International Journal of Soft Computing and Engineering (IJSCE)
ISSN: 2231-2307, Volume-1 Issue-4, September 2011

Performance Analysis of Various Window Sizes for Colorization of Grayscale Images using LBG and KFCG Vector Quantization Codebooks in RGB and Kekre's LUV Color Spaces

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Abstract— Colorization is a computer aided process of adding colors to a grayscale image or videos. The paper presents use of assorted window sizes and their impact on colorization of grayscale images using Vector Quantization (VQ) Codebook generation techniques in different color spaces such as RGB and Kekre's LUV. The paper also analyses the performance of Vector Quantization Algorithms Linde Buzo and Gray Algorithm (LBG) and Kekre's Fast Codebook Generation Algorithm (KFCG) for colorization of grayscale images. Experimentation is conducted on both RGB and Kekre's LUV color space for the different pixel windows of sizes 1x2, 2x1, 2x2, 2x3, 3x2, 3x3, 1x3, 3x1, 2x4, 4x2, 1x4 and 4x1 to compare results obtained across various grid sizes

Index Terms— Color palette, Color spaces, Vector Quantization, LBG, KFCG.

I. INTRODUCTION

There was a time when all images were solely grayscale due to limitation in technology. Color images always provide more clear information than grayscale images. Coloring of old Black and White movies and rare images of monuments, celebrities is one of the interesting applications of colorization of gray scale images. The color details in the images can be utilized for analysis and study of particular image in the applications like medical tomography, information security, image segmentation, etc.

Many techniques have been proposed to perform the task of coloring grayscale image as described in [1,2,3]. But all of these techniques have inherent drawback of needing certain amount of human interaction such as selecting a color from color palette, choosing a seed pixel and segmenting the regions of image for colorization. The main purpose of this paper is to reduce human interaction and achieve the effect of colorization of grayscale images. All that is needed is a source image of similar feature as of input grayscale image to be colored [20]. Also the hindrance of needing source color image to be bigger than the target to be colored grayscale image [3,19,20] is removed by use of Vector Quantization based on colorization process discussed here.

Colors perceived in an object are determined by nature of light reflected from the object. Due to the structure of human eye, all colors are seen as variable combinations of three basic colors Red, Green, Blue (RGB). The task of coloring a grayscale image involves assigning RGB values to an image which varies along only the luminance value [5]. Hence grayscale image colorization works on principle of mapping luminance values to color space values that can be used to reconstruct the original color. Since there exist one to many mapping between luminance values and color values, if pixel by pixel values is constructed then the probability of finding correct match for the given luminance value is extremely low. Thus to improve the probability of finding correct match (nearest match), more than one pixels are grouped together to form pixel window (grid). Vector Quantization algorithms LBG and KFCG are applied on initial color palettes generated using different pixel window sizes 1x2, 2x1, 2x2, 2x3, 3x2, 3x3, 1x3, 3x1, 2x4, 4x2,1x4 and 4x1 to obtain the codebook of size 512. Depending on minimum Euclidean distance, color components of input source image are transferred to grayscale image pixel windows found and used for colorization of respective grayscale pixel windows from input grayscale image.

The effect of changing pixel window size on the vector quantization codebook as well as the colorization process using LBG and KFCG codebook generation algorithms with various codebook sizes is analyzed and presented here in this paper.

II. COLOR SPACES USED FOR EXPERIMENTATION

A. RGB Color space

The RGB color space is the standard red-green-blue color space used when constructing a color image. The R, G and B values indicate the red, green and blue components respectively of the color pixel. The R, G and B values can vary from 0 to 255, thus allowing for the construction of 24 bit color images.

Manuscript received May 30, 2011.

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The luminance is calculated using a weighted average of the R, G and B values such that the sum of the weights is unity.

B. Kekre's L UV Color Space[15,19]

In the proposed technique Kekre's LUV color space is also used. Where L gives luminance and U and V give chromaticity values of color image. Positive values of U indicate prominence of red components in color image and negative value of V indicates prominence of green component. The RGB-to LUV and LUV-to-RGB conversion matrices are given in equations 1 and 2 respectively.

$$\begin{bmatrix} L \\ U \\ V \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ -2 & 1 & 1 \\ 0 & 1 & 1 \end{bmatrix} * \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & -2 & 0 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} * \begin{bmatrix} L/3 \\ U/6 \\ V/2 \end{bmatrix} \quad (2)$$

III. VECTOR QUANTIZATION CODEBOOK GENERATION ALGORITHMS

Vector Quantization (VQ) [7,8] is the lossy technique for compression of data and has been successfully used in various applications like an pattern recognition[11], speech data compression and face detection[12,13], Image segmentation[14] ,speech data compression [16],content based image retrieval CBIR[17,18] etc.

