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

H. B. Kekre¹, Sudeep D. Thepade², Ratnesh N. Chaturvedi³

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.

Keywords

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1. Introduction

Digital images can be classified roughly to 24 bit color images and 8 bit 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 restore 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][10], 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.

<table>
<thead>
<tr>
<th>LL</th>
<th>LH</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL</td>
<td>HH</td>
</tr>
</tbody>
</table>

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:

\[
\begin{bmatrix}
  a_1 & a_2 \\
  a_3 & a_4
\end{bmatrix} \otimes
\begin{bmatrix}
  b_1 & b_2 \\
  b_3 & b_4
\end{bmatrix} = \\
\begin{bmatrix}
  a_1b_1 & a_1b_2 & a_2b_1 & a_2b_2 \\
  a_1b_3 & a_1b_4 & a_2b_3 & a_2b_4 \\
  a_3b_1 & a_3b_2 & a_4b_1 & a_4b_2 \\
  a_3b_3 & a_3b_4 & a_4b_3 & a_4b_4
\end{bmatrix}
\]

\[\text{----(1)}\]

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 \(N=p\times q=pq\)) as given by equations 2.

\[
C = \\
\begin{bmatrix}
  c_{11} & c_{12} & \cdots & c_{1p} \\
  c_{21} & c_{22} & \cdots & c_{2p} \\
  \vdots & \vdots & \ddots & \vdots \\
  c_{p1} & c_{p2} & \cdots & c_{pp}
\end{bmatrix}
\]

\[
D = \\
\begin{bmatrix}
  d_{11} & d_{12} & \cdots & d_{1q} \\
  d_{21} & d_{22} & \cdots & d_{2q} \\
  \vdots & \vdots & \ddots & \vdots \\
  d_{q1} & d_{q2} & \cdots & d_{qq}
\end{bmatrix}
\]

\[\text{----(2)}\]

\[
I_q \otimes C = \\
\begin{bmatrix}
  0 & \cdots & 0 & \cdots & 0 \\
  \vdots & \ddots & \vdots & \ddots & \vdots \\
  0 & \cdots & 0 & \cdots & 0
\end{bmatrix}
\]

\[\text{----(4)}\]

Similarly the other rows of hybrid wavelet transform matrix are generated as \(I_q \otimes C_3\), \(I_q \otimes C_4\), \(I_q \otimes C_3\) ...... and the last ‘q’ row are generated as equation 5:

\[
I_q \otimes C_P = \\
\begin{bmatrix}
  0 & \cdots & 0 & \cdots & 0 \\
  \vdots & \ddots & \vdots & \ddots & \vdots \\
  0 & \cdots & 0 & \cdots & 0
\end{bmatrix}
\]

\[\text{----(5)}\]

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

\[
T_{CD} = \\
\begin{bmatrix}
  C & \otimes & D \\
  \cdots & \ddots & \cdots \\
  \cdots & \cdots & C & \otimes & D
\end{bmatrix}
\]

\[\text{----(6)}\]

## 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

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.
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 figure 1 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 subbands 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 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.

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

<table>
<thead>
<tr>
<th>Hybrid Wavelet Transform</th>
<th>DCT-Haar</th>
<th>DST-Haar</th>
<th>Walsh-Haar</th>
<th>Hartley-Haar</th>
<th>Slant-Haar</th>
<th>Kekre-Haar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Img 1</td>
<td>414.157</td>
<td>480.937</td>
<td>493.514</td>
<td>892.150</td>
<td>890.423</td>
<td>839.461</td>
</tr>
<tr>
<td>Img 2</td>
<td>92.825</td>
<td>259.790</td>
<td>121.334</td>
<td>249.258</td>
<td>245.206</td>
<td>227.541</td>
</tr>
<tr>
<td>Img 3</td>
<td>231.707</td>
<td>297.064</td>
<td>280.605</td>
<td>514.984</td>
<td>522.083</td>
<td>473.745</td>
</tr>
<tr>
<td>Img 4</td>
<td>93.141</td>
<td>200.541</td>
<td>116.585</td>
<td>229.968</td>
<td>177.668</td>
<td>180.510</td>
</tr>
<tr>
<td>Img 5</td>
<td>25.574</td>
<td>89.562</td>
<td>77.685</td>
<td>144.956</td>
<td>143.037</td>
<td>136.372</td>
</tr>
<tr>
<td>Img 7</td>
<td>271.253</td>
<td>491.248</td>
<td>278.649</td>
<td>336.651</td>
<td>321.953</td>
<td>328.811</td>
</tr>
<tr>
<td>Img 8</td>
<td>77.026</td>
<td>239.991</td>
<td>84.220</td>
<td>132.598</td>
<td>128.107</td>
<td>130.493</td>
</tr>
<tr>
<td>Avg</td>
<td>175.265</td>
<td>276.779</td>
<td>200.433</td>
<td>346.675</td>
<td>338.030</td>
<td>323.007</td>
</tr>
</tbody>
</table>

Figure 2: Test bed of Image used for experimentation.

