

# New Clustering Algorithm for Vector Quantization using Walsh Sequence

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## ABSTRACT

In this paper we present an effective clustering algorithm to generate codebook for vector quantization (VQ). Constant error is added every time to split the clusters in LBG, resulting in formation of cluster in one direction which is  $135^\circ$  in 2-dimensional case. Because of this reason clustering is inefficient resulting in high MSE in LBG. To overcome this drawback of LBG proportionate error is added to change the cluster orientation in KPE. Though the cluster orientation in KPE is changed, its variation is limited to  $\pm 45^\circ$  over  $135^\circ$ . KEVR introduces new orientation every time to split the clusters. But in KEVR the error vector sequence is the binary representation of numbers, so the cluster orientation change slowly in every iteration. To overcome this drawback we propose the technique which uses Walsh sequence to rotate the error vector. The proposed technique (Kekre's error vector rotation using Walsh – KEVRW) is based on KEVR algorithm. The proposed methodology is tested on different training images for code books of sizes 128, 256, 512, 1024. Our result shows that KEVRW gives less MSE and high PSNR compared to LBG, KPE and KEVR.

## General Terms

Image Processing, Vector Quantization, Data Compression.

## Keywords

Codebook, Code vector, Encoding, Walsh Function, Codebook Generation Algorithm, Image Compression.

## 1. INTRODUCTION

The fundamental goal of image compression is to reduce the number of bits required to store and transmit the image as well as to maintain the quality of the image. Several compression techniques have been developed such as vector quantization (VQ) [1][2], block truncation coding[3], transform coding, hybrid coding, and various adaptive versions of these methods. Among these techniques, vector quantization is widely used in image compression owing to its simple structure and low bit rate. Many types of VQ, such as classified VQ [4], address VQ [5], side match VQ [6], and predictive classified VQ [7] have been used for various purpose. VQ is widely used in many applications such as pattern recognition [8], face detection [9], image segmentation [10] [11], speech data compression [12], Content Based Image Retrieval (CBIR) [13], tumor detection in mammography images [14] etc. Vector quantization is a lossy image compression technique. VQ can be defined as a mapping

function that maps  $k$  dimensional vector space to a finite set  $CB = \{C_1, C_2, C_3, \dots, C_N\}$ . The set  $CB$  is called codebook consisting of  $N$  number of code vectors and each code vector  $C_i = \{c_{i1}, c_{i2}, c_{i3}, \dots, c_{ik}\}$  is of dimension  $k$ . There are three main steps in vector quantization process: 1. Code book generation. 2. Encoding procedure 3. Decoding procedure. In Encoding phase image is divided into non overlapping blocks and each block then converted to the training vector  $X_i = \{x_{i1}, x_{i2}, \dots, x_{ik}\}$ . The codebook is then searched for the nearest code vector  $C_{\min}$  by computing squared Euclidean distance as presented in equation (1) with vector  $X_i$  with all the code vectors of the codebook  $CB$ . Then for each input vector the index of its nearest code vector transmitted to the receiver. In the decoding procedure, an index is replaced by the corresponding code vector to reconstruct the encoded image at the receiver.

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

where

$$d(X_i, C_j) = \sum_{p=1}^k (X_{ip} - C_{jp})^2 \quad (1)$$

A variety of encoding methods are available in literature like Partial Distortion search (PDS)[15], Mean-distance-ordered Partial Codebook Search Algorithm (MPS) [16], nearest neighbor search algorithm based on orthonormal transform (OTNNS) [17], Kekre's fast search algorithm [18] etc. The most important task for the vector quantization techniques is to design a good codebook [19]. To generate codebook there are various algorithms. The generalized Lloyd clustering algorithm (referred to as the LBG algorithm) [20] proposed by Linde, Buzo, and Gray is the most popular method for codebook generation. In this paper we present the codebook generation algorithm which is a modification to Kekre's error vector rotation algorithm (KEVR). We have used walsh sequence to generate the error matrix. The paper also compares the proposed algorithm with LBG, Kekre's proportionate error algorithm (KPE) [21], Kekre's error vector rotation algorithm (KEVR) [22], with respect to mean squared error (MSE) and peak signal to noise ratio (PSNR). In the next section we discuss LBG, KPE, KEVR algorithms. Section 3 gives some information on Walsh sequence. Proposed methodology is explained in Section 4, followed by results and conclusion in sections 5 and 6 respectively.

