Walsh, Sine, Haar& Cosine Transform With Various Color Spaces for 'Color to Gray and Back'

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Abstract

The paper shows performance comparison of various color spaces with Image transforms alias Walsh, Cosine, Sine&Haar for 'Color to Gray and Back'. The color information of the image is embedded into its gray scale version/equivalent [1][2][3]. Instead of using the original color image for storage and transmission, matted gray (Gray scale version with embedded color information) can be used, resulting into better bandwidth or storage utilization. Total twenty-eight variations of the algorithm for 'Color to Gray and Back' are proposed and evaluated for qualitative performance using four image transforms and seven color spaces (RGB, YCbCr, YCgCb, YUV, YIQ, XYZ and Kekre's LUV) [4]. Among all considered image transforms and color spaces, Discreet Cosine Transform (DCT) gives better performance with YCbCr color space in 'Color to gray and Back'.

Key Words: Color Embedding, Color-to-Gray Conversion, Transforms, Color Spaces, Compression.

1. INTRODUCTION

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 matted gray image is obtained [2]. This also reduces the bandwidth required to transmit the image over the network. Matted gray image, which is obtained from color image, can be printed using a black-and-white printer or transmitted using a conventional fax machine. This matted gray image then can be used to retrieve its original color image.

In earlier researches, this has been done in YCbCr[2] and Kekre's-LUV [1] color spaces using Haar Wavelet Transform. Further, In [3] Haar, Kekre& Walsh Wavelet transforms are employed for 'Color to Gray and Back'.

Here the better performance of 'Color to Gray and Back' using Haar [5], Walsh[6], Discrete Cosine Transform(DCT) [7] and Discrete Sine Transform(DST) [8] in various color spaces like RGB, YCbCr, YCgCb, YUV, YIQ, XYZ and Kekre's LUV[4].

The paper is organized as follows. Section 2 describes various color spaces. Section 3 presents method to convert color-to-matted gray image. Section 4 presents method to recover color image. Section 5 describes experimental results and finally the concluding remark are given in section 6.

2. COLOR SPACES

Here along with RGB six other color space alias YCbCr, YCgCb, YUV, YIQ, XYZ and Kekre's LUV are also employed for 'Color-to-Gray and Back'.

2.1 Kekre's LUV Color Space(K-LUV)

Kekre's LUV color space [4] is special form of Kekre Transform, where L is luminance and U and V are chromaticity value of color image. RGB to LUV conversion matrix is given in equation 1.

$$\begin{vmatrix} L \\ U \\ V \end{vmatrix} = \begin{vmatrix} 1 & 1 & 1 \\ -2 & 1 & 1 \\ 0 & -1 & 1 \end{vmatrix} \bullet \begin{vmatrix} R \\ G \\ B \end{vmatrix} \text{--------------} (1)$$

The LUV to RGB conversion matrix is given in equation 2.

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = \begin{vmatrix} 1 & -2 & 0 \\ 1 & 1 & -1 \\ 1 & 1 & 1 \end{vmatrix} \bullet \begin{vmatrix} L/3 \\ U/6 \\ V/2 \end{vmatrix} \text{-------}(2)$$

2.2 YCbCr Color Space

In YCbCr [4], Y is luminance and Cb and Cr are chromaticity value of color image. To get YCbCr components, convert RGB to YCbCr components. The RGB to YCbCr conversion matrix is given in equation 3.

$$\begin{vmatrix} Y \\ Cb \\ Cr \end{vmatrix} = \begin{vmatrix} 0.2989 & 0.5866 & 0.1145 \\ -0.1688 & -0.3312 & 0.5000 \\ 0.5000 & -0.4184 & -0.0816 \end{vmatrix} \bullet \begin{vmatrix} R \\ G \\ B \end{vmatrix} \text{-------}(3)$$

The YCbCr to RGB conversion matrix is given in equation 4.

