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The Noise Reduction over Wireless Channel Using Vector Quantization Compression and Filtering

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ABSTRACT

The transmission of compressed data over wireless channel conditions represents a big challenge. The idea of providing robust transmission gets a lot of attention in field of research. In this paper we study the effect of the noise over wireless channel. We use the model of Gilbert-Elliot to represent the wireless channel. The parameters of the model are selected to represent three cases of channel. As data for transmission we use images in gray level size 512x512. To minimize bandwidth usage we compressed the image with vector quantization also in this compression technique we study the effect of the codebook in the robustness of transmission so we use different algorithms to generate a codebook for the vector quantization finally we study the restoration efficiency of received image using filtering and indices recovery technique.

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1. INTRODUCTION

The transmission of data over noisy channel make us concerned about the robustness of transmission and the effectiveness of restoration process in case of erroneous data. There is lot of parameters affect in the quality of received image. Some researchers think that the problem can be solved by optimize in the source coding as shown in the articles [1], [2] and [3], others think that the solution exists in the optimization in the channel coding as shown in the articles [4] and [5], other guesses think that we should make combination between the source and channel coding or what we call joint source channel coding (JSCC) as shown in the articles [6], [7] and [8], in this proposition they think we have to optimize the source and the channel coding according to the channel conditions which is unpredictable and depending on probability also it consumes lot of time and resources of processing unit because they are iterative algorithms.

In the optimization of the source coding they depend on adding some transforms to enhance the quality of reconstructed image but this is not a guarantee that the transmission is robust or that going to make the restoration process more efficient with less processing; however in the channel coding they create some algorithm that add some data as shown in the articles [9] and [10] (corrector bits or add some redundancy) in the original information or changing the data organization (interleaving) in way that we can estimate or guess the original information as shown in the article [11] or get it from the redundant data which is in general minimize the compression ratio and maximize in bandwidth usage.

The vector quantization provides high efficiency as a source coding technique with high compression ratio and reasonable quality; however we can't keep this enhancement after transmission. As shown in the article [12] that the indices are transmitted over a noisy channel, which is obviously most often the case, transmission errors usually occur (the received indices are not all the same of the transmitted indices). Since the vector quantization is a block coding technique the error also will be all the pixels in the block and to make restoration it becomes a big challenge because we don't have any information about the nature of pixels that contains in that block. Our proposition based on working on the nature of indices by using different codebooks and try to collecting some data that will be send and use in restoration process to study the influence of changing the codebook creation in the reception and restoration process and in the quality of received image.

This paper is organized as follows in the first part we try to introduce the concept of the vector quantization and the generation of indices that will be transmitted over the channel, after that the creation of codebook using two different approaches, than the parameters used for the model of Gilbert-Elliot as wireless channel. In third part we will introduce a technique of restoration (indices recovery). Finally we present the simulation results, discussion and conclusion.

2. VECTOR QUANTIZATION

Recently image compression, especially at low bit rate, has assumed a major role in applications such as storage on low memory devices, narrow-band channel transmitting, wireless transmitting and streaming data on the internet [13]. Shannon first suggested that encoding a sequence of samples from a source can provide better result than encoding individual samples in terms of compression efficiency [14].Image Data compression using vector quantization (VQ) has received a lot of attention.

Since VQ has a high coding efficiency and simple decoder architecture, it is very suitable for low-bit rate applications.

The general VQ algorithm has three main steps [15]:

- First divide the image into blocks (usually they are 2x2, 4x4, 8x8, or 16x16).
- After that a codebook with best estimation of blocks is constructed and indexed.
- Finally, the original image blocks are substituted by the index of best estimate code from the codebook.

The basic principle of vector quantization is to match each input vector with a code-vector in the codebook so that the distortion between the input vector and the chosen code-vector is minimum [14]. Quantization is an irreversible process so there is no way to find the original value from the quantized value [16]. The difference between the input and output signals of the quantizer generate the quantizing error, or quantizing noise [17].

