# WAVELET VIDEO COMPRESSION

**By**

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy**

**December 2006**

**Dedicated**
**to**

**My Wife and Family**

Abstract of thesis presented to the Senate of Universiti Putra Malaysia, in fulfilment of the requirement for the degree of Doctor of Philosophy

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**December 2006**

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**Faculty: Computer Science and Information Technology**

The thesis proposes the current approaches in wavelet technology which has provided efficient framework of multi-resolution space-frequency representation with promising applications in video processing. This discrete wavelet transform (DWT) is becoming increasingly important in visual applications because of its flexibility in representing non-stationary signals such as images and video sequences. The main objective of this thesis is to develop a wavelet video compression system. There are however many parameters within a wavelet analysis and synthesis which govern the quality of a decoded video sequences such as boundary policies, quantization threshold, decomposition strategies and the choice of wavelet filter-banks. An evaluation of the visual quality of images and video sequences at different parameter settings leads to recommendations on the wavelet filter parameters to be used in video compression.

In this thesis the video compression schemes of 2D frame by frame and 3D spatio-temporal wavelet transformation are proposed. The standard spatio-temporal scheme has fixed number of sub-bands generated after the temporal decomposition and adopting adaptive quantization to the fixed number of sub-bands. The proposed spatio-temporal scheme proposed a flexible number of sub-bands generated depending on the penetration depth of the wavelet

transformation. The global and level-dependent-threshold quantization methodology with the statistical adaptive estimation of wavelet shrinkage for the transformed coefficients have been adopted and provides high compression performance even without entropy coding and comparable to other coding scheme utilizing other quantization methods. The level-dependent-threshold is found to be a useful tool for providing fixed rate and used throughout the simulations for the empirical evaluation of the tested parameters as compared to global threshold.

Extensive experimental investigations on a wide variety of monochrome and color images, and video sequences in QCIF, CIF and SIF resolutions are reported in this thesis. The international benchmark of visual quality evaluation of Mean Squared Error (MSE), Compression Ratio (CR), and Peak Signal to Noise Ratio (PSNR) are used as the objective measure of performance quality. Experimental results had shown that bi-orthogonal 9/7 (Bior-4.4) wavelet filters perform comparable for images and video sequences with less temporal activity however filter-banks from Symlet family (Sym-5) has shown to perform the best and out-performed others when applied to video sequences with even higher background activity such as the Car-phone and Akiyo sequences. Coding performance has been reported and performed best with dyadic DWT decomposition, periodic extensions and level-dependent threshold quantization.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falasafah

**WAVELET BAGI PEMAMPATAN VIDEO**

Oleh

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Tesis ini mengkaji secara mendalam konsep *wavelet* yang telah digunakan bagi aplikasi yang melibatkan pemprosesan video. *Discrete wavelet transform* – DWT, yang menggunakan kaedah multi-dimensi berupaya digunakan untuk pemprosesan imej dan gambar video secara berkesan. DWT telah menjadi penting bagi aplikasi data berbentuk video kerana kebolehannya dalam mengintegrasikan isyarat yang tidak tetap seperti video. Kajian utama tesis ini adalah bagi mengenalpasti kaedah wavelet-filter-banks dalam pemampatan sequent video. Namun terdapat beberapa kekangan yang perlu diambil-kira bagi menjamin kualiti keluaran yang tinggi seperti *boundary policies, quantization threshold* dan strategi decomposition. Penilaian kepada kualiti keluaran gambar dan video menggunakan beberapa *parameter* tersebut akan membolehkan cadangan terhadap penggunaan *parameter* penting untuk pemilihan wavelet filter yang boleh digunakan dalam pemampatan video.