## 2. CODEBOOK GENERATION ALGORITHM

### 2.1 Linde, Buzo and Gray (LBG)

#### Algorithm [20]

The LBG algorithm is an iterative procedure. Starting with an initial codebook, the LBG algorithm performs the clustering of the training set, where an exhaustive search procedure is conducted to classify each vector in the training set according to its corresponding closest codeword in current codebook. The criteria to decide the closeness is squared Euclidean distance between the code vector and the training vector. Then each training vector records the index of its closest codeword in the codebook. After completing the clustering process for the whole training set, each codeword in the current codebook is updated with the centroid of those training vectors so that the current codeword is the closest codeword of them. The newly generated codebook is then used in the next iteration to minimize the overall averaged distortion in the codebook design procedure. Both the clustering and the updating procedures are executed repeatedly until the desired size of code book formed.

### 2.2 Kekre's Proportionate Error

#### Algorithm (KPE) [21]

Here to generate two code vectors  $C_1$  &  $C_2$ , proportionate error is added to the code vector. Magnitude of elements of the code vector decides the error ratio. Hereafter the procedure is same as that of LBG. While adding proportionate error a safe guard is also introduced so that neither  $v_1$  nor  $v_2$  go beyond the training vector space.

### 2.3 Kekre's Error Vector Rotation

#### Algorithm (KEVR) [22]

In this algorithm two code vectors  $C_1$  &  $C_2$  are generated by adding and subtracting error vector rotated in  $k$ -dimensional space at different angle. Error vector  $e_i$  is the  $i^{\text{th}}$  row of the error matrix of dimension  $k$ . The error vectors matrix  $E$  is given in Equation (2).

$$E = \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \\ . \\ . \\ . \\ . \\ e_k \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & \dots & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & \dots & 1 & 1 & 1 & -1 \\ 1 & 1 & 1 & 1 & \dots & 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & 1 & \dots & 1 & 1 & -1 & -1 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ . & . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . & . \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \end{bmatrix} \quad (2)$$

The error vector sequence have been obtained by taking binary representation of numbers starting from 0 to  $k-1$  and replacing 0's by 1's and 1's by -1's.

## 3. WALSH SEQUENCE

Walsh functions have become quite useful in the applications of image processing [23]. Walsh functions were established as a set of normalized orthogonal functions, analogous to sine and cosine functions, but having uniform values  $\pm 1$

throughout their segments [24]. The Walsh functions are closely related to binary sequences, and they are, by definition, of length  $2^n$ . These Walsh sequences are generated by sampling Walsh functions at the center of the interval. Walsh matrix is symmetrical. The first 8 Walsh sequences are given in Figure 1.

1	1	1	1	1	1	1	1
1	1	1	1	-1	-1	-1	-1
1	1	-1	-1	-1	-1	1	1
1	1	-1	-1	1	1	-1	-1
1	-1	-1	1	1	-1	-1	1
1	-1	-1	1	-1	1	1	-1
1	-1	1	-1	-1	1	-1	1
1	-1	1	-1	1	-1	1	-1