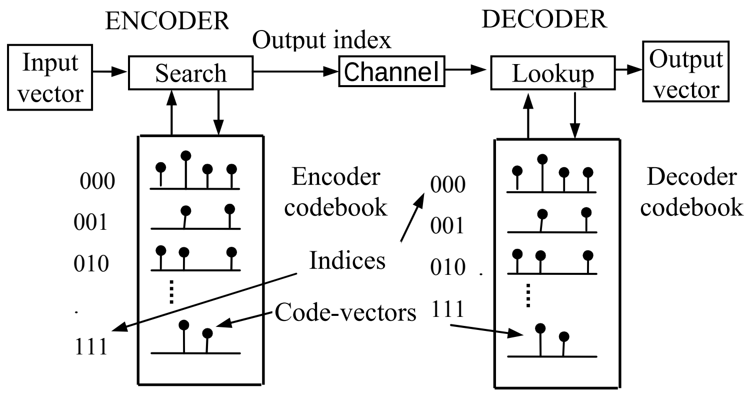

Figure 1. Vector quantization procedure

3. GENERATION OF CODEBOOK

The objective of codebook design is to minimize the combined reconstruction error over a representative training data set. If the training set is representative, the designed codebook will minimize the reconstruction error of input data however, except for the case of very small dimension. Codebook size, and/or training sets exhaustive search for the set of codebook vectors that minimized the total error is intractable problem [18]. A global codebook has one codebook for a class of images. The codebook is being derived from vectors of all images in the class. It is less overhead as compared to local codebook due to which it has lower performance.

3.1. Basic SOM Algorithm

Kohonen proposed a Self-Organization MAP (SOM) for unsupervised neural net-work in 1980 [19]. Initially SOM is trained with the randomly initialized weight vectors and generate an initial codebook. The initial Codebook Generation algorithm is summarized as follows [20]:

Step 1: Transform the facial images in dataset to intensity variation vectors, and combine all data together into one training set.
Step 2: Specify the size of the codebook to N and initialize the codevectors by using continuous intensity variation vectors.
Step 3: Select a new training vector from the training set.
Step 4: Find the best matching codevector closest to the training vector.
Step 5: Move the best-matching and its neighborhood codevectors towards the training vector.
Step 6: Repeat from Step 3 until the map converges.

3.2. Basic LBG Algorithm

The design of optimal vector quantizers were proposed and extensively studied by Linde, Buzo, and Gray using a clustering approach, and is referred to as the LBG algorithm [21]. This algorithm is a generalization of the Lloyd-Max design algorithm for scalar quantization [22]. The LBG algorithm and other variations of this algorithm are based upon minimizing a distortion measure which represents the penalty or cost associated with the mapping. The LBG algorithm for codebook generation is as follows: [23]

Step 1. Given an arbitrary codebook, encode each input vector according to the nearest-neighbor criterion. Use a distance metric to compare all the input vectors to the encoded vectors, and then sum these errors (distances) to provide a distortion measure. If the distortion is enough small (less than a predefined threshold), then quit. If not, go to the step 2.
Step 2. For each codebook entry, compute the Euclidean centroid of all the input vectors encoded into that specific codebook vector.
Step 3: use the computed centroids as the new codebook, and go to step 1.

4. TRANSMISSION CHANNEL (GILBERT-ELLIOTT)

During the 1980s, the emergence of digital communication based on digital technologies promoted the second generation of mobile communication system and its standardization development, the application of digital technologies not only increased system capacity, but also made wireless business quality more reliable [24]. The Gilbert-Elliott model, often used for the modeling of a discrete channel with memory, is simply a Markov chain of two states: a state "GOOD" and "BAD" and that within each state, the channel behaves as a BSC of BER 'ϵ_G' in case of the state "GOOD" and 'ϵ_B' in case of the state "BAD".