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = \begin{vmatrix} 1 & -0.0010 & 1.4020 \\ 1 & -0.3441 & -0.7140 \\ 1 & 1.7718 & 0.0010 \end{vmatrix} \bullet \begin{vmatrix} Y \\ Cb \\ Cr \end{vmatrix} \text{-------}(4)$$

2.3 YUV Color Space

The YUV color model [4] is used in PAL, NTSC, and SECAM composition color video standard. Where Y is luminance and U and V are chromaticity value of color image. To get YUV components, convert RGB to YUV components. The RGB to YUV conversion matrix is given in equation 5.

$$\begin{vmatrix} Y \\ U \\ V \end{vmatrix} = \begin{vmatrix} 0.299 & 0.587 & 0.144 \\ -0.14713 & -0.22472 & 0.436 \\ 0.615 & -0.51498 & 0.10001 \end{vmatrix} \bullet \begin{vmatrix} R \\ G \\ B \end{vmatrix} \text{----(5)}$$

The YUV to RGB conversion matrix is given in equation 6.

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = \begin{vmatrix} 0.7492 & -0.50901 & 1.1398 \\ 1.0836 & -0.22472 & -0.5876 \\ 0.97086 & 1.9729 & -0.000015 \end{vmatrix} \bullet \begin{vmatrix} Y \\ U \\ V \end{vmatrix} \text{----(6)}$$

2.4 YIQ Color Space

The YIQ color space [4][11] is derived from YUV color space and is optionally used by NTSC composite color video standard. The `I` stands for phase and `Q` for quadrature which is the modulation method used to transmit the color information. RGB to YIQ conversion matrix is given in equation 7.

$$\begin{vmatrix} Y \\ I \\ Q \end{vmatrix} = \begin{vmatrix} 0.299 & 0.587 & 0.144 \\ 0.595716 & -0.274453 & -0.32126 \\ 0.211456 & -0.522591 & 0.31135 \end{vmatrix} \bullet \begin{vmatrix} R \\ G \\ B \end{vmatrix} \text{----(7)}$$

The YIQ to RGB conversion matrix is given in equation 8.

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = \begin{vmatrix} 1 & 0.9563 & 0.6210 \\ 1 & -0.2721 & -0.6474 \\ 1 & -1.107 & 1.7046 \end{vmatrix} \bullet \begin{vmatrix} Y \\ I \\ Q \end{vmatrix} \text{-----(8)}$$

2.5 YCgCb Color Space

To get YCgCb [4][10] components, convert RGB to YCgCb components. The RGB to YCgCb conversion matrix is given in equation 9.

$$\begin{vmatrix} Y \\ Cg \\ Cb \end{vmatrix} = \begin{vmatrix} 1 & 1 & 1 \\ 1 & -1 & 0 \\ 1 & 0 & -1 \end{vmatrix} \bullet \begin{vmatrix} R \\ G \\ B \end{vmatrix} \text{-------(9)}$$

The YCgCb to RGB conversion matrix is given in equation 10.

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = \begin{vmatrix} 1 & 1 & 1 \\ 1 & -2 & 0 \\ 1 & 0 & -2 \end{vmatrix} \bullet \begin{vmatrix} Y/3 \\ Cg/3 \\ Cb/3 \end{vmatrix} \text{-------(10)}$$

2.6 XYZ Color Space

The RGB to XYZ [4][9] conversion matrix is given in equation 11.

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = \begin{vmatrix} 0.412453 & 0.357580 & 0.180423 \\ 0.212671 & 0.71160 & 0.072169 \\ 0.019334 & 0.119193 & 0.950227 \end{vmatrix} \bullet \begin{vmatrix} R \\ G \\ B \end{vmatrix} \text{------(11)}$$

The XYZ to RGB conversion matrix is given in equation 12.