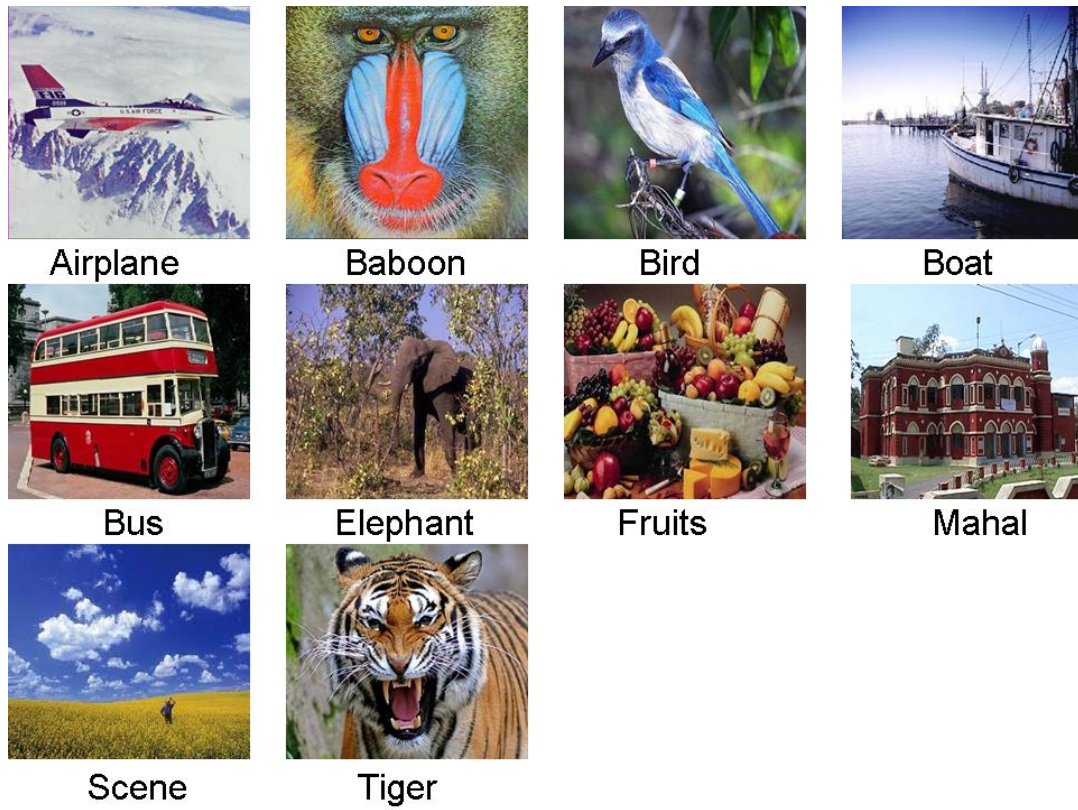
Figure 1: First 8 Walsh sequences

## 4. PROPOSED ALGORITHM (Kekre's Error Vector Rotation using Walsh Sequence – KEVRW)

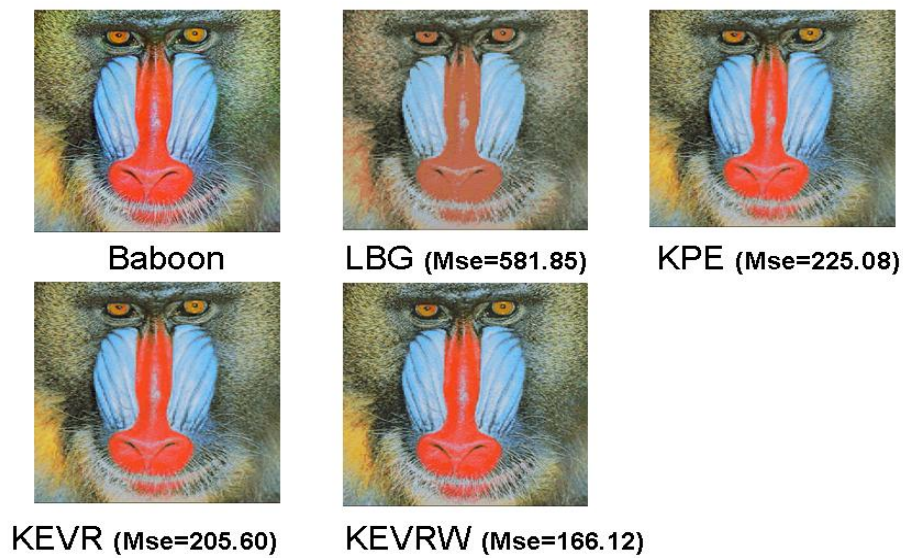
In this algorithm image is divided into non overlapping blocks. Each block is converted into training vector of dimension  $k$ . Initially all vectors are considered to be in one cluster. Its centroid represents first code vector. Generate 'n' Walsh sequences where code book size of  $2^n$  is required by sampling Walsh functions at the center of interval. Since each sequence is symmetric from the center, crop the sequence from both sides equally such that the length of the sequence is  $k$ . Then add and subtract first Walsh sequence to the first code vector to generate two code vectors. Calculate Euclidean distance between the training vectors in the cluster and the code vectors to split the cluster into two. Update the cluster centroids. In the next iteration, add and subtract next Walsh sequence to the cluster centroids. The procedure is repeated for each cluster till the code book of desired size is obtained.