We consider, in the following, three different channels that parameters are given in Table 4. Channel 1 present the more bad transmission conditions with an average duration of fading (channel in the state "BAD") four times greater than that of channels 2 and 3. It remains 80% of the time in the state "BAD". However, channel 3 remains only 20% of the time in this state. Note that the BER of the state "BAD" is 10% for the three channels considered and the mean BERs of these channels are respectively of the order of 8% for channel 1, 5% for channel 2 and 2 % for channel 3.

Table 1. Parameters of the considered channels

	Channel 1	Channel 2	Channel 3
ϵ_G BER for the state "GOOD"	0.001	0.001	0.001
ϵ_B BER for the state "BAD"	0.1	0.1	0.1
P_{GB} : Probability of transition from the "GOOD" to state "BAD"	0.005	0.005	0.00125
P_{BG} : Probability of transition from the"BAD" to state "GOOD"	0.00125	0.005	0.005
P_G : Probability that the channel is in state "GOOD"	0.2	0.5	0.8
P_B : Probability that the channel is in state "bad"	0.8	0.5	0.2
mean BER	0.0802	0.0505	0.0208
Average length in bits of a fading (residence time in the state "BAD")	800	200	200

5. INDICES RECOVERY

This technique depends on collecting some verification information (bloc mean and complexity variation) is embedded into the indices of the VQ encoded data. First, we divide the indices matrix (code vectors) into sub blocs of size w×w. for each indice we calculate the absolute difference between it vector mean value and the median mean value of neighboring code vector. After that, we keep the maximum absolute difference for each w×w sub bloc.

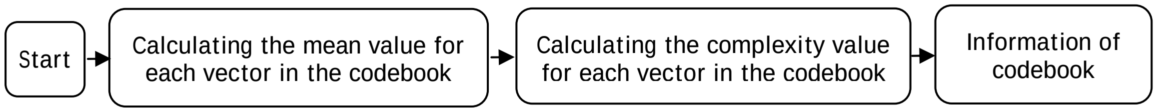

Figure 2. Verification information

In reception we have the received indices matrix that contains some erroneous indices. We calculate in reception the same information in emission. Then we compare it with the original information received which is the maximum for w×w sub bloc. If the calculated value is higher than the max we replace it with the median value of neighboring indices.

6. NOISE DETECTION

Several sequences are generated during the impulse detection procedure. The first is a sequence of original indices matrix and its vector means, x(i,j) and Mx(i,j) respectively. (i,j) is position of indice, it can be $1 \leq i \leq M$, $1 \leq j \leq N$ where M and N are the number of the indices in horizontal and vertical direction respectively, The second is a variation matrix, f(Mx(i,j)) is used to indicate whether the indice at (i,j) in noisy indices detected as noisy or noise free. The third is a sequence of received indices matrix and its means, x'(i,j) and Mx'(i,j) respectively [9].

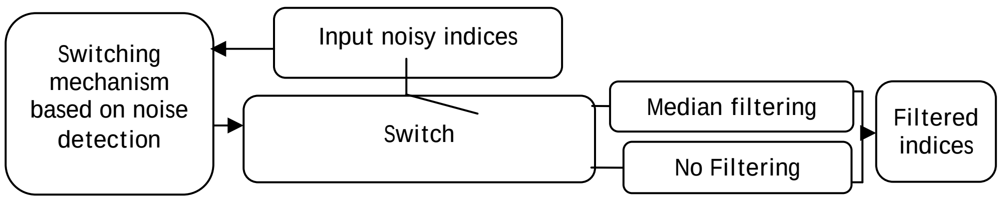

Figure 3. Block diagram of proposed Filter

1. Lets take a (2p+1)×(2p+1) window around Mx(i,j) means Mx(i+k,j+l) where $-p \leq (k,l) \leq p$, and $p \geq 1$. Where

$$Mx(i,j) = \frac{1}{q \times q} \sum_{k=1}^{q \times q} x_k(i,j) \quad (1)$$

x_k is the gray level of code vector pixel. q×q is the bloc size of quantified pixels.

