Real Time Transcoding using Fast Requantization Codebook for Vector Quantization

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Abstract— Requantization of pre-compressed multimedia is a popular method for reducing the bit rate of a previously compressed data. The need for bit-rate reduction of the data stream, known as transcoding, requires adjustment of the transmission of bit-rate according to the bandwidth of the available channels. This introduces distortion of the reconstructed data. For real time applications the transcoding should be of low computational complexity, while ensuring low distortion. This paper introduces a fast algorithm which aims at reducing both distortion and enhances the speed of constructing the requantized codebook. The requantized codebook can be directly used for transcoding or could be used as an initial codebook instead of a blind or random initial codebook during the codebook reconstruction in an iterative method. Simulation results shows that the proposed codebook when used as an initial codebook requires less number of iterations, reduces distortion and minimizes the local optimization problem of an iteratively developed optimized system. These advantages reduce the computational time for real time communication over heterogeneous network.

Index Terms— Requantization, Transcoding, Vector Quantization (VQ)

I. INTRODUCTION

Visual communication often requires adjustment of the transmission bit-rate according to the bandwidth of the available channels. Hence, a need arises for a bit-rate reduction of the data stream, known as transcoding or transrating. For real-time applications, it is crucial that the transcoding will be of low computational complexity, and ensures minimum distortion. The general approach to transcoding is using quantization in various stages of image compression. The process of requantization consists of two stages. The first stage of quantization occurs at the source and is out of control of the system performing requantization. The second stage of quantization is performed for transcoding that reduces the bit rate to suit the bandwidth of the transmission channel.

In a Vector Quantization (VQ) system this requires requantization of a new codebook. Accordingly, the focus of this work is on the analysis and design of the second stage quantizer for VQ coded images, such as JPEG and MPEG. Fig.1 illustrates the transcoding process in a communication system using VQ. In stage 1, an image is coded using one codebook Q1. If transmission speed is required to be higher for the second stage, then requantization can be used to design a second codebook Q2 to meet the requirements. The problem of requantization has been studied in the literature [1]-[5]. The algorithm developed in [1] is an iteratively optimized method for designing the requantization codebook based on the original training data.

In [2], the the requantization process is decoupled into two independent stages that does not require the original training input set. It enhances the computational speed by requantizing codebook Q2 using codebook Q1 plus some additional data rather than using the original training set need to train Q1. This is a feasible solution since the original training set may not be available. Theoretical analysis has been dealt with giving a simple expression for the total requantization noise as the sum of the quantization noise of the two stages which can be used to compute the image quality after requantization/recompression. In [3] a heuristic algorithm is proposed for requantizing JPEG images using the Laplacian distribution of the ACDCT coefficients, and the reconstructed image has a better quality than a “blind” requantization. In [4], a re-quantization method for recompression of images in the DCT domain has been analyzed from a rate-distortion point of view. The process of re-quantization involves selection of the second stage quantization step. To avoid added distortion due to re-quantization, the paper proposes to select the re-quantization step as an even multiple of the original quantization step.

This paper presents a novel method of achieving the same performance as that of [1] and [2] with better computational speed. It is similar to [2], in that it does not require the training vectors Vr to quantize Q2, it is different from paper-2 as it also does not require any integer values like Ci, and also optimal quantization can be achieved in a single iteration. In addition to the Codebook Q1, we will however require the maximum and minimum average values of the Q1 codebook vectors and the codebook size N. The aim of the proposed
system is to reduce the computational load in real time applications by making the quantization process a non-
iterative and to make it suitable so as to be able to implement the same on to a reconfigurable platform. For better PSNR
result, using our generated codebook we can further iterate for optimization using Q1 as the input vectors. We can also
show that using our derived codebook as the initial codebook for Linde Buzo and Gray (LBG) [5][6] iterative algorithm, the
problem of local optimization can be overridden. Also, the number of iteration for an optimized codebook is much less
than [1] and [2].

The paper is organized as follows. In Section II, the proposed system model is formulated. Section III, discusses
the new algorithm for codebook design. Simulation results with discussion are presented in Section IV. In Section V, we
discuss the applicability of the developed method followed by the conclusion.

II. SYSTEM MODEL FORMULATION

In this paper a discretely sampled data distribution is considered for the ease of presentation. The proposed method
can be applied to any smooth data distribution. The following notations have been similar to [1].

The Transmission speed of the heterogeneous network is given as R1 and R2, indexed with codebook Q1 and Q2
with codebook size N and M, respectively. Since the transmission speed R2 is slower than R1, the codebook Q2
size M is smaller than the codebook size N. The Distortion due to quantization of \( V \) is given as

\[
D = \sum_{i=0}^{N-1} d(Q1(I(T_i)), Y_i) = \sum_{i=0}^{N-1} d(V_i, X_i)
\]

Training input set for codebook Q1 is \( V \), where \( V \) is

\[
V = \{ V_1, V_2, \ldots, V_n \}
\]

and \( V \) is a \( k \) dimensional source vector. Q1= \( \{ X_1, X_2, \ldots, X_n \} \), optimally trained for \( V \), and \( N=2^k \),
gives the size of the codebook Q1, and \( n \) is no. of binary bits required to index vector I(X) sent to the channel. \( k=1 \) for scalar quantization.