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = \begin{vmatrix} 3.240479 & -1.53750 & -0.498535 \\ -0.969256 & 1.875992 & 0.041556 \\ 0.055648 & -0.204043 & 1.057311 \end{vmatrix} \bullet \begin{vmatrix} X \\ Y \\ Z \end{vmatrix} \text{------(12)}$$

3. CONVERSION OF COLOR TO MATTED GRAY IMAGE

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. Here the transform-based mapping method is elaborated as per the following steps.[1][2][3]

I. Image to be converted to desired color space of size N x N i.e. K-LUV, YIQ, YUV, XYZ, YCbCr and YCgCb or kept in RGB.
II. First color component is kept as it is and second & third color component are resized to N/2 x N/2.
III. Transform i.e. DCT, DST, Haar or Walsh to be applied to all the components of image.
IV. First component to be divided into four subbands: corresponding to the low pass [LL], vertical [LH], horizontal [HL], and diagonal [HH] subbands, respectively.
V. LH to be replaced by second color component, HL to replace by third color component and HH by zero.
VI. Inverse Transform to be applied to obtain Matted Gray image of size N x N.

4. Recovery of Color Image

One nice feature of the proposed embedding method is the ability to recover the color from the matted gray image (gray scale version with embedded color information).For that, reverse all steps in the color-to-gray mapping. [1][2][3]

I. Transform to be applied on Matted Gray image of size N x N to obtain four subbands as LL, LH, HL and HH.
II. Retrieve LL as first color component, LH as second color component and HL as third color component of size N/2 x N/2.
III. Inverse Transform to be applied on all three color component.
IV. All three color component are resized to N x N.
V. All three color component are merged to obtain Recovered Color Image.
VI. If not in RGB, convert recovered color image to RGB color space.

5. RESULTS & DISCUSSION

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 matted 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 Fig 1. Fig 2 shows the conversion of sample original color image to its matted gray equivalent having colors embedded into it, and matted gray to recovered color image.

FIGURE 1: Test bed of Image used for experimentation.

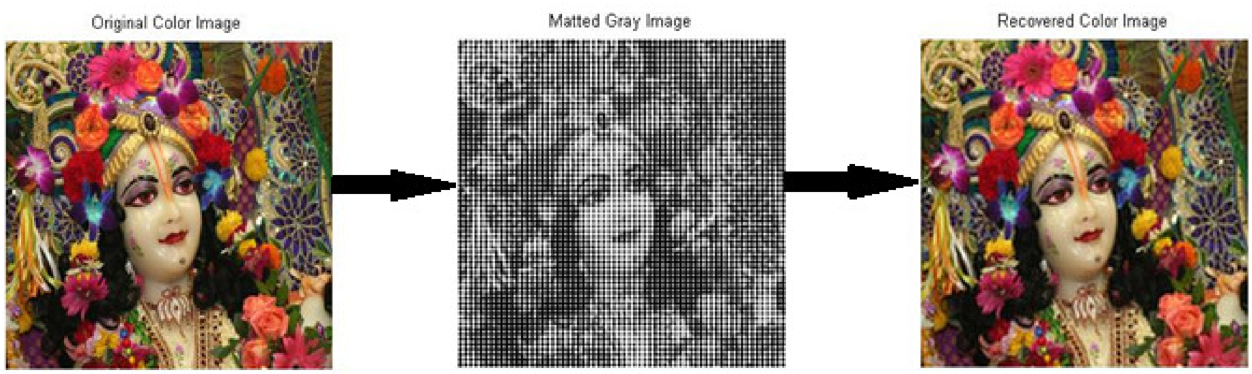

FIGURE 2: Conversion of Original Color to Matted Gray and Matted Gray to Recovered Color Image

It is observed in Fig 3 that YCbCr color space shows the least MSE between Original Color Image and the Recovered Color Image for the Transforms [DCT, DST, Haar, Walsh]. As observed in Fig 4, YUV and YIQ color spaces show the least MSE between Original Gray Image and the Matted Gray Image for the Transforms [DCT, DST, Haar, Walsh], indicating better performance as compared to other considered color spaces.

