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THREE DESCRIPTIONS OF SCALAR QUANTIZATION SYSTEM FOR EFFICIENT DATA TRANSMISSION

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ABSTRACT

This paper introduces a new three descriptions data transmission for multiple description scalar quantization (MDSQ) system using the designed index assignment of $k = 2$. This paper focus on improving the reconstructed image in terms of PSNR for the central decoder and to reduce the central distortion. Analysis of the system with different value of k is also carried out. The three descriptions system requires three encoders and at the receiver requires one central decoder and six side decoders. Simulation results show that the performance of the proposed three description MDSQ scheme out performs the ordinary two descriptions MDSQ scheme.

Keywords: multiple description scalar quantization; index assignment.

INTRODUCTION

Vaishampayan in [1], produces the first practical multiple description coding (MDC) method namely as multiple description scalar quantization (MDSQ). In that paper he develops the work from the theoretical investigation to the construction of the practical MDC system. Several MDC based methods have been introduced such as MDC based on sub-sampling, quantization and transformation.

In [2], the paper explains how the concept of MDC with compression to be used in communication network. The original data can be reconstructed from any of the descriptions independently by an acceptable quality attached with some loss. Reconstruction is better when there are more descriptions available. If data are sent via the multiple descriptions of a network, some paths may incur lost or corruption to the receiving data. MDC formulates a form of diversity at the application layer to help the unreliable network achieves better transmission. Furthermore, MDC technique can be merged with multipath routing to contribute for cross-layer diversity in both the application description as describe in [2].

Most of the research works in MDSQ are concerned only with two descriptions as presented in [3] [4] [5]. The proposed MDSQ scheme is focused on three descriptions, which consists of three encoders and seven decoders (including of one central decoder). K-channels will transmit the K-description into corresponding encoders which will come with $(2^K - 1)$ decoders. Assume that a diversity system which is having a three encoders, all these encoders are capable to transmit the information through the channels reliably. These three encoders will produce three equivalent rate, R_1, R_2 and R_3 bits/source sample (bpss). Also, the encoders will produce the correspondence descriptions so that each description will give low yet acceptable quality by itself before all of the descriptions joint to contribute to a better and higher quality. Generally, the three descriptions are transmitted separately through the channels, respectively. The system is able to manage the acceptable quality without asking retransmission of any lost packets, unless the loss rate is very high.

Most of the practical applications require more than two packets for transmission to achieve better quality since the packets that transmit over IP networks are limited in size. In fact, three descriptions scalar quantization system for efficient data transmission would provide lower distortion and promote better PSNR reconstruction quality instead of two descriptions.

This paper introduces a three descriptions MDSQ scheme and proposes an new index assignment technique for the three encoders each implemented with a scalar quantizer respectively. Simulation result show that for central distortion and central decoder the PSNR of the proposed three descriptions with $k = 2$ MDSQ scheme, which are 38.50 dB and 28.91 dB for rate of 0.1051 bpp. The central distortion of the proposed scheme is reduced from 41.91 dB while the central decoder the PSNR is promoted from 27.21 dB at the same rate, 0.1051 bpp compared to the ordinary two descriptions MDSQ scheme.

The main contribution of this paper is to present the index assignment technique at $k = 2$ for the proposed scheme. Let k be the number of diagonals used in the index assignment. The greater the number of k, the better the central distortion performance can be accomplished.

The rest of the paper is presented as follows. Section II presents the proposed MDSQ scheme with three descriptions and the proposed index assignment to be employed in the suggested scheme. Section III indicates the experimental results of the three different schemes. The comparisons of the central distortion and the reconstructed images will be discussed in term of PSNR. In Section IV, a conclusion of this paper is drew.

THREE DESCRIPTIONS OF MULTIPLE DESCRIPTION SCALAR QUANTIZATION

The block diagram of the proposed MDSQ scheme with three encoders is as shown in Figure-1. The

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data source, X is mapped to the encoders. The encoder consists of two main interests, scalar quantizers and the index assignment designed. The scalar quantizers map the source X to the nearest codeword in the codebook to minimise the distortion. The quantizer codeword index basically refers to the index assignment then mapped to the three descriptions, each to be transmitted over separate channel, respectively.