Tesis ini mengkaji potensi skim pemampatan video menggunakan pergerakkan wavelet dari *frame* ke *frame* dalam dimensi 2D, serta transformasi dalam dimensi 3D atau kaedah *spatio-temporal* dalam pemprosesan visual data. Kaedah biasa skim *spatio-temporal* ini menggunakan jumlah sub-bands yang tetap setelah dilakukan dekomposisi diantara *frame*

gambar *(temporal).* Kaedah *spatio-temporal* yang dicadangkan ini mempunyai keupayaan menjana jumlah sub-bands yang flexibal. Jadi penggunaan pemampatan mengunakan kaedah penyingkaran secara *global* dan *level-dependent threshold* ini telah menunjukkan pemampatan yang tinggi, walaupun tanpa *entropy coding* dan setanding dengan sistem yang menggunakan kaedah quantization lain.

Satu kajian *experimental* menggunakan beberapa jenis gambar imej hitam-putih dan warna serta gambar video warna dalam beberapa format seperti QCIF, CIF, SIF dalam beberapa nisbah pemampatan telah dilakukan menggunakan pengukuran *Mean Squared Error* (MSE), Nisbah Pemampatan (CR) dan *Peak Signal to Noise Ratio (PSNR).* Kajian mendapati jenis wavelet bi-orthogonal 9/7 (bior-4.4) telah menunjukkan prestasi yang kurang baik jika digunakan bagi gambar yang kurang pergerakkan dan terbaik, namun jenis wavelet Symlet (sym-5) telah menunjukkan prestasi memberangsagkan jika digunakan bagi pemampatan gambar yang mempunyai pergerakkan yang banyak terutamanya dibahagian latar belakang, seperti sequen Carphone dan Akiyo. Prestasi pemampatan yang tinggi telah dilaporkan menggunakan dekomposisi secara *dyadic DWT, periodic extensions* dan *level-dependent threshold quantization*, dengan jumlah kedalaman transformasi bergantung kepada saiz image dan video.

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I certify that an Examination Committee has met on 7th. December 2006 to conduct the final examination of Rohmad Bin Fakeh on his Doctor of Philosophy thesis entitled "Wavelet Video Compression" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. The Committee Members for the candidate are as follows:

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## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

_____

**ROHMAD BIN FAKEH**

Date : 6 April 2007

**TABLE OF CONTENTS**


| | | Page |
|---|---|---|
| **DEDICATION** | | ii |
| **ABSTRACT** | | iii |
| **ABSTRAK** | | v |
| **ACKNOWLEDGEMENTS** | | vii |
| **APPROVAL** | | x |
| **DECLARATION** | | xii |
| **LIST OF TABLES** | | xvii |
| **LIST OF FIGURES** | | xxiii |
| **LIST OF ABBREVIATIONS** | | xxxv |
| **CHAPTER** | | |
| 1 | **INTRODUCTION** | |
| 1.1 | Motivation | 1.1 |
| 1.2 | Economic Perspective | 1.3 |
| 1.3 | Research Problems | 1.6 |
| 1.3.1 | The Choice of Coding Strategy | 1.8 |
| 1.3.2 | Border Distortion | 1.8 |
| 1.3.3 | Decomposition Strategy | 1.14 |
| 1.3.4 | Adaptive Choice of Wavelet Filter-bank | 1.14 |
| 1.4 | Research Objectives | 1.15 |
| 1.5 | Scope of Research | 1.16 |
| 1.6 | Research Contributions | 1.17 |
| 1.7 | Thesis Structure | 1.18 |
| 2 | **LITERATURE REVIEW** | |
| 2.1 | Introduction | 2.1 |
| 2.2 | Visual Data Compression | 2.1 |
| 2.3 | Real Space Coding Techniques | 2.2 |
| 2.3.1 | Vector Quantization | 2.3 |
| 2.3.2 | Fractal | 2.6 |
| 2.4 | Spatial Frequency Coding Techniques | 2.8 |
| 2.4.1 | Discrete Cosine Transform | 2.10 |
| 2.4.2 | Image Coding Architecture | 2.12 |
| 2.4.3 | Video Coding Architecture | 2.13 |
| 2.5 | Discussion | 2.19 |
| 2.6 | What are Wavelet Transforms? | 2.22 |
| 2.6.1 | Wavelets are building blocks for general functions | 2.22 |
| 2.6.2 | Wavelets have space-frequency localisation | 2.22 |
| 2.6.3 | Wavelets have fast transform algorithms | 2.23 |
| 2.6.4 | Fourier Transform | 2.24 |
| 2.6.5 | Discrete Wavelet Transform | 2.24 |