2. Find Median value of this window m(i,j)

$$m(i,j)=Median[Mx(i+k,j+l)] \quad (3)$$

3. Find absolute difference between Mx(i,j) and m(i,j), and assign

$$f(Mx(i,j)) = |x(i,j) - m(i,j)| \quad (3)$$

4. Find the maximum value of f for $1 \leq (i,j) \leq w$
5. Send just this maximum values with original indices matrix, x(i,j). we have NV =M×N/w×w values. This is negligible.
6. in the receiver, Calculate

$$f(x'(i,j)) = |x'(i,j) - m'(i,j)| \quad (4)$$

With :

$$m'(i,j)=Median[Mx'(i+k,j+l)] \quad (5)$$

7. If f(Mx'(i,j)) > max [f(Mx(i,j))] x'(i,j) is detected as noisy then the estimated value of x'(i,j) will be modified as

$$\hat{x}(i,j) = \begin{cases} m'(i,j) & if \quad x'(i,j) \quad is \quad erroneous \\ x'(i,j) & otherwise \end{cases} \tag{6}$$

After all that we make the same algorithm but we replace the original indices matrix mean Mx(i,j) by original indices matrix complexity Cx(i,j).

$$Cx(i,j)=maxk(xk(i,j)) - mink(xk(i,j)) \quad k=1,.., qxq \tag{7}$$

7. RESULTS AND ANALYSIS

For the simulation we use four images (lena, Boat, Goldhill, Peppers) size 512x512, in the gray level, the block size is 4x4, and universal codebook size is 256 x16, the quality of reconstructed image without transmission using LBG codebook and SOM codebook is represented as shown below:

Table 2. The quality of reconstructed image (dB)

	LBG codebook	SOM codebook
lena	30.3848	29.7034
Boat	28.9948	28.0961
Goldhill	29.4160	29.0325
Peppers	25.8798	25.1396

For transmission over wireless channel the parameters of Gilbert-Elliott model are selected as indicated in table 1. The simulation results present: received image, filtered, recovered indices, and recovered indices with filtering.

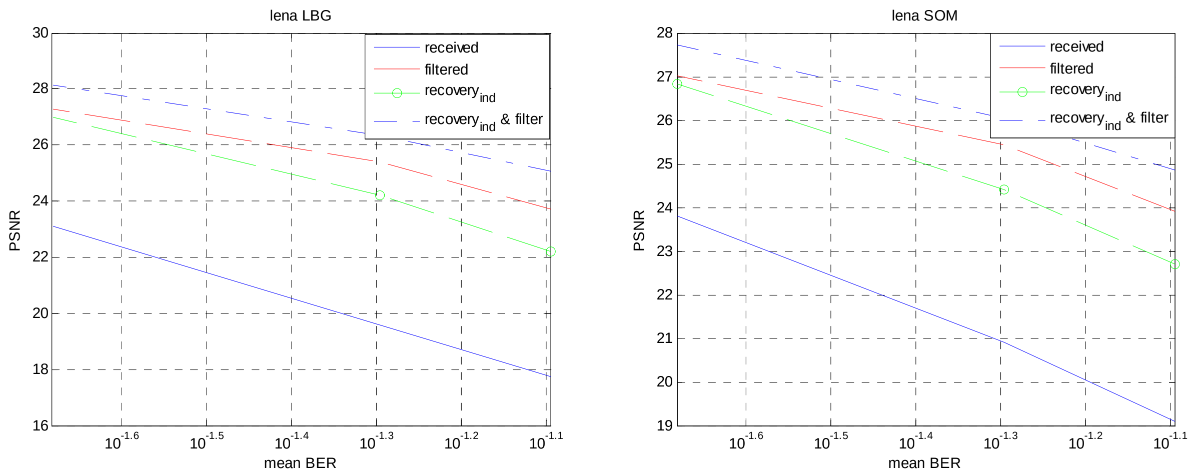

Figure 4. Received and restored image (lena) (left with: LBG codebook. Right with: SOM codebook)