## 5. RESULTS

The algorithms discussed above are implemented using MATLAB 7.0 on Pentium IV, 1.66GHz, 1GB RAM. To test the performance of these algorithms ten color images as shown in Figure 2 belonging to different classes are used. The images used belong to class Animal, Bird, Monument, Vehicle, Fruits, and Scenery etc. Image is divided into  $2 \times 2$  blocks, so each training vector is of dimension 12. To implement KEVRW (proposed algorithm), Walsh sequences of length 16 is generated and cropped by two columns from both sides to generate the Walsh sequence of dimension 12. Figure 3 shows the results of LBG, KPE, KEVR and Proposed algorithm (KEVRW) from codebook size 1024 on Baboon image. It can be seen that the LBG method loses color and sharpness in the image. KPE and KEVR gives better results compare to LBG. The proposed technique-KEVRW retains color and the sharpness as compared to KPE and KEVR. Table 1 shows the comparison of LBG, KPE, KEVR and KEVRW for codebook sizes 128 and 256 with respect to MSE, PSNR for the training images. Table 2 shows the comparison of LBG, KPE, KEVR and KEVRW for codebook sizes 512 and 1024 with respect to MSE, PSNR for the training images. Figure 4 shows the average MSE performance for LBG, KPE, KEVR and KEVRW for different code book (CB) sizes.