2.6.6 Wavelet Packet Transform 2.27
2.6.7 How Wavelets extract Information ? 2.29
2.7 State of the art in Wavelet Image Coding 2.34
2.7.1 Zero-Tree Coding 2.34
2.7.2 Set Partitioning in Hierarchical Trees (SPIHT) 2.36
2.7.3 Space Frequency Quantization (SFQ) 2.36
2.7.4 Related Research 2.37
2.8 Summary and Discussion 2.54

3 **WAVELET TRANSFORMATION**
3.1 Introduction 3.1
3.2 Multi-resolution Representation 3.2
3.2.1 Properties of Scaling Functions 3.4
3.2.2 Wavelet functions 3.5
3.3 Discrete Wavelet Transform (DWT) 3.8
3.3.1 Discrete Wavelet Analysis 3.9
3.3.2 Discrete Wavelet Synthesis 3.10
3.4 Wavelet Transform Vs Filter-Banks 3.12
3.5 Filter-Bank Approach 3.13
3.6 Regularity and Vanishing Moments 3.14
3.6.1 Regularity 3.14
3.6.2 Estimation of Regularity 3.15
3.6.3 Vanishing Moments 3.16
3.7 Wavelet Filter bank 3.17
3.8 Wavelet Boundary Policy 3.19
3.8.1 Boundary Filters 3.20
3.8.2 Boundary Treatment 3.21
3.9 Summary and Discussion 3.23

4 **RESEARCH METHODOLOGY**
4.1 Introduction 4.1
4.2 Proposed Wavelet Compression Algorithm 4.2
4.2.1 Wavelet Image Compression Scheme 4.2
4.2.2 Proposed 2D Wavelet Video Compression Scheme 4.6
4.2.3 Proposed 3D Wavelet Video Compression Scheme 4.8
4.3 Input Sequences 4.11
4.3.1 Monochrome Images 4.11
4.3.2 Color Images 4.11
4.3.3 Source Picture Format 4.12
4.3.4 Original Sequences 4.14
4.3.5 Color Space Conversion 4.14
4.4 Wavelet Transformaion 4.17
4.4.1 Temporal Compresion 4.17
4.4.2 Spatial Compresion 4.19
4.4.3 The Choice of Wavelet Filter-Banks 4.23
4.4.3.1 The Wavelet Filter-Banks 4.25
4.4.4 Penetration Depth / Level of Transformation 4.31
4.5 Wavelet Threshold Selection 4.33
4.5.1 Global Thresholding 4.34
4.5.2 Level Dependent Thresholding 4.35

4.6 Wavelet Boundary Policy 4.36
4.6.1 Zero-Padding 4.38
4.6.2 Symmetrization 4.39
4.6.3 Smooth Paddng 4.41
4.6.4 Periodic Extension 4.41
4.7 Performance Measure 4.42
4.8 Summary and Discussion 4.44