VQ can be define as a mapping function that maps k-dimensional vector space to a finite set **CB = {C_1, C_2,C_3, ……, C_N}**. The set CB is called codebook consisting of N number of codevectors and each codevector C_i= {c_{i1}, c_{i2}, c_{i3}, ……, c_{ik}} is of dimension k. The key to VQ is the good codebook. Codebook can be generated in spatial domain by clustering algorithms.

In encoding phase image is divided into non overlapping blocks and each block then is converted to the training vector **X_i = (x_{i1}, x_{i2}, ……., x_{ik})**. The codebook is then searched for the nearest codevector C_{min} by computing squared Euclidian distance as presented in equation (3) with vector **X_i** with all the codevectors of the codebook **CB.** This method is called exhaustive search (ES).

$$d(X_i, C_{min}) = \min_{1\leq j\leq N}\{d(X_i,C_j)\} \quad (3)$$

$$\text{where} \quad d(X_i,C_j) = \sum(X_{ip} - C_{jp})^2$$

It is obvious that, if the codebook size is increased to reduce the distortion the searching time will also increase.

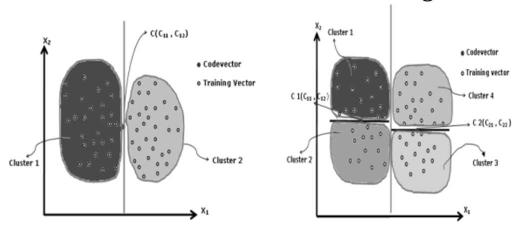
In the following sections A and B, the existing algorithms such as LBG and KFCG are discussed briefly.

A. Linde Buzo and Gray Algorithm (LBG)[7,8]

In this algorithm centroid is first calculated by taking average as the first code vector for the training set. Two vectors are generated by using constant error addition to the codevector. Euclidean distances of all the training vectors are computed with vectors v1 & v2 and two clusters are formed based on closest of v1 or v2. This modus operandi is replaced for every cluster. The shortcoming of this algorithm is that the cluster elongation is +135O to horizontal axis in two dimensional cases resulting in inefficient clustering.

B. Kekre's Fast Codebook Generation (KFCG) Algorithm [9,10]

Here the Kekre's Fast Codebook Generation algorithm for image data compression is used. This algorithm reduces the time of code book generation. Initially we have one cluster with the entire training vectors and the code vector C1 which is centroid. In the first iteration of the algorithm, the clusters are formed by comparing first element of training vector with first element of code vector C_1. The vector X_i is grouped into the cluster 1 if $x_{i1}< c_{11}$ otherwise vector X_{i1} is grouped into cluster2 as shown in Figure 1a. where code vector dimension space is 2. In second iteration, the cluster 1 is split into two by comparing second element X_{i2} of vector X_i belonging to cluster 1 with that of the second element of the code vector. Cluster 2 is split into two by comparing the second element x_{i2} of vector X_i belonging to cluster 2 with that of the second element of the code vector as shown in Figure. 1b.



1(a). First Iteration 1(b) Second Iteration
Fig. 1. KFCG algorithm for 2-D case.

IV. PROPOSED COLORING TECHNIQUE

Since the coloring problem always requires human interaction. So reference image of same class and of same feature is taken as of input source image. The color transfer algorithm is discussed for Kekre's LUV color space for different m x n pixel grid sizes. The main steps of algorithm for a color transfer are:

1) Convert RGB components of source color image into respective Kekre's LUV color components.

2) Divide the image in to non overlapping blocks of m x n pixels. Hence m x n x3 dimensional training vector set corresponding to LUV components of each pixel is obtained. On this set LBG and KFCG algorithms are applied and color palette is generated. (i.e. codebook of size 512.)

3) The input gray image is divided in to non overlapping blocks of mxn pixels. Each of these gray blocks is searched for nearest codevector of color palette using Mean Squared Error for color component values of the respective gray pixel in the block.

4) Once the nearest match is obtained gray block is replaced with Kekre's LUV code vector.

5) The final color image in Kekre's LUV domain is then converted into RGB plane and MSE of original color image and recolored image is calculated.

Figure 2. Shows the Block Diagram of proposed method. An input source color image is divided into group of adjacent pixels called pixel window (grid) of size MxN. Each pixel window is arranged as array of three color components of inclusive pixels we called it as Training Vector.

