102	16085	16098	16083	16081	16056	16081	16056
Img 3	5009.7	4999.3	5007.6	4997.9	4960.3	4952.8	4960.3	4952.9
Img 4	15365	15364	15353	15359	15340	15354	15340	15354
Img 5	5176.4	5174.5	5176.6	5174.6	5169.9	5157.2	5169.9	5157.2
Img 6	2275.5	2270.8	2274.9	2270.6	2264.1	2258.5	2264.1	2258.5
Img 7	21686	21713	21673	21701	21687	21707	21687	21707
Img 8	26794	26779	26777	26766	26789	26776	26789	26776
Img 9	4736.3	4734.8	4735.7	4732.4	4730.1	4728.5	4730.2	4728.6
Img 10	3586.7	3565.3	3586.9	3565.7	3572.5	3544.6	3572.5	3544.6
Average	10889.77	10880.7	10884.6	10877.01	10868.87	10855.96	10868.88	10855.98

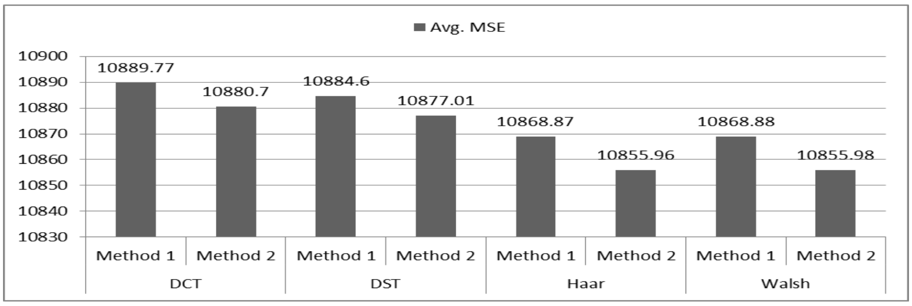

Figure 4: Average MSE of Original Gray w.r.t Reconstructed Gray for Method 1 & Method 2

Table 2: MSE between Original Color-Recovered Color Image

	DCT		DST		Haar		Walsh	
	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
Img 1	342.0067	366.6414	342.9398	367.2088	386.8236	423.3483	386.8729	423.3483
Img 2	75.8286	81.4437	77.9538	82.28	94.1871	99.7293	94.2068	99.7293
Img 3	192.5905	203.287	193.5373	204.4691	219.2903	236.8208	219.3281	236.8208
Img 4	79.1031	80.6879	81.9712	82.5248	96.5088	90.456	96.511	90.456
Img 5	20.5683	22.0376	20.461	21.947	25.5576	35.3552	25.5559	35.3552
Img 6	54.5566	56.3903	54.8799	56.5376	62.8413	64.5713	62.8463	64.5713
Img 7	85.0285	78.7563	91.6735	85.1475	88.1694	86.4924	88.1612	86.4924
Img 8	35.1006	45.3876	39.0699	49.1969	40.256	50.2221	40.2682	50.2221
Img 9	39.6396	40.2827	41.0451	41.9209	47.9449	48.5895	47.94	48.5895
Img 10	145.4311	155.213	145.3459	154.9879	155.5559	167.9644	155.5542	167.9644
Average	106.9854	113.0128	108.8877	114.6221	121.7135	130.3549	121.7245	130.3549

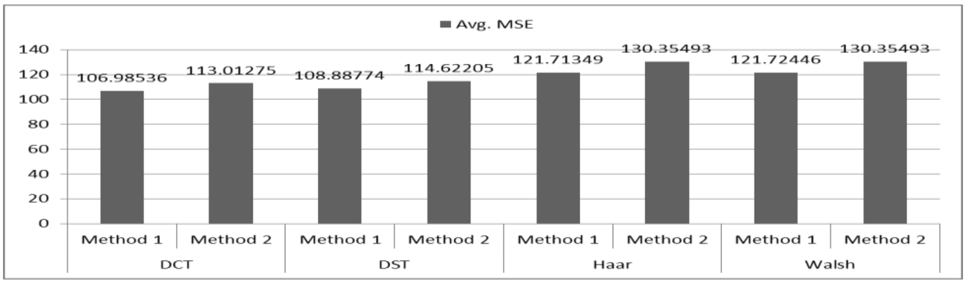

Figure 5: Average MSE of Original Color w.r.t Recovered Color for Method 1 & Method

It is observed in Table 2 and Figure 5 that DCT using method 1 gives least MSE between Original Color Image and the Recovered Color Image. Among all considered image transforms, DCT using method 1 gives best results. And in Table 1 and Figure 4 it is observed that Haar using method 2 gives least MSE between Original Gray Image and the Reconstructed Gray Image. Among all considered image transforms, less distortion in Gray Scale image after information embedding is observed for Haar Transform using method 2. 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 DCT using method 1 is applied the recovered color image is of best quality as compared to other image transforms used in method 1 and method 2.

V. CONCLUSION

This paper have presented two 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 send color images through regular black and white fax systems, by embedding the color information in a gray image. These methods are based on transforms i.e DCT, DST, Haar, Walsh and Normalization technique. DCT using method 1 is proved to be the best approach with respect to other transforms using method 1 and method 2 for 'Color-to-Gray and Back' Our next research step could be to test wavelet transforms and hybrid wavelets for 'Color-to-Gray and Back'.

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BIOGRAPHICAL NOTE:

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