THREE-DESCRIPTION SCALAR AND LATTICE VECTOR QUANTIZATION TECHNIQUES FOR EFFICIENT DATA TRANSMISSION

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THREE-DESCRIPTION SCALAR AND LATTICE VECTOR QUANTIZATION TECHNIQUES FOR EFFICIENT DATA TRANSMISSION

by

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LIST OF ABBREVIATIONS

BFOS	Breiman-Freidman-Olshen-Stone algorithm
Bpp	Bits per pixel
Bpss	Bits per source sample
DSP	Digital signal processing
ECDQ	Entropy coded dithered quantizers
ERC	Error resilient coding
FDM	Frequency division multiplexing
FEC	Forward error correcting
FPGA	Field-programmable gate array
GLA	Generalized Lyold algorithm
GPGPU / GPU	General purpose graphics processing unit
GTGA	Greedy tree growing algorithm
HDVC	High definition video conferencing
HDTV	High-definition television
IP	Internet protocol
LVQ	Lattice vector quantization
MD	Multiple description
MDC	Multiple description coding
MDLVQ	Multiple description lattice vector quantization
MDSQ	Multiple description scalar quantization

MDVQ	Multiple description vector quantization
MSE	Mean square error
MUX	Multiplexer
pdf	Probability density function
PSNR	Peak Signal-to-Noise ratio
RD	Rate-distortion
RMDSQ	Robust multiple description scalar quantizer
SD	Single description
SDC	Single description coding
SDTV	Standard-definition television
SLVQ	Shifted lattice vector quantization
SQ	Scalar quantization
SVC	Scalable video coding
VLVQ	Voronoi lattice vector quantization
VoIP	Voice over internet protocol
VQ	Vector quantization
WZ	Wyner–Ziv coding

LIST OF SYMBOLS

σ_q^2	Mean square error
e_q	Quantization error
Λ	Lattice
Λ'	Sublattice
λ	Lattice point
λ'	Sublattice point
$\mathbb{R}$	Real number set
Z	Integer number set
σ	Standard deviation
$\equiv$	Congruency relation for integer numbers
$\mathcal{H}$	Hamiltonian algebra
G	Generator matrix
$\tilde{G}$	Unitary matrix
I_L	L - dimensional identity matrix
$G(\Lambda)$	Normalized second moment
$\bar{d}_{123}$	Central distortion
$\bar{d}_1$	Side distortion
$P(\lambda)$	Probability of lattice point λ
$V(0)$	Voronoi region
$V_0(0)$	Discrete Voronoi region

N_i	Number of lattice vectors
θ_Λ	Theta series of a lattice
α	Index assignment map
$\langle X, Y \rangle$	Inner product
$\hat{X}$	Reconstruction of X
$Q(x)$	Quantization of x
Γ_m	Multiplicative group of automorphisms of order m
$\mathbb{Z}$	Scalar lattice (uniform lattice)
$\mathbb{Z}_2$	Square lattice
$\mathbb{Z}_L$	Hypercubic lattice
A_2	Hexagonal two-dimensional lattice
D_2	Checker board lattice
E_8	Gosset Lattice
Λ_{16}	Barnes-Wall lattice
Λ_{24}	Leech lattice
k	Number of diagonals used