From Training vector, apply the codebook generation algorithms to find color palette(codebook). The size of color palette is 512 x M x N x 3. Where M and N are size of pixel window.

Input gray image is also divided into pixel window of size M x N . Every pixel window of gray scale image is searched for the best match color values into the color palette. Once the nearest match is obtained the color palette vector is transferred to grayscale image as color components to colorize gray scale image.

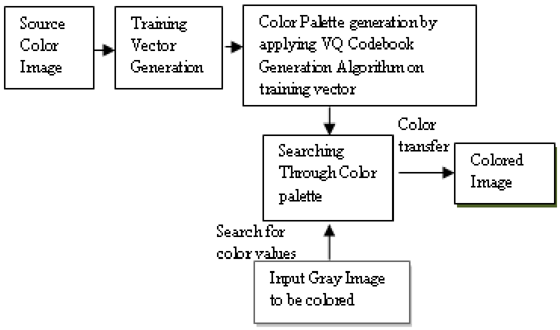


Fig. 2. Block Diagram of proposed method

V. RESULTS

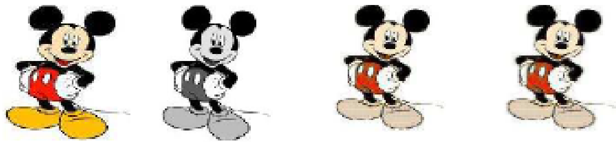
The proposed algorithms are implemented using MATLAB 7.0 on Pentium IV, 1.66GHz, 1GB RAM. The quality of output of colorization algorithm is subjective to the type of source color image used to generate color palette and the target (to be colored) gray scale image. To test the performance of these algorithms color image is converted to grayscale image and this gray image is recolored back. Finally MSE of original color image and colored image is compared. Five color images belonging to different classes of size 128x128x3 are used.

Figure 3 to Figure 7. Shows the results of LBG and KPE for Face, Cartoon, Zebra, flower, Book and Scenery images considering same image as reference image.

Figure 8 to Figure 9 Shows the results of LBG and KFCG for scenery and dog images considering different image as reference image.

(a) Original image | (b) Gray image | (c) 1x2grid LBG mse:92 | (d) 1x2grid KFCG mse:112

Fig 3 Colorization of face grayscale image using similar source image for pixel window 1x2



(a) Original image | (b) Gray image | (c) 1x2 grid LBG mse1260 | (d) 1x2 grid KFCG mse1059

Fig 4 Colorization of cartoon grayscale image using similar source mage for pixel window 1x2

(a) Original image | (b) Gray image | (c) 1x2 grid LBG mse178.4 | (d) 1x2 grid KFCG mse 135

Fig 5 Colorization of Zebra grayscale image using similar source image for pixel window 1x2

(a) Original Image | (b) Gray Image | (c) 1x2grid LBG mse1203 | (d) 1x2 grid KFCG mse1250

Fig 6 Colorization of Flower gray scale image using similar source image for pixel window 1x2

(a) Original image | (b) Gray image | (c) 1x2grid LBG mse:73.8 | (d) 1x2grid KFCG mse:75.5

Fig 7 Colorization of Book grayscale image using similar source image for pixel window 1x2

Original Image | Reference Image | Gray Image | 1x2 grid LBG mse990 | 1x2grid KFCG mse 83.6

Fig 8 Colorization of Scenery grayscale image using different source image

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Fig 9 Colorization of Dog grayscale image using different source image

Table I. Results of LBG and KFCG for five color images from different categories of size 128x128x3

Input Image	VQ Tech	Grid Sizes											
		1x2	2x1	2x2	2x3	3x2	3x3	2x4	4x2	1x3	3x1	1x4	4x1
Face	LBG	92.7	87.1	107.4	116.7	114.6	113.8	5576	5652	107.3	106	122.2	114
	KFCG	112.5	105.8	112.7	112.2	114.5	98.9	5570	5670	108.1	111	109.8	104.9
Cartoon	LBG	1260	1244	1056	1493	1420	1447	6928	9595	1251	1243	1532	1392
	KFCG	1059	1302	862	1166	1124	1139	6701	9352	1253	982	1034	1105
Zebra	LBG	178.4	147	440.9	721.7	675.1	741.7	2486	4236	373	286	610.6	465.7
	KFCG	135.0	153.5	383.6	644.7	639.9	750	2396	4312	252.7	226	410.4	341.0
Book	LBG	73.89	76.64	107.1	123.8	131.8	121.3	3400	3664	90	97	116	128
	KFCG	75.58	78.92	89.31	102.3	102.2	104	3380	3703	76.8	78.3	86.5	86.0
Flower	LBG	1203	1244	1244	1406	1388	1228	7833	7916	1246	1240	1274	1266
	KFCG	1250	1216	1232	1450	1441	1239	7960	8000	1251	1243	1264	1264
Average LBG		561.5	**559.7**	591.0	772.2	745.9	730.6	734	726.2	613.4	594	731.1	673.3
Average KFCG		**526.4**	571.6	536.0	695.4	684.4	666	647	645.5	586.1	527	581.2	580.2