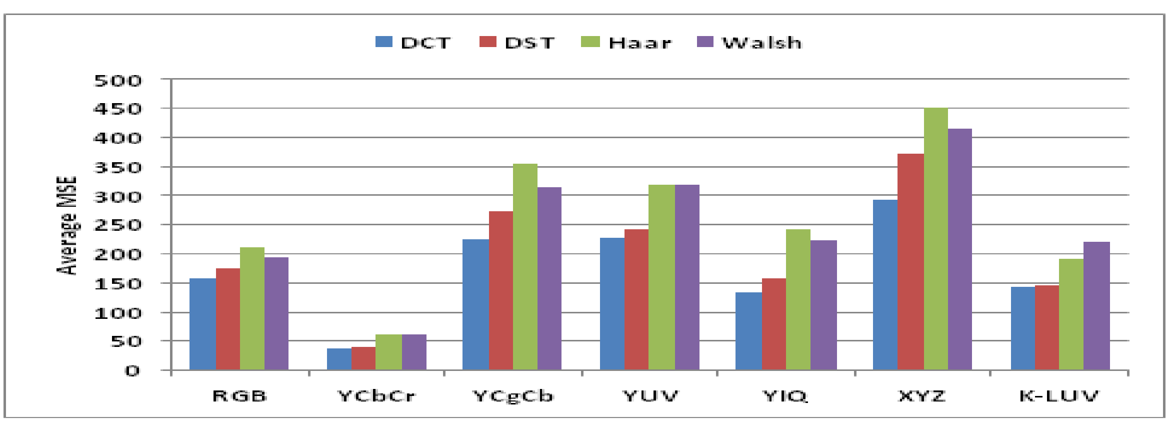

FIGURE 3: MSE between Original Color-Recovered Color Image

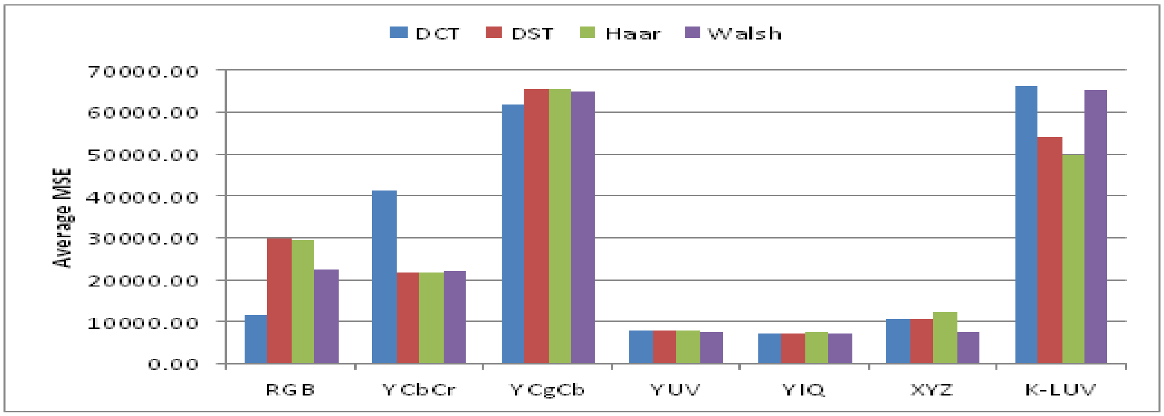

FIGURE 4 : MSE between Original Gray-Matted Gray Image

It is observed in Fig 5 that DCT gives least MSE between Original Color Image and the Recovered Color Image in any of the color space of the image. Among all cosidered image transforms, DCT gives best results. And in Fig 6 it is observed that Haar gives least MSE between Original Gray Image and the Matted Gray Image in any of the color space of the image. Among all considered image transforms, less distortion in Gray Scale image after information embedding is observed for Haar Transform.

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 is applied on YCbCr color space the recovered color image is of best quality as compared to other image transforms and color spaces.