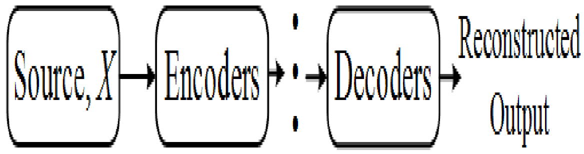

Figure-1. Block Diagram of the proposed MDSQ scheme with three description.

The decoder knows which description(s) is received and thus decodes accordingly. In this scheme, the distortion caused by using all of three descriptions is defined as central distortion. Side distortion refers to the distortion resulted by using only one or two description(s). The reconstructed output refers to the decoded images after the decoders receive and decoded the data.

The proposed MDSQ scheme with three encoders is as shown in Figure-2. The function $f=(f_1, f_2, f_3)$ are the three SQs transmits separate data. At the receiver, there are seven decoders indicated as $g=(g_1, g_2, g_3, g_{12}, g_{13}, g_{23}, g_{123})$ is shown in Figure-1. These seven decoders include six side decoders $(g_1, g_2, g_3, g_{12}, g_{13}, g_{23})$ and one central decoder, g_{123}. The output of the decoders is denoted as $\{\hat{X}_1, \hat{X}_2, \hat{X}_3, \hat{X}_{12}, \hat{X}_{13}, \hat{X}_{23}, \hat{X}_{123}\}$. The data source, X is mapped and quantized by the quantizers $f=(f_1, f_2, f_3)$ that produces three descriptions. The descriptions are sent via three channels and they are having different rates of transmission indicated as R_1, R_2, R_3 bits/source sample (bpss).

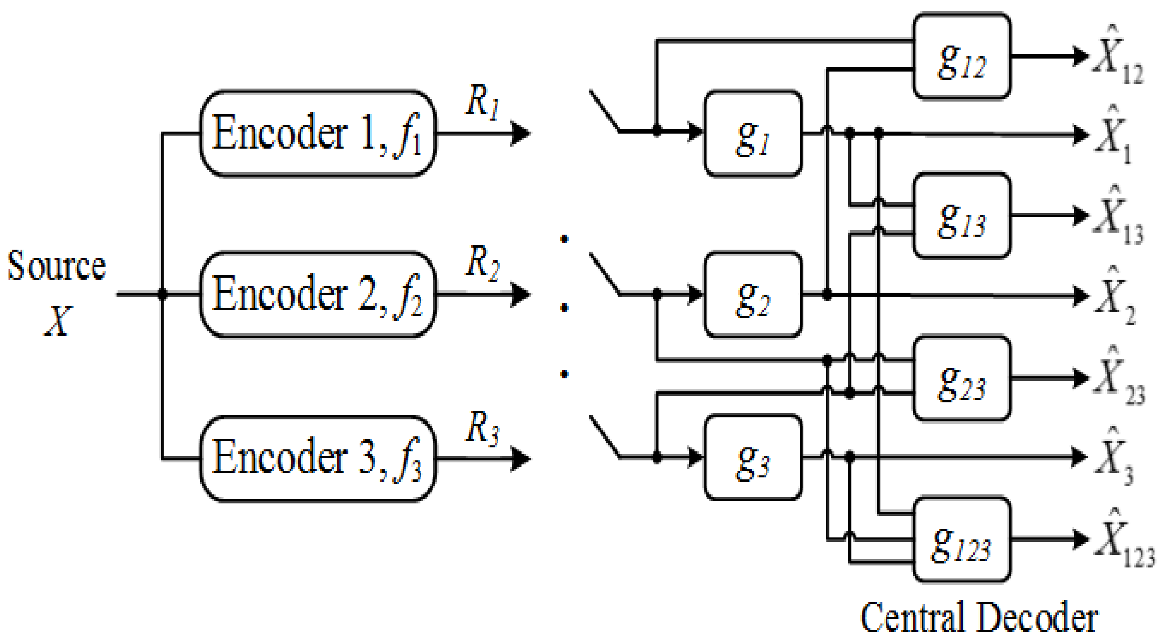

Figure-2. The proposed MDSQ scheme with three descriptions.