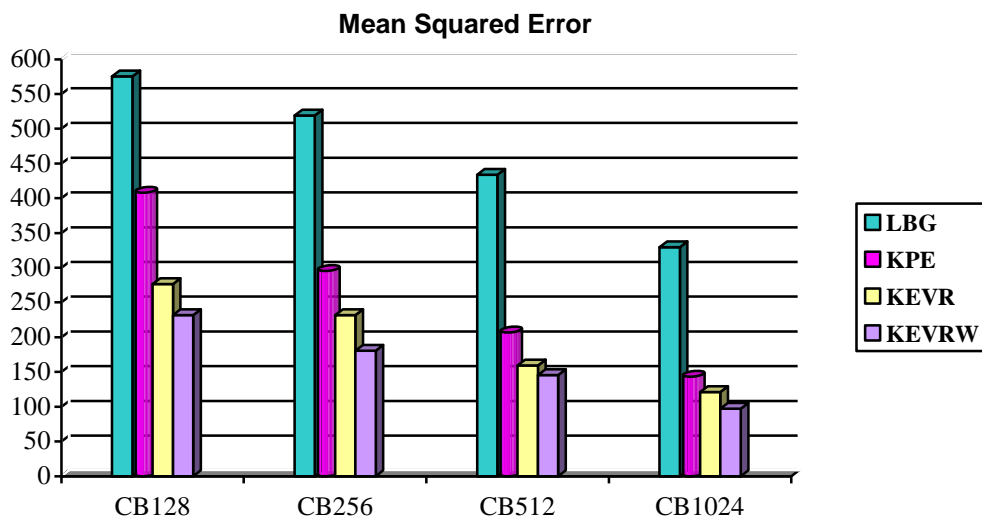
**Figure 2: Training Images**



**Figure 3: Results of LBG, KPE, KEVR and KEVRW from codebook size 1024 on Baboon image**

**Table 1. Comparison of LBG, KPE, KEVR AND KEVRW for codebook size 128 and 256 with respect to MSE, PSNR for the training images.**

Images	Parameters	LBG	KPE	KEVR	KEVRW	LBG	KPE	KEVR	KEVRW
		128				256			
Airplane	MSE	221.63	189.22	127.96	<b>99.44</b>	201.96	139.96	100.81	<b>71.68</b>
	PSNR	24.67	25.36	27.06	<b>28.16</b>	25.08	26.67	28.10	<b>29.58</b>
Baboon	MSE	956.30	527.00	400.06	<b>359.91</b>	875.22	399.62	352.45	<b>299.66</b>
	PSNR	18.32	20.91	22.11	<b>22.57</b>	18.71	22.11	22.66	<b>23.36</b>
Bird	MSE	497.08	338.80	231.07	<b>212.59</b>	444.97	258.67	190.18	<b>161.26</b>
	PSNR	21.17	22.83	24.49	<b>24.86</b>	21.65	24.00	25.34	<b>26.06</b>
Boat	MSE	337.88	320.94	192.25	<b>156.15</b>	314.84	257.13	154.69	<b>112.49</b>
	PSNR	22.84	23.07	25.29	<b>26.20</b>	23.15	24.03	26.24	<b>27.62</b>
Bus	MSE	652.57	521.07	338.14	<b>225.24</b>	584.22	319.99	266.43	<b>163.59</b>
	PSNR	19.98	20.96	22.84	<b>24.60</b>	20.47	23.08	23.87	<b>25.99</b>
Elephant	MSE	726.53	537.02	387.68	<b>316.49</b>	659.86	370.48	339.08	<b>267.21</b>
	PSNR	19.52	20.83	22.25	<b>23.13</b>	19.94	22.44	22.83	<b>23.86</b>
Fruits	MSE	530.54	441.87	261.84	<b>255.94</b>	485.33	314.84	223.01	<b>204.20</b>
	PSNR	20.88	21.68	23.95	<b>24.05</b>	21.27	23.15	24.65	<b>25.03</b>
Mahal	MSE	468.22	425.20	283.35	<b>216.31</b>	427.48	298.82	230.56	<b>166.30</b>
	PSNR	21.43	21.84	23.61	<b>24.78</b>	21.82	23.38	24.50	<b>25.92</b>
Scene	MSE	704.74	199.80	161.14	<b>131.17</b>	592.29	170.38	135.67	<b>103.02</b>
	PSNR	19.65	25.12	26.06	<b>26.95</b>	20.41	25.82	26.81	<b>28.00</b>
Tiger	MSE	658.10	579.90	383.37	<b>344.06</b>	605.89	425.52	325.49	<b>256.51</b>
	PSNR	19.95	20.50	22.29	<b>22.76</b>	20.31	21.84	23.01	<b>24.04</b>
Average	MSE	575.36	408.08	276.69	<b>231.73</b>	519.21	295.54	231.84	<b>180.59</b>
	PSNR	20.84	22.31	23.99	<b>24.80</b>	21.28	23.65	24.80	<b>25.95</b>

**Figure 4 Average MSE performances for LBG, KPE, KEVR and KEVRW for different code book (CB) sizes**

**Table 2. Comparison of LBG, KPE, KEVR AND KEVRW for codebook size 512 and 1024 with respect to MSE, PSNR for the training images.**