TEKNIK-TEKNIK PENGKUANTUMAN SKALAR DAN KEKISI VEKTOR TIGA PENERANGAN UNTUK PENGHANTARAN DATA YANG CEKAP

ABSTRAK

Abad yang kedua puluh satu telah menyaksikan pertumbuhan teknologi komunikasi yang besar dan mempunyai kesan yang mendalam kepada kehidupan harian kita. Majoriti penyelidikan yang mengkaji dalam berbilang penerangan pengekodan (MDC) hanya berminat dalam pengekodan dua penerangan. Walau bagaimanapun, kebanyakan aplikasi praktikal memerlukan lebih daripada dua penghantaran bingkisan untuk memperolehi kualiti yang lebih memuaskan. Matlamat kajian ini adalah menubuhkan pengkuantuman skalar bagi sistem tiga penerangan pengkodan dengan menggunakan umpukan indeks tersarang yang diubahsuaikan. Tambahan pula, kajian ini juga bertujuan untuk menubuhkan pengkuantuman kekisi vektor bagi sistem tiga penerangan pengkodan dengan menggunakan fungsi penandaan dalam kekisi $\mathbb{Z}_4$ yang berdimensi empat. Ini adalah disebabkan oleh kekisi $\mathbb{Z}_4$ menawarkan lebih banyak takat kekisi sebagai jiran yang mengakibatkan pusat penyahkod supaya mencapai kualiti pembinaan semula yang lebih baik. Tesis ini meletakkan penekanan kepada pengeksploitasian sistem tiga penerangan MDC dengan menggunakan pengkuantuman skalar dan kekisi vektor. Cadangan sistem tiga penerangan mengandungi tiga pengekod dan tujuh penyahkod (termasuk satu pusat penyahkod). Cadangan umpukan indeks tersarang yang diubahsuaikan dengan berdimensi tiga telah dilaksanakan pada skema pengkuantuman skalar bagi tiga penerangan pengkodan.

Algoritma umpukan indeks menggunakan matriks untuk menunjukkan proses pemetaan dalam skema pengkuantuman skalar bagi tiga penerangan pengkodan yang dicadangkan. Tesis ini juga mencadangkan algoritma untuk fungsi penandaan dengan menggunakan kekisi $\mathbb{Z}_4$ bagi sistem MDC yang berpenerangan tiga. Unjuran tesseract dalam ruang berdimensi empat bagi kekisi $\mathbb{Z}_4$ menghasilkan empat keluaran dan data-data dihantar melalui tiga saluran, di mana salah satu keluaran itu ditakrifkan sebagai masa. Sistem pengkuantuman tiga penerangan yang cekap, memberi herotan yang rendah dan kualiti pembinaan nisbah puncak isyarat-hingar (PSNR) yang baik. Dengan mengenakan nombor penggunaan pepenjuru dalam umpukan indeks, kualiti pembinaan semula pada pusat penyahkod adalah semakin baik. Keputusan penyelakuan menunjukkan PSNR bagi pusat penyahkod menaik ke 34.53 dB pada kadar 0.1051 bpp dan 38.07 dB pada kadar 0.9346 bpp untuk skema cadangan MDSQ yang mempunyai tiga penerangan dengan $k = 2$. Peratus penambahan untuk kualiti pembinaan semula bagi pusat penyahkod menaik dari 6.36 % hingga 18.97 % bagi skema cadangan berbanding dengan skema-skema terkenal. Selain itu, cadangan skema pengkuantuman kekisi vektor bagi sistem tiga penerangan pengkodan (3DLVQ- $\mathbb{Z}_4$) mengatasi prestasi skema-skema MDC yang terkenal dari 4.4 % hingga 11.43 %. Kualiti pembinaan semula bagi pusat penyahkod menaik kepada 42.63 dB dan purata pembinaan semula bagi penyahkod sisi meraihi pada 32.13 dB, kedua-duanya pada kadar bit 1.0 bpp untuk skema cadangan 3DLVQ- $\mathbb{Z}_4$.