Codebook refers to the collection sets of the codewords for any one of the encoders, f_1, f_2, f_3. For every codeword generated by the encoder, the decoder produces a reconstruction value. A codebook is provided for encoding and decoding mapping, which used to simplify the implementation complexity of the quantization process. In this scheme, similar codebook is used as in [1]:

$$\hat{\chi}^0 = \{\hat{x}^0_{hij}, (h,i,j) \in C\} \quad (1)$$

$$\hat{\chi}^1 = \{\hat{x}^1_h, h \in I_1\} \quad (2)$$

$$\hat{\chi}^2 = \{\hat{x}^2_i, i \in I_2\} \quad (3)$$

$$\hat{\chi}^3 = \{\hat{x}^3_j, j \in I_3\} \quad (4)$$

where the C is the subset of $I_1 \times I_2 \times I_3$.
Assume that C is chosen by:

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$$\{h:(h,i,j)\in C\}=I_1 \tag{5}$$

$$\{i:(h,i,j)\in C\}=I_2 \tag{6}$$

$$\{j:(h,i,j)\in C\}=I_3 \tag{7}$$

The encoder assigns □ into three cells, whereby the three cells are the three channels, respectively. The assignment of □ is defined as the partition A. The encoders apply the partition of $\mathrm{A}=\{A_{hij},(h,i,j)\in C\}$ on □, where:

$$A_{hij}=\{x: f_1(x)=h,\, f_2(x)=i,\, f_3(x)=j\} \tag{8}$$

The encoding functions are defined as:

$$f_1 = □ \to I_1 \tag{9}$$

$$f_2 = □ \to I_2 \tag{10}$$

$$f_3 = □ \to I_3 \tag{11}$$

which pick over the indexes h, i and j respectively. Channel 1, channel 2 and channel 3 are used to transmit the output of the encoders, with indexes h, i and j.

At the receiver, if all the indexes h, i and j are received, reconstruction is done by the central decoder. If only two of the indexes are successfully received, the output quality of the reconstruction via side decoders is always lower than the central decoder.

Generally, it is impossible to reconstruct the image without any distortion and obtain perfect quality of the output after the process of encoding and decoding. Let the random variable X be the input to the proposed MDSQ scheme, and $\hat{X}_N$ be the output of the decoder g_N, N = {1, 2, 3, 12, 13, 23, 123}. Also, let the output of the encoders, f_1, f_2 and f_3 to be indicated by random indexes of h, i and j, respectively.

Assumed that D_{123} as the central distortion whereas the side distortions are labeled as D_1, D_2, D_3, D_{12}, D_{13} and D_{23}. In this scheme, the distortion is defined as the expected value of the square of the difference between encoded and decoded image, which is actually used in the most cases and the simplest case, in short, the mean square error, MSE. The error is the amount by which the values of the original source image differ from the decoded image.
The MSE is expressed as:

$$MSE=\frac{1}{mn}\sum_{0}^{m-1}\sum_{0}^{n-1}\left\| \boldsymbol{f}(p,q)-\boldsymbol{g}(p,q)\right\|^2 \tag{12}$$

where f is the matrix of source image, g is the matrix of the reconstructed image, m represents the number of rows of pixels of the images, p represents the index of that row, n represents the number of column of pixels of the image, and q represents the index of that column.

The index assignment matrix technique plays the important roles for the MDSQ in [6] and [7]. This technique ties the relationship between the quantization step length and the designed quantizer. The source X is quantized by the central quantizer of the encoder as in Figure-3. A central quantizer produces index l ($l\in T$, where T is the one-dimensional index space). The index is then input to the index assignment block, which carries out the mapping of $\alpha: l\to(h,i,j), l\in T, (h,i,j)\in T^3$ at T^3 is now the three-dimensional index space. Let (h, i, j) be the first, second and third quantizers' indexes.