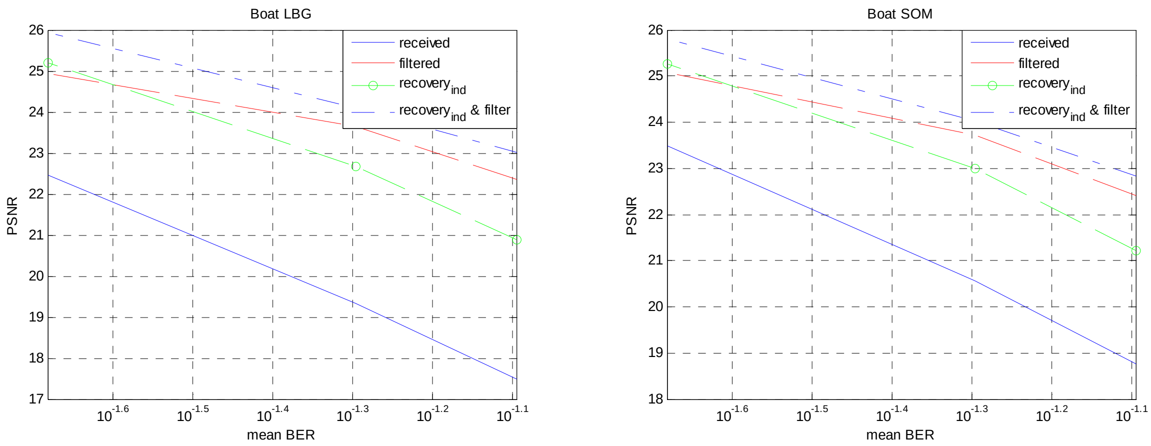

Figure 5. Received and restored image (Boat) (left with: LBG codebook. Right with: SOM codebook)

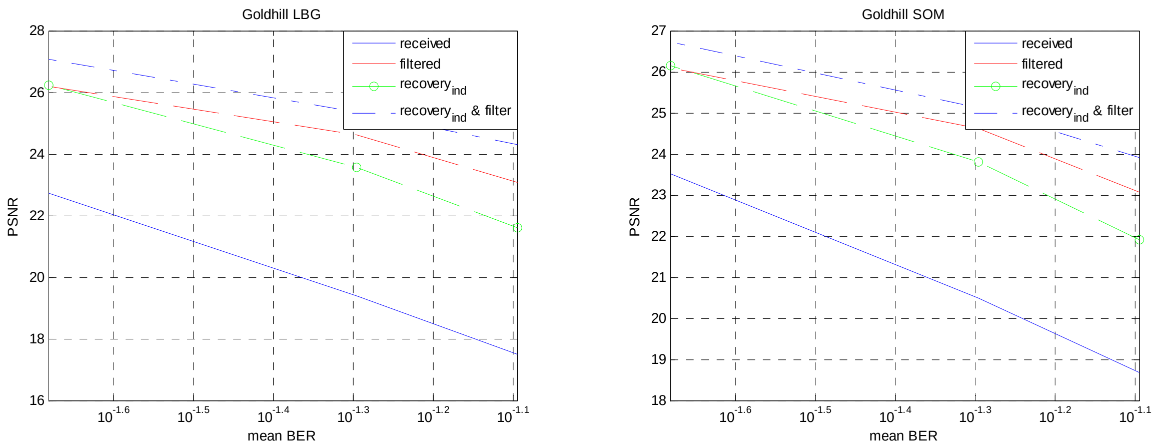

Figure 6. Received and restored image (Goldhill) (left with: LBG codebook. Right with: SOM codebook)