5 **RESULTS AND DISCUSSION**
5.1 Introduction 5.1
5.2 Wavelet Boundary Policy 5.2
5.2.1 Single Frame of Video and Image 5.2
5.2.2 Video Sequences 5.6
5.2.3 Discussion 5.19
5.3 Wavelet Threshold Strategy 5.20
5.3.1 Global Threshold 5.20
5.3.2 Level Dependent Threshold 5.25
5.3.3 Discussion 5.31
5.4 Penetration Depth / Level of Transformation 5.32
5.4.1 Color Images 5.32
5.4.2 Video Sequences 5.35
5.4.3 Discussion 5.37
5.5 Decomposition Strategy 5.37
5.5.1 Video Sequences 5.37
5.5.2 Discussion 5.43
5.6 Choice of Wavelet Function 5.44
5.6.1 Single Frame of Video Coding (Images) 5.45
5.6.1.1 Lena 5.45
5.6.1.2 Barbara 5.49
5.6.1.3 Goldhill 5.52
5.6.1.4 Akiyo Image 5.55
5.6.2 Discussion 5.61
5.6.3 Video Sequences 5.65
5.6.3.1 Akiyo 5.65
5.6.3.2 Claire 5.68
5.6.3.3 Carphone 5.71
5.6.3.4 Foreman 5.74
5.6.3.5 Grandmother 5.78
5.6.3.6 Miss America 5.81
5.6.3.7 Mother & Daughter 5.84
5.6.3.8 News 5.86
5.6.3.9 Salesman 5.90
5.6.3.10 Suzie 5.93
5.6.4 Discussion 5.96

5.7 Proposed Video Coding 5.109
5.7.1 Image Compression System 5.109
5.7.2 2D Video Compression System 5.109
5.7.2.1 QCIF Resolution 5.110
5.7.1.2 CIF and SIF Resolution 5.114
5.7.3 3D Video Compression System 5.119
5.8 Summary and Discussion 5.134

6 **CONCLUSION AND FUTURE RESEARCH**
6.1 Introduction 6.1
6.2 Conclusion 6.2
6.3 Future work 6.3

**REFERENCES / BIBLIOGRAPHY** R1
**APPENDICES** A1
**BIODATA OF THE AUTHOR** B1

## LIST OF TABLES


| Table | | Page |
|---|---|---|
| 1.1 | The compression requirements: the target bit-rate | 1.15 |
| 3.1 | Type of extension for analysis and synthesis filtering to the left and to the right bound of the signal. | 3.21 |
| 4.1 | Standard Picture Format Supported by H.263 | 4.13 |
| 4.2 | Matrix of RGB to YCbCr Color Conversion | 4.15 |
| 4.3 | List of Filter length for Biorthogonal Filters | 4.27 |
| 4.4 | List of Filter length for Daubechies Filters | 4.28 |
| 4.5 | List of Filter length for Coifets Filters | 4.30 |
| 4.6 | List of Filter length for Symlets Filters | 4.31 |
| 4.7 | The Number of possible iterations for Biorthogonal Filter | 4.32 |
| 4.8 | The Number of possible iterations for Daubachies Filter | 4.32 |
| 4.9 | The Number of possible iterations for Symlets Filter | 4.33 |
| 4.10 | The Number of possible iterations for Coiftels Filter | 4.33 |
| 4.11 | The size of the time-scale domain with zero-padding depends on the selected wavelet filter banks | 4.36 |
| 5.1 | Results for Border Distortion through Zero-Padding, Symmetric, Smooth Padding, and Periodic Extensions of (a) Lena, (b) Barbara and (c) Goldhill at 1.0bpp, using bior-4.4 | 5.2 |
| 5.2 | Results of Border Distortion through Zero-Padding, Symmetric, Smooth Padding and Periodic Extensions of Goldhill , using Bior4.4 at (a) 1.0bpp, (b) 0.5 bpp, (c) 0.25 bpp, (d) 0.125bpp, (e) 0.0625bpp | 5.4 |
| 5.3 | Results of Border Distortion through (a) Periodic Extensions (b) Symmetric, (c) Zero-Padding, (d) Smooth Padding of Goldhill using Bior4.4 at 1.0bpp, 0.5 bpp, 0.25 bpp, 0.125bpp, 0.0625bpp | 5.5 |
| 5.4 | Simulation results for Salesman sequences of QCIF size at 5fps decoded at average data rate of 32kbps using the proposed algorithm with bior-4.4 | 5.10 |
| 5.5 | Simulation results for Carphone sequences of QCIF size at 5fps decoded at average data rate of 32kbps using the proposed algorithm with bior-4.4 | 5.11 |