The considered five sample images are used for performance comparison of proposed colorization techniques using LBG and KFCG for RGB as well as Kekre's LUV color spaces various pixel window sizes. The Figure 10 shows bar chart of average mean squared error obtained across all five images with respect to initial few pixel windows for RGB and Kekre's LUV color space. It is observed that, Kekre's LUV color space gives less MSE reflecting better coloring as compared to RGB color space. Hence in table 1 only Kekre's LUV color space results for different images using 12 varying pixel window sizes (1x2, 2x1, 2x2, 2x3, 3x2, 3x3, 1x3, 3x1, 2x4,4x2,1x4,4x1)are given.

From the data given in Table I, it is seen that the performance gradually decreases as the pixel window size increases. Further MSE for unidirectional pixel window is less indicating better performance compared to bidirectional. Pixel window sizes 1x2 and 2x1 are showing better results as compared to larger pixel window sizes. Figure 11 shows the comparison of average mean sqared error obtained across all images on Kekre's LUV color space for top five pixel windows. It can be seen from the chart, KFCG performs well with respect to LBG. Also performance deteriorates as pixel window size increases from unidirectional (1x2, 2x1, 1x3, 3x1, 1x4 and 4x1) to becomes bidirectinal(2x3, 3x2, 2x4, 4x2 and 3x3).

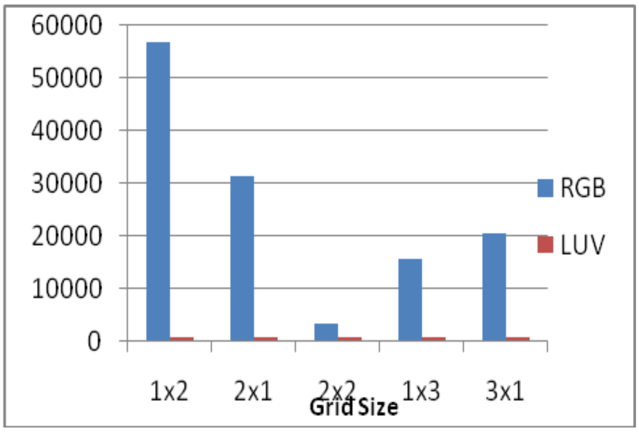

Fig 10 Average MSE across various Grid sizes for color spaces RGB and LUV

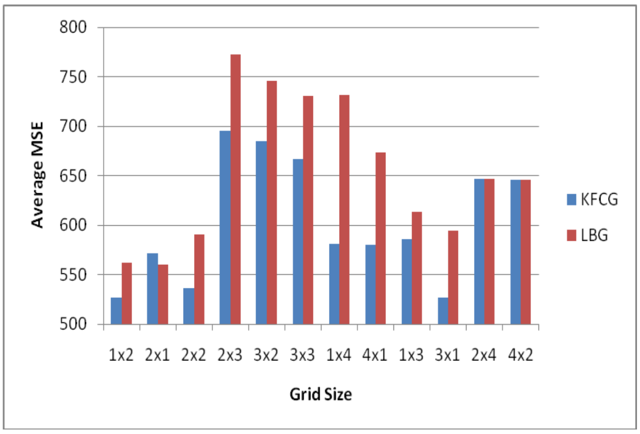

Fig 11 Average MSE across various Grid sizes using Kekre's LUV color space

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VI. CONCLUSIONS

The paper presents the performance analysis of using pixel windows of various sizes for vector quantization codebook generation. These codebooks generated using LBG and KFCG are used as color palettes for colorization of grayscale images with help of RGB and Kekre's LUV color spaces. The experimentation results shows that the colorization using single dimensional pixel window give better results than those of two directional pixel windows for both the codebook generation methods. The KFCG codebook generation method surpasses the LBG by giving better colorization. Kekre's LUV color space proves to be better than RGB color space.

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