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

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

<table>
<thead>
<tr>
<th>Hybrid Wavelet Transform</th>
<th>DCT-Haar</th>
<th>DST-Haar</th>
<th>Walsh-Haar</th>
<th>Hartley-Haar</th>
<th>Slant-Haar</th>
<th>Kekre-Haar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Img 1</td>
<td>349.186</td>
<td>385.128</td>
<td>386.818</td>
<td>503.798</td>
<td>599.525</td>
<td>564.973</td>
</tr>
<tr>
<td>Img 2</td>
<td>80.149</td>
<td>168.605</td>
<td>94.169</td>
<td>159.734</td>
<td>153.689</td>
<td>149.095</td>
</tr>
<tr>
<td>Img 3</td>
<td>195.693</td>
<td>227.849</td>
<td>219.305</td>
<td>334.411</td>
<td>339.004</td>
<td>323.339</td>
</tr>
<tr>
<td>Img 4</td>
<td>80.393</td>
<td>132.695</td>
<td>96.508</td>
<td>210.899</td>
<td>203.392</td>
<td>192.967</td>
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<tr>
<td>Img 5</td>
<td>21.017</td>
<td>69.613</td>
<td>25.565</td>
<td>92.201</td>
<td>64.825</td>
<td>72.741</td>
</tr>
<tr>
<td>Img 6</td>
<td>55.776</td>
<td>68.185</td>
<td>62.842</td>
<td>102.097</td>
<td>105.469</td>
<td>100.810</td>
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<td>Img 7</td>
<td>247.077</td>
<td>361.961</td>
<td>249.004</td>
<td>271.053</td>
<td>265.834</td>
<td>267.120</td>
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<tr>
<td>Img 8</td>
<td>59.631</td>
<td>146.387</td>
<td>62.873</td>
<td>87.532</td>
<td>84.365</td>
<td>85.913</td>
</tr>
<tr>
<td>Img 9</td>
<td>75.295</td>
<td>110.339</td>
<td>83.136</td>
<td>131.102</td>
<td>135.079</td>
<td>123.553</td>
</tr>
<tr>
<td>Img10</td>
<td>339.331</td>
<td>359.365</td>
<td>347.930</td>
<td>399.283</td>
<td>398.457</td>
<td>393.741</td>
</tr>
<tr>
<td>Avg</td>
<td>150.355</td>
<td>203.013</td>
<td>162.815</td>
<td>239.211</td>
<td>234.964</td>
<td>227.426</td>
</tr>
</tbody>
</table>

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

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)

<table>
<thead>
<tr>
<th>Image</th>
<th>DCT-Haar</th>
<th>DST-Haar</th>
<th>Walsh-Haar</th>
<th>Hartley-Haar</th>
<th>Slant-Haar</th>
<th>Kekre-Haar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Img 1</td>
<td>374.698</td>
<td>406.670</td>
<td>423.348</td>
<td>680.392</td>
<td>701.884</td>
<td>667.416</td>
</tr>
<tr>
<td>Img 2</td>
<td>83.508</td>
<td>167.225</td>
<td>99.729</td>
<td>185.424</td>
<td>191.489</td>
<td>170.119</td>
</tr>
<tr>
<td>Img 3</td>
<td>208.155</td>
<td>242.064</td>
<td>236.821</td>
<td>393.621</td>
<td>404.162</td>
<td>360.951</td>
</tr>
<tr>
<td>Img 4</td>
<td>81.898</td>
<td>140.227</td>
<td>90.456</td>
<td>153.007</td>
<td>144.154</td>
<td>141.469</td>
</tr>
<tr>
<td>Img 5</td>
<td>22.909</td>
<td>71.376</td>
<td>35.355</td>
<td>168.744</td>
<td>143.198</td>
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<tr>
<td>Img 6</td>
<td>57.460</td>
<td>69.970</td>
<td>64.571</td>
<td>105.129</td>
<td>102.706</td>
<td>97.812</td>
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<tr>
<td>Img 7</td>
<td>233.690</td>
<td>349.338</td>
<td>240.045</td>
<td>275.071</td>
<td>278.744</td>
<td>250.565</td>
</tr>
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<td>Img 8</td>
<td>73.380</td>
<td>156.092</td>
<td>78.289</td>
<td>108.474</td>
<td>108.699</td>
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<td>Img 9</td>
<td>75.698</td>
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<td>124.448</td>
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<tr>
<td>Avg</td>
<td>157.260</td>
<td>209.169</td>
<td>171.967</td>
<td>263.286</td>
<td>263.449</td>
<td>250.565</td>
</tr>
</tbody>
</table>

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’.

References


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