| | | |
|---|---|---|
| 5.6 | Simulation results for Claire sequences of QCIF size at 5fps decoded at average data rate of 32kbps using the proposed algorithm with bior-4.4 | 5.12 |
| 5.7 | Results of Y-component of Miss America with (Average video bit-rate of 62 kbps, 7.5 fps Periodic Extensions, and using Bi-orthogonal of length 9/7), average PSNR of 41.5 dB. | 5.14 |
| 5.8 | Results of Y-component of Miss America with (Average video bit-rate of 62 kbps, 7.5 fps, Symmetric Extensions, and using Bi-orthogonal of length 9/7), and average PSNR of 39.0 dB, at global threshold of 16.7. | 5.15 |
| 5.9 | Results of Miss America data with (62 kbps, 15 fps Periodic Extensions, and using Bi-orthogonal of length 9/7) average PSNR of 37.2 dB, of global threshold of 212 | 5.16 |
| 5.10 | Results of Miss America data with (Average video bit-rate of 62 kbps, 15 fps Symmetric Extensions, and using Bi-orthogonal of length 9/7) average PSNR of 34.0 dB, of global threshold of 42 | 5.17 |
| 5.11 | Results of the difference between Periodic and Symmetic to Zero Padding for the best boundary strategy for the respective video sequences | 5.19 |
| 5.12 | The detail Results of Global Threshold values, MSE, Compression Ratio (CR), PSNR Values and Coefficients Density for Akiyo QCIF sequences using bior-4.4 and Periodic Extensions | 5.21 |
| 5.13 | The detail Results of Global Threshold values, MSE, Compression Ratio (CR), PSNR Values and Coefficients Density for Akiyo QCIF and Miss America sequences using bior-4.4 and Periodic Extensions | 5.24 |
| 5.14 | The detail Results of Level Dependent Threshold values, MSE, Compression Ratio (CR), PSNR Values and Coefficients Density for Akiyo QCIF and Miss America sequences using bior-4.4 and Periodic Extensions | 5.30 |
| 5.15 | The detail Results of MSE, MAE, Compression Ratio (CR) and PSNR Values for Color Image of Size 1280x720 pixels using Global Threshold | 5.34 |
| 5.16 | The detail Results of MSE, MAE, Compression Ratio (CR) and PSNR Values for the decoded CIF News video at 30fps, using bior-2.2 and Level Dependent Threshold at 7. | 5.35 |
| 5.17 | The detail Results of MSE, MAE, Compression Ratio (CR) and PSNR Values for the decoded CIF News video at 30fps, using bior-2.2 and Level Dependent Threshold at 9. | 5.36 |
| 5.18 | Average in PSNR for Wavelet Packet and Discrete Wavelet Transform of three video sequences of Miss America, Foreman, and Carphone , using the best nine types filters and Global threshold of 10 | 5.38 |