Images	Parameters	LBG	KPE	KEVR	KEVRW	LBG	KPE	KEVR	KEVRW
		512				1024			
Airplane	MSE	171.74	94.29	68.34	<b>56.06</b>	131.90	58.68	48.82	<b>38.26</b>
	PSNR	25.78	28.39	29.78	<b>30.64</b>	26.93	30.45	31.24	<b>32.30</b>
Baboon	MSE	743.28	303.05	261.26	<b>246.23</b>	581.85	225.08	205.60	<b>166.12</b>
	PSNR	19.42	23.32	23.96	<b>24.22</b>	20.48	24.61	25.00	<b>25.93</b>
Bird	MSE	373.50	199.64	139.27	<b>127.90</b>	297.20	137.63	104.60	<b>84.64</b>
	PSNR	22.41	25.13	26.69	<b>27.06</b>	23.40	26.74	27.94	<b>28.85</b>
Boat	MSE	272.06	164.43	93.09	<b>90.16</b>	220.35	97.20	68.63	<b>58.34</b>
	PSNR	23.78	25.97	28.44	<b>28.58</b>	24.70	28.25	29.77	<b>30.47</b>
Bus	MSE	496.00	191.49	141.91	<b>130.39</b>	380.52	122.59	105.92	<b>86.13</b>
	PSNR	21.18	25.31	26.61	<b>26.98</b>	22.33	27.25	27.88	<b>28.78</b>
Elephant	MSE	572.23	285.72	254.71	<b>217.51</b>	434.49	214.08	200.29	<b>142.27</b>
	PSNR	20.56	23.57	24.07	<b>24.76</b>	21.75	24.83	25.11	<b>26.60</b>
Fruits	MSE	417.74	222.99	168.64	<b>166.88</b>	331.92	167.24	134.54	<b>117.82</b>
	PSNR	21.92	24.65	25.86	<b>25.91</b>	22.92	25.90	26.84	<b>27.42</b>
Mahal	MSE	359.58	185.20	136.05	<b>134.45</b>	269.75	123.21	98.63	<b>86.91</b>
	PSNR	22.57	25.45	26.79	<b>26.85</b>	23.82	27.22	28.19	<b>28.74</b>
Scene	MSE	396.12	132.97	102.37	<b>82.62</b>	220.45	91.69	75.72	<b>55.17</b>
	PSNR	22.15	26.89	28.03	<b>28.96</b>	24.70	28.51	29.34	<b>30.71</b>
Tiger	MSE	535.70	288.07	228.15	<b>204.68</b>	424.77	194.96	166.40	<b>133.80</b>
	PSNR	20.84	23.54	24.55	<b>25.02</b>	21.85	25.23	25.92	<b>26.87</b>
Average	MSE	433.80	206.79	159.38	<b>145.69</b>	329.32	143.24	120.91	<b>96.95</b>
	PSNR	22.06	25.22	26.48	<b>26.90</b>	23.29	26.90	27.72	<b>28.67</b>

## 6. CONCLUSIONS

In this paper a codebook generation algorithm using Walsh sequence is proposed and compared with traditional LBG, KPE and KEVR. This paper aims to present an improvement to KEVR algorithm. In KEVR, only one digit of error vector changes in each iteration, which results in slowly changing cluster orientation. This drawback is removed in proposed technique-KEVRW. In KEVRW, the Walsh sequence is used to generate error vector. The Walsh sequences are symmetric in nature and half the number of digits change in successive Walsh sequences. So there is a fast change in cluster orientation. This gives effective clustering. It is observed that KPE and KEVR give far better performance as compared to LBG algorithm. However the proposed new algorithm KEVRW improves this performance. The proposed method reduces MSE by 59% to 70% for codebook size 128 to 1024 with respect to LBG, by 43% to 32% with respect to KPE and by 16% to 19% with respect to KEVR. It is observed that more error reduction is obtained for images like Baboon and Bus. It can be concluded that the images having more edges will give more reduction of error.

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