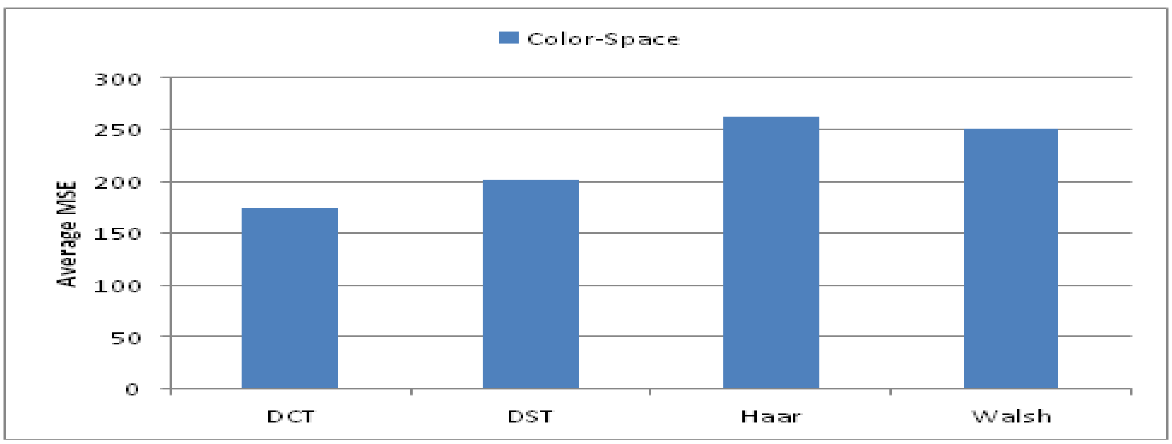

FIGURE 5 : Average MSE's of Original Color-Recovered Color Image of Color Spaces w.r.t Transform

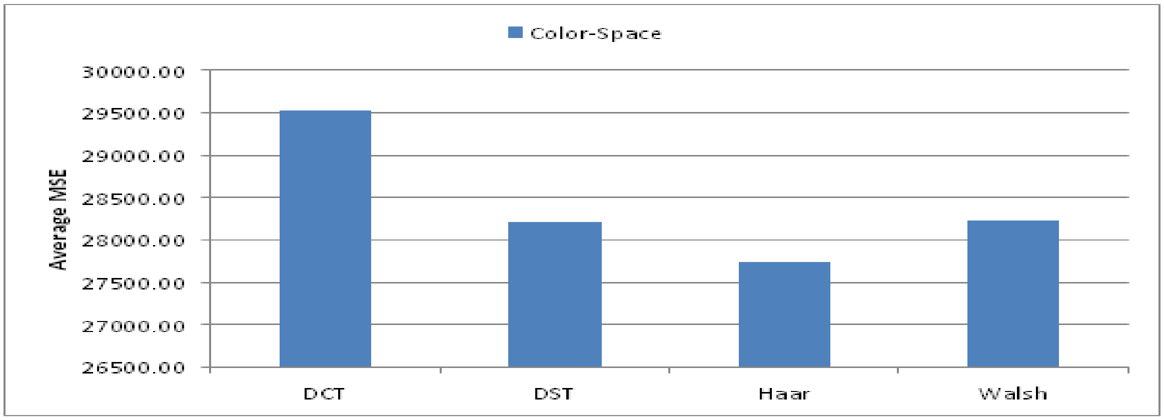

FIGURE 6 : Average MSE's of Original Gray-Matted Gray Image of Color Spaces w.r.t Transform

6. CONCLUSION

This paper have presented a method to convert image to matted gray with color information embedding into it and method of retrieving color information from matted gray image. The method allows one to send color images through regular black and white fax systems, by embedding the color information in a gray image. The method is based on transforms i.e DCT, DST, Haar, Walsh and color spaces alias RGB, YCbCr, YCgCb, YUV, YIQ, XYZ and Kekre's LUV. The YCbCr color space is proved to be better with DCT for 'Color-to-Gray and Back' Our next research step could be to test hybrid transforms, wavelet transforms and hybrid wavelets for 'Color-to-Gray and Back'.

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