THREE-DESCRIPTION SCALAR AND LATTICE VECTOR QUANTIZATION TECHNIQUES FOR EFFICIENT DATA TRANSMISSION

ABSTRACT

In twenty-first century, it has been witness the tremendous growth of communication technology and has had a profound impact on our daily life. Throughout history, advancements in technology and communication have gone hand-in-hand, and the most recent technical developments such as the Internet and mobile devices have achieved in the development of communication to a new phase. Majority of researches who work in Multiple Description Coding (MDC) are interested with only two description coding. However, most of the practical applications necessitate more than two packets of transmission to acquire preferable quality. The goals of this work are to develop three description coding system of scalar quantizers using modified nested index assignment technique at the number of diagonals used in the index assignment of two. Furthermore, this work aims to develop three description lattice vector quantizers using designed labeling function in the four dimensional lattice $\mathbb{Z}_4$ since it offers more lattice points as neighbours that lead the central decoder to achieve better reconstruction quality. This thesis put emphasis on exploiting three description MDC system using scalar quantizers and lattice vector quantizers. The proposed three description system consists of three encoders and seven decoders (including of one central decoder). A three dimensional modified nested index assignment is implemented in the proposed three description scalar quantization scheme. The index assignment algorithm utilizes a matrix, to indicate the mapping process in the proposed three description scalar quantization scheme. As this thesis suggests a new labeling algorithm that uses lattice $\mathbb{Z}_4$ for three description MDC system. Projection of a tesseract in four-dimensional space of lattice $\mathbb{Z}_4$ yields four outputs and the data are transmitted via three channels where one of the outputs is defined as time. The three description quantization system is efficient that provides low distortion and good peak signal-to-noise ratio (PSNR) reconstruction quality. The greater the number of diagonals used in the index assignment, k in MDSQ scheme, the higher quality of the central reconstruction can be accomplished. Simulation results show that the central PSNR is promoted to 34.53 dB at rate of 0.1051 bpp and 38.07 dB at 0.9346 bpp for the proposed three description with $k = 2$ Multiple Description Scalar Quantization (MDSQ) scheme. The percentage gain for the central reconstruction quality is improved from 6.36 % to 18.97 % by the proposed three description scalar quantizer which is at $k = 2$ compared to the renowned MDSQ schemes. Moreover, the proposed three description lattice vector quantization (3DLVQ- $\mathbb{Z}_4$) scheme outperforms the renowned MDC schemes from 4.4 % to 11.43 %. The central reconstruction quality is promoted to 42.63 dB and the average side reconstruction quality inaugurates 32.13 dB, both at bit rate of 1.0 bpp for the proposed 3DLVQ- $\mathbb{Z}_4$ scheme.

CHAPTER 1

INTRODUCTION

1.1 Project Overview and Motivation

The past few decades have seen a momentous improvement of communications technology in a modern society. In fact, the communication technology has experienced expeditious evolution since the days when pigeons are used as messengers. Affirmatively, technology creates a world without boundaries.

The world have been connected like never before by texting, email, instant messaging, social networks, newsgroups, blogging, video transmission, video conferences, etc. The innovation of technology rapidly aroused that many people have been benefited, regarding to the areas with respect to education, healthcare, finance, medical, etc.

To enhance the robustness of data transmission techniques, Multiple Description Coding (MDC) has been introduced by researchers as in [1], [2]. MDC generates several independent description, whereby the decoders able to reconstruct the received data with moderate accuracy [3]. There are many MDC related works that combines with data compression techniques, which utilizes the techniques of scalar quantization (SQ) [4], [5] vector quantization (VQ) [6], [7], lattice vector quantization (LVQ) [8], [9] etc.

Scalar quantization in MDC system, usually known as multiple description scalar quantization (MDSQ) technique have been copiously researched since it is very straightforward and comprehensive technique. Since MDSQ is basically one-to-one mapping in codebook, it takes time to compute for the encoding and decoding process. Besides, MDSQ distorts a lots in coarse side decoders and produces low quality in the side reconstructed images. There is trade-off in MDSQ which manipulated by the index assignment matrix, where by the more diagonals in the index assignment matrix degrade the reconstructed quality of side decoders but perform better in reconstruction of central decoder.

In order to accelerate the computation for the encoding and decoding process, multiple description vector quantization (MDVQ) is introduced [10], [11]. Unfortunately, codebook generation of MDVQ design embraces high computational loads and very time consuming.

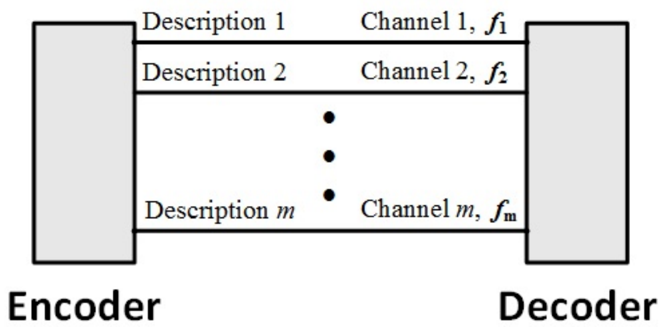

Figure 1.1: Application of MDC scheme onto FDM.