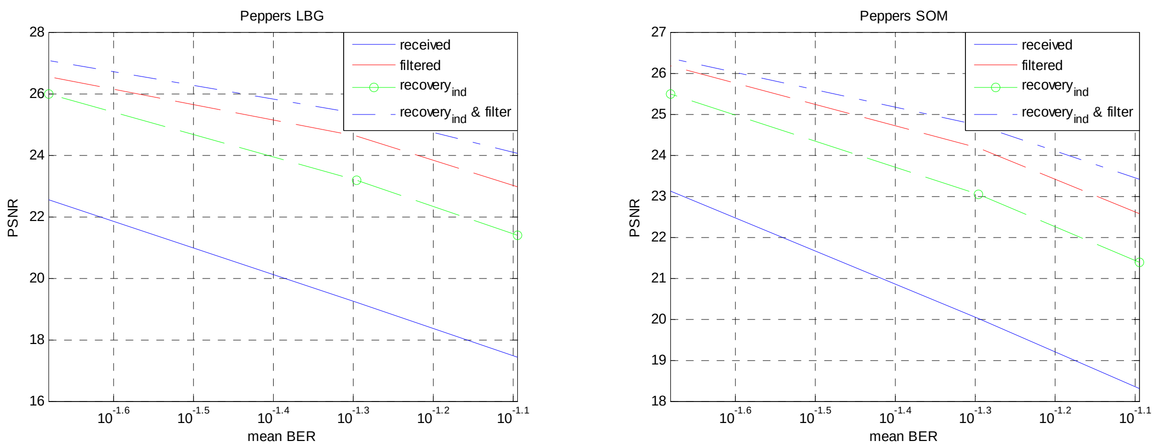

Figure 7. Received and restored image (Peppers) (left with: LBG codebook. Right with: SOM codebook)

Before we comment in these results we should see the backgrounds of each technique for codebook creation and the relationship between code vectors in the codeword.

As mentioned in [25] and [26] the main difference between LBG and SOM algorithms is in the order of the codevector indexes. The LBG algorithm does not define any order in the codebook; the codewords for the model vector can be selected arbitrarily. On the other hand the codebook trained using the SOM algorithm has an internal order, adjacent codebook entries. This is due to the fact that SOMs use the method of competitive learning [27]. For more details the articles [28] and [29] provide more information about differences in codebook creation between LBG and SOM algorithms.

That's why the simulation results show that SOM provid better results for received image because even we get an error in indices the erroneous index will be close to the original one.

After the restoration process the combination between indices recovery and standard median filter provide the best result however we can't benefit on this improvement achieved in received image using SOM codebook for restoration process. The collected information using LBG codebook for indices recovery will be with high precision because there is big difference between codevectors so all collected information can specify the right block for recovery process however in SOM codebook the collected information can't give us or detect a specific block in the recovery process.

Also we shouldn't forget that the quality of reconstructed image using LBG is better than SOM. There are many articles propose a solution as shown in [30] we can enhance the quality of image by using Savitzky-Golay polynomial; in article [31] the enhancement can be achieved by using optimal Kohonen topological map to determine the optimal codebook and also avoid the problem of "dead units" that can arise for example with the LBG algorithm, another suggestion to solve this problem is mentioned in articles [32] and [33] by applying hierarchical SOM.

The simulation results prove that we can enhance the quality of received image using SOM codebook also provide an efficient restoration technique using noise reduction and median filter. Our suggestion look simple and easy compared with other suggestions which make us interested to make lot of research based on proposed solution.

8. CONCLUSION

In this paper we provide a suggestion that can improve the quality of received image without minimize the compression ratio or maximize the bandwidth usage as shown in [28] and [29]. Our suggestion depending on the relationship between produced indices in the codevectors. We also test the efficiency of restoration in this case to benefit from the maximum improvement achieved. The use of SOM codebook provides good quality of received image compared with LBG codebook. We also discovered that the combination between indices recovery and standard median filter provide the best results. However, we still have a problem in restoration process to specify the collected data in SOM codebook. The solution can be by using methods shown in [30], [31], [32] and [33] or by using transforms that can analyze the image to improve the quality of reconstructed image and also help us to collect information with more precision.

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