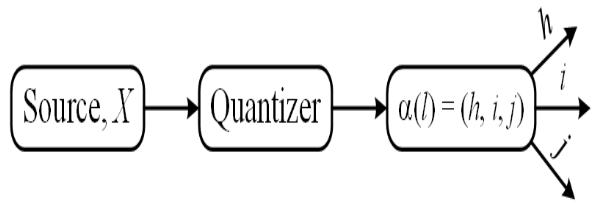

Figure-3. Encoder mapping diagram.

The index assignment method utilizes a matrix, to indicate the mapping process. Since the proposed scheme involves three descriptions, we proposed the index assignment method which has code pair of (h, i, j) to fit into the three scalar quantizer. In this work, we assume that h-axes is always follow the i-axes rather than j-axes. In other words, the third quantizer is having the same design as the first quantizer. Let k be the number of diagonals used in the index assignment. This technique is used in the proposed work where the index assignment k = 2 as shown in Figure-4.

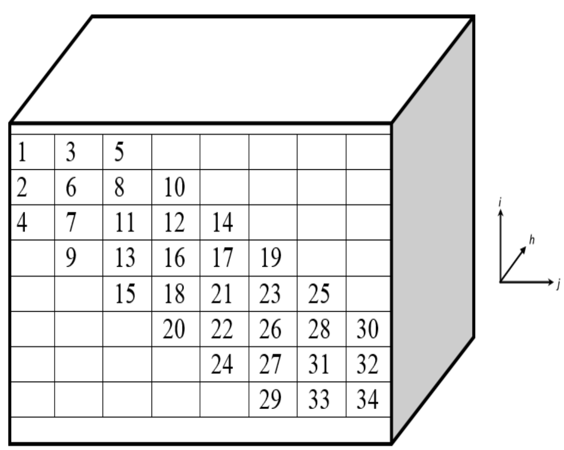

Figure-4. The proposed modified nested index assignment k = 2.

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The decoder produces a reconstruction value for every code word created by the encoder. As it is impossible to know which values in the interval are actually yielded by the source, the decoder decides to carry out a value which is the best to represent all the values in the interval which is logical and sensible.

Central decoding is performed with simple matrix lookup by referring to the proposed modified nested index assignment k = 2 when all of the three descriptions are available. If only two of the descriptions are transmitted, side decoding can be still carried out by taking the two transmitted data and perform with the matrix lookup with respect to the corresponding quantizers. When any two of the descriptions are lost, the only received description will be decoded by selecting one of the values from that row or column according to the proposed index assignment matrix.

RESULTS

Experiments were conducted on the 512 × 512 grey-scale Lena image to evaluate the performance of the proposed system. Simulations are performed to observe the PSNR and the distortion for all of the decoders in the ordinary two descriptions MDSQ scheme, three descriptions with k = 1 MDSQ scheme and three descriptions with k = 2 MDSQ scheme. Assume that both of the three descriptions transmitted through the corresponding channel are sending the equivalent rate of transmission,
$R_1 = R_2 = R_3$.

The term peak signal-to-noise ratio (PSNR) is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation. Since there is a very wide dynamic range for many data sources, regardless for the image or signal sources, that is, ratio between the largest and smallest possible values of a changeable quantity. The PSNR is usually expressed in terms of the logarithmic decibel scale, in unit of dB.

Moreover, PSNR is most easily defined through the MSE. The mathematical representation of the PSNR is as:

$$PSNR = 10\log_{10}\left(\frac{R_I^2}{MSE}\right) \quad (13)$$

$$PSNR = 20\log_{10}\left(\frac{R_I}{\sqrt{MSE}}\right) \quad (14)$$

where R_I is the maximum possible pixel value that exists in the original image.

Figure-5 demonstrates the decoded output of the ordinary MDSQ scheme of two descriptions at transmission rate of 0.9346 bpp.

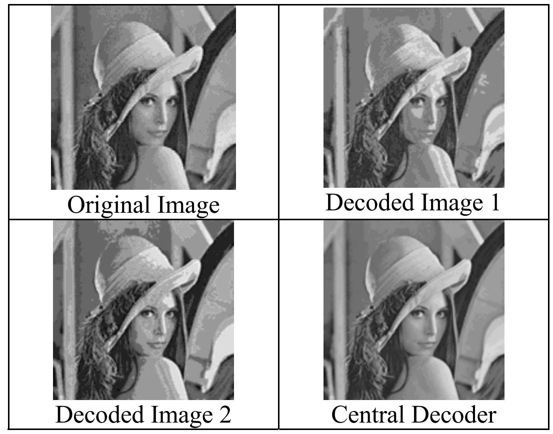

Figure-5. The decoded image of the ordinary MDSQ scheme with two descriptions at 0.9346 bpp.