The general concept of applying MDC scheme onto frequency division multiplexing (FDM) is illustrated as in Figure 1.1. The MDC system generates up to m^{th} description and transmits the data in parallel by the correspondence channels. Each channel functions in specific frequency so that multiple data signals are combined for simultaneous transmission via a shared communication medium.

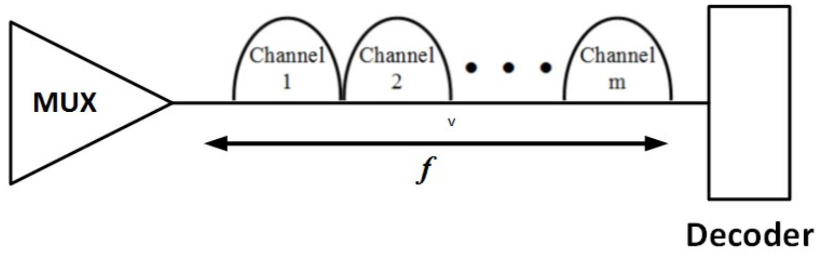

Figure 1.2: Block diagram of application MDC scheme onto FDM.

Figure 1.2 describes the block diagram for application of MDC scheme to be applied in FDM. For example, the system are divided up into different subcarrier frequencies for voice, upstream and downstream data transmissions (frequency duplex," i.e. simultaneous transmissions in both directions); as the generated description represents each subcarrier.

By applying suitable quantization techniques onto MDC scheme, the input vectors to the encoders can directly be used as the addresses in codebooks to select the correspondence codewords with the appropriate information. The system can thereby enable fast encoding, classifying and decoding. Therefore, MDC scheme is useful for real-time video applications, i.e. interactive video on the Internet or video teleconferencing.

Nowadays, the ubiquitous requirement has been imposed for most applications which incorporate relevant multimedia communications. However, the available networks are unable to satisfy the demand for having the unlimited bandwidth and dependability. Therefore, MDC aims to address this issue.

1.2 Problem Statement

Efficiency data transmission and security of the transmitted information are very crucial in communication technology. One of the main obstacles for trustworthy and reliable network in communication technology nowadays is the channel impairment. Single-channel network limits the performance regarding to the safety and robustness of the data transmission.

Most of the research works in MDC are concerned only with two description as presented in [12], [13], [14], [15]. However, most of the practical applications involves huge amount of data, and they are transmitted using packets over the Internet protocol (IP) networks which are limited in size. Thus transmission with more than two packets for retransmission is very much demanded to achieve better quality of reconstruction data.

The quality of reconstruction can be improved if there are more descriptions available for transmission. In MDC system, if some paths in the network may incur data lost or corruption, the data can still be reconstructed using the other available data paths. A diversity system with three description for packets carriage helps to enlarge the chance of offering more reliable data transmission network. Alternatively, the probability of all description fail or abort is lessen than in the single description or two description system.

1.3 Objectives of the Research

The key objectives of this work are as follows:

i. To develop three description scalar quantizers using modified nested index assignment algorithm.

ii. To develop three description lattice vector quantizers using the lattice $\mathbb{Z}_4$ labeling function algorithm.

iii. To verify both of the developed algorithms.

1.4 Summary of Research Activities

This research focuses on the design and to ameliorate of data transmission system for application in communication networks based on a designated MDC scheme that amalgamates of scalar and lattice vector quantization techniques.

The summary of research activities is illustrated in Figure 1.3. First, the design specifications are determined for the three description system, which consists of three encoders and seven decoders (including of one central decoder). Then, the algorithm is exploited, to be implemented in three description system for scalar quantization and lattice vector quantization.

There are two branches from algorithm development i.e. scalar quantization technique and lattice vector quantization technique. In this project, the model design is built and simulated using MATLAB codes. For scalar quantization technique, the encoders perform the encoding process. The index assignment design is implemented