The Distortion due to quantization of \( V \) using Q1 is

\[
D = \sum_{i=0}^{N-1} d(V_i, X_i) = \sum_{i=0}^{N-1} d(V_i, X_i)
\]

where \( V \) is a \( k \) dimensional source vector and \( X \) is the squared distance between \( V \) and \( X \), i.e.,

\[
d(V_i, X_i) = \sum_{k=0}^{k-1} (V_i(k) - X_i(k))^2
\]

where \( V(k) \) and \( X(k) \) are the \( k \)th elements in the vectors \( V \) and \( X \), respectively. The channel symbols I (X) of \( n \) bits
are transmitted over channel with speed of \( R \) bit per second (bps). To reconstruct \( X \) from codebook Q1, the decoder
operates on I(X). The second codebook is described as Q2 = \( \{ Y_0, Y_1, \ldots, Y_M \} \), where \( M=2^m \). Q2 is represented as

\[
Y = Q2(Q1(V_i)), if Q1(V_i) \in \Phi
\]

where the space partition for Q2 is denoted by

\[
\Phi = \{ \Phi_0, \Phi_1, \ldots, \Phi_M \}
\]

IV. RESULTS

As discussed earlier, the above algorithm was experimented for a discretely sampled data distribution for the ease of accurate analysis. Fig. 2 shows the distribution plot for the training input set of 2 dimensional 64 input vectors \( V \). Using the proposed method we designed the codebook Q1 with \( N=28 \). Using this as the initial codebook we further used iterative LBG algorithm to optimize the codebook Q1. The distortion associated with Q1 and \( V_i \) (recovered) with the proposed method had much less distortion than that optimized with a random codebook. We further applied our proposed method to design Q2 using both Q1 and \( V_i \), the results are plotted graphically in Fig. 2, which shows optimizing Q2 with \( V_i \), as that of Q1 gives more optimized results.
V. APPLICATION CASE STUDY

The proposed method was applied to Lena image for Q1 for k = 2 and k = 4 dimensional vector and codebook size N=7, N=16, N=32. The results are tabulated and distortion compared in Fig 3. Note that the distortion appears as a large value since the codebook size is extremely small for a 256x256 Lena image.

Table I and Table II, tabulates the distortion result for the proposed algorithm applied to a 4 dimensional sample data distribution and for Fig. 4 respectively. It shows that the optimized distortion for Q1 using the proposed method to initialize the codebook Q1 for LBG[5],[6], gives considerably much less distortion as that of using a random or blind initial set.

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Distortion using LBG with proposed method Q1</th>
<th>Distortion using LBG with random Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>107038</td>
<td>915453</td>
</tr>
<tr>
<td>2</td>
<td>44034</td>
<td>135356</td>
</tr>
<tr>
<td>3</td>
<td>36256</td>
<td>88027</td>
</tr>
<tr>
<td>4</td>
<td>35444</td>
<td>84223</td>
</tr>
<tr>
<td>5</td>
<td>35444</td>
<td>84223</td>
</tr>
<tr>
<td>6</td>
<td>35444</td>
<td>84223</td>
</tr>
</tbody>
</table>

Table I. Result Analysis For 2 Dimensional Codeword

Figure 3. Recovered Lena Image for different codebook

Table II. Result Analysis For 256x256 Lena Image

<table>
<thead>
<tr>
<th>Codeword Dimension</th>
<th>Codebook Q2 size(M)</th>
<th>Codebook design style</th>
<th>Distortion Observed(MSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4x4</td>
<td>16</td>
<td>Proposed Method</td>
<td>2567137 (156.68)</td>
</tr>
<tr>
<td>4x4</td>
<td>16</td>
<td>Random</td>
<td>2787184 (179.1)</td>
</tr>
<tr>
<td>2x2</td>
<td>32</td>
<td>Proposed Method</td>
<td>1555139 (94.9)</td>
</tr>
<tr>
<td>2x2</td>
<td>32</td>
<td>Random</td>
<td>1798719 (106.7)</td>
</tr>
<tr>
<td>4x4</td>
<td>7</td>
<td>Proposed Method</td>
<td>2339780 (142.8)</td>
</tr>
<tr>
<td>4x4</td>
<td>7</td>
<td>Random</td>
<td>4063688 (248)</td>
</tr>
</tbody>
</table>
CONCLUSIONS

We have described a simple optimized codebook design, which can be used for both scalar k=1 or vector quantization of different dimensions. The proposed method optimizes a transcoder in a communication to minimize the distortion. If the proposed codebook is used as initial codebook it effectively reduces the number of iteration required in LBG and hence speeds up requantization as necessary in real time applications. It is also seen that the local optimization problem of LBG algorithm with a bad initial codebook can be minimized. The simulation work can be extended for a larger codebook size thereby preserving a good image quality and enable transmission through a requantization module over heterogeneous networks.

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REFERENCES