Figure-6 demonstrates the decoded output of the proposed MDSQ scheme of three descriptions with k = 1 at transmission rate of 0.9346 bpp.

Figure-6. The decoded image of the proposed MDSQ scheme with three descriptions. k = 1 at 0.9346 bpp.

Figure-7 demonstrates the decoded output of the proposed MDSQ scheme of three descriptions with k = 2 at transmission rate of 0.9346 bpp.

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Figure-7. The decoded image of the proposed MDSQ scheme with three descriptions. k = 2 at 0.9346 bpp.

The graph of central distortion versus bit rate for the proposed scheme is shown in Figure-8. For most of the cases, it is practical and feasible to implement more diagonals in the index assignment matrix [8]. Therefore, at rate of 0.9346 bpp, in the proposed scheme, the central distortion is reduced to 38.56 dB as compared to the three descriptions with k = 1 MDSQ scheme and the ordinary two descriptions MDSQ scheme, 41.90 dB and 41.91 dB, respectively, as referred to Figure-9.

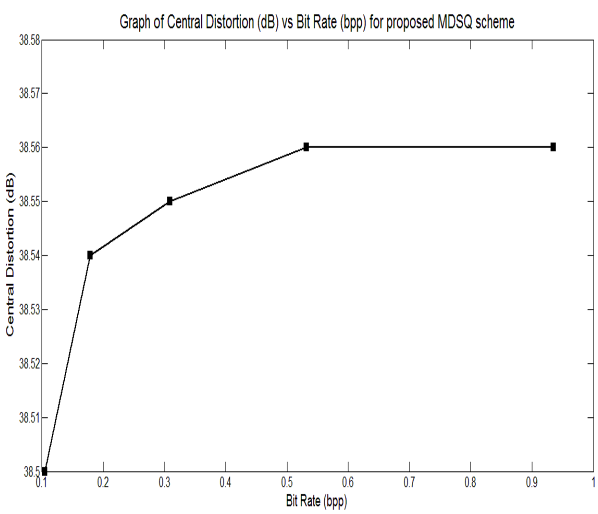

Figure-8. Graph of central distortion vs bit rate for proposed MDSQ scheme.

Figure-9 describes the simulation result obtained for central distortion of the three descriptions with k = 1 MDSQ scheme, which is 41.90 dB for rate of 0.1051 bpp to 0.9346 bpp. However, the central distortion remains the same at 41.91 dB at rate of 0.1051 bpp to 0.9346 bpp for the ordinary two descriptions MDSQ scheme. These two MDSQ scheme basically provide the same central distortion at the same time, only at 0.01 dB difference. When all of the descriptions successfully transmitted and received, the central decoder carries out the highest reconstruction quality which leads to the results that show certain trend.

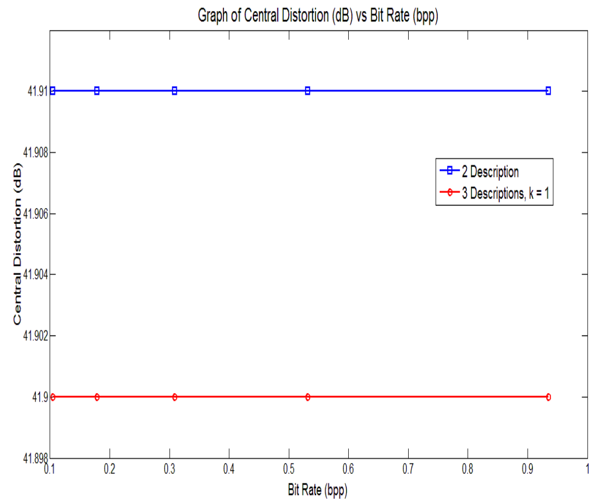

Figure-9. Graph of central distortion vs bit rate for other two MDSQ schemes.

Figure-10 illustrates the central PSNR for the proposed MDSQ scheme of three descriptions with k = 2, which is improved to 28.91 dB at 0.1051 bpp. Although there is slightly difference for the higher bit rate, it is still consider achieving a satisfied performance.

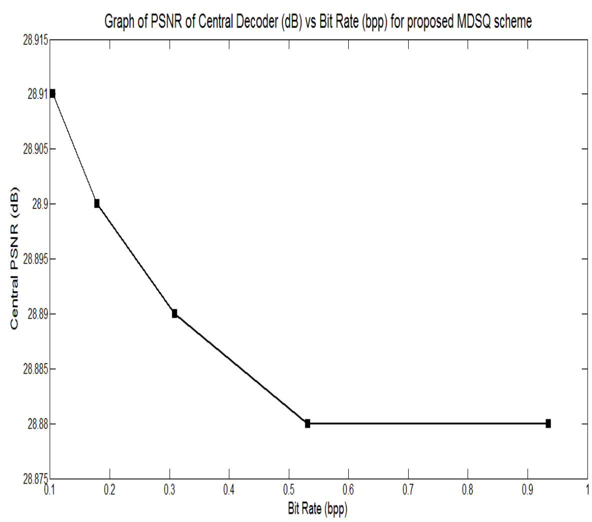

Figure-10. Graph of central PSNR vs bit rate for proposed MDSQ scheme.

From Figure-11, the ordinary two descriptions MDSQ scheme and three descriptions with k = 1 MDSQ scheme, which are having the same PSNR for the central decoder, at 27.21 dB. This trend reveals that the ordinary two descriptions MDSQ scheme is giving poor reconstruction quality. In fact, the higher the number of diagonals used in the index assignment, the better the reconstruction quality can be achieved.

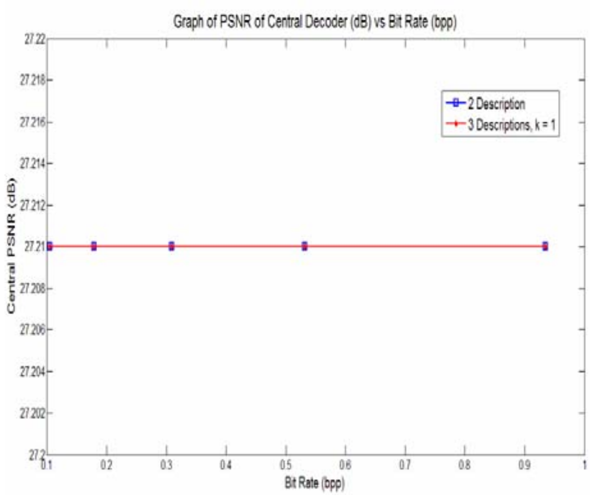

Figure-11. Graph of central PSNR vs bit rate for other two MDSQ schemes.

From the PSNR of the central decoder with the proposed MDSQ scheme of three descriptions with k = 2, it achieves the best quality for the reconstruction image compare to the other two schemes. As discussed in the distortion performance, the main root cause is due to the index assignment design. As mentioned, the greater the number of k in the index assignment design, the better the central distortion performance can be achieved. However, this is also proven that the more the encoders are designed in the MDSQ scheme, the better the central distortion can be achieved. Moreover, the higher the PSNR, the better reconstruction image quality of the central decoder can be acquired.

CONCLUSIONS

This paper presented of the three descriptions MDSQ scheme and index assignment method with code pair of (h, i, j). In this proposed MDSQ scheme used k = 2, whereby k refers to the number of diagonals used in the index assignment. The greater the number of k, the better the central distortion performance can be accomplished. Simulation results show that the central distortion is reduced so that the higher PSNR can be achieved. The central distortion is decreased to 38.50 dB and central PSNR is promoted to 28.91 dB at rate of 0.1051 bpp for the proposed MDSQ scheme. Thus, a better reconstruction image quality of the central decoder can be performed when PSNR is increased.

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