| | | |
|---|---|---|
| 5.19 | Average in PSNR for Wavelet Packet and Discrete Wavelet Transform of three video sequences of Miss America, Foreman, and Carphone , using the best eight types filters and Global threshold of 20 | 5.39 |
| 5.20 | Average in PSNR for Wavelet Packet and Discrete Wavelet Transform of three video sequences of Miss America, Foreman, and Carphone , using the best eight types filters and Global threshold of 45 | 5.40 |
| 5.21 | Average in PSNR for Wavelet Packet and Discrete Wavelet Transform of three video sequences of Miss America, Foreman, and Carphone , using the best eight types filters and Global threshold of 85 | 5.41 |
| 5.22 | Average in PSNR for Wavelet Packet and Discrete Wavelet Transform of three video sequences of Miss America, Foreman, and Carphone, using the best eight types filters and Global threshold of 125 | 5.42 |
| 5.23 | Average and difference in PSNR for Wavelet Packet and Discrete Wavelet Transform of eight video sequences, using Sym5 Filter for Low-Pass-Temporal and Haar Filter for High-Pass-Temporal Frequencies, at two Decomposition Levels, and Global threshold of 20 | 5.43 |
| 5.24 | The families of Wavelet Filters | 5.44 |
| 5.25 | The detail result for Lena of size 512x512 pixels using the best wavelet filter (bior-6.8) | 5.49 |
| 5.26 | The detail result for Barbara of size 512x512 pixels using the best wavelet filter (db-15) | 5.52 |
| 5.27 | The detail result for Goldhill of size 512x512 pixels using the best wavelet filter (bior-6.8) | 5.55 |
| 5.28 | The detail result for Akiyo QCIF size using the best wavelet filter (bior-3.7) | 5.58 |
| 5.29 | Detail result for Lena of size 512x512 pixels using bior-6.8 | 5.58 |
| 5.30 | Detail result for Barbara of size 512x512 pixels using bior-6.8 | 5.59 |
| 5.31 | Detail result for Goldhill of size 512x512 pixels using bior-6.8 | 5.59 |
| 5.32 | For LVD of Level 2 of Mean Squared error (MSE), with mm=6, CR= 3:1 , Density=84451, Periodic, of Three Source Images at Size 512x512 | 5.62 |
| 5.33 | For LVD of Level 3 of Mean Squared error (MSE), with mm=6, CR= 10.8:1 , Density=24185, Periodic, of Three Source Images at Size 512x512 | 5.62 |
| 5.34 | For LVD of Level 4 of Mean Squared error (MSE), with mm=6, CR= 39.7:1 , Density=6596, Periodic, of Three Source Images at Size 512x512 | 5.63 |

5.35 For LVD of Level 5 of Mean Squared error (MSE), with mm=6, CR= 149.5:1 , Density=1754, Periodic, of Three Source Images at Size 512x512. 5.63

5.36 For LVD of Level 6 of Mean Squared error (MSE), with mm=6, CR= 571:1 , Density=459, Periodic, of Three Source Images at Size 512x512 5.63

5.37 For LVD of Level 7 of Mean Squared error (MSE), with mm=6, CR= 2202:1 , Density=119, Periodic, of Three Source Images at Size 512x512 5.64

5.38 For LVD of Level 8 of Mean Squared error (MSE), with mm=, CR= 8456:1 , Density=31, Periodic, of Three Source Images at Size 512x512 5.64

5.39 For LVD of Level 9 of Mean Squared error (MSE), with mm=6, CR= 37449:1 , Density=7, Periodic, of Three Source Images at Size 512x512 5.64

5.40 The detail results of the best 12 Wavelet Bases for 50 frames Akiyo Video of QCIF size using the Periodic Extension and Level Dependent Threshold 5.68

5.41 The detail results of the best 12 Wavelet Bases for 50 frames Claire Video of QCIF size using the Periodic Extension and Level Dependent Threshold 5.71

5.42 The Overall detail results of the best 12 Wavelet Bases for 50 frames Carphone Video of QCIF size using the Periodic Extension and Level Dependent Threshold 5.74

5.43 The Overall detail results of the best 12 Wavelet Bases for 50 frames Foreman Video of QCIF size using the Periodic Extension and Level Dependent Threshold 5.77

5.44 The Overall detail results of the best 12 Wavelet Bases for 50 frames Grandma Video of QCIF size using the Periodic Extension and Level Dependent Threshold 5.80

5.45 The Overall detail results of the best 12 Wavelet Bases for 50 frames Miss America Video of QCIF size using the Periodic Extension and Level Dependent Threshold 5.83

5.46 The Overall detail results of the best 12 Wavelet Bases for 50 frames Mother & Daughter Video of QCIF size using the Periodic Extension and Level Dependent Threshold 5.86

5.47 The Overall detail results of the best 12 Wavelet Bases for 50 frames News Video of QCIF size using the Periodic Extension and Level Dependent Threshold 5.89

5.48 The Overall detail results of the best 12 Wavelet Bases for 50 frames Foreman Video of QCIF size using the Periodic Extension and Level Dependent Threshold 5.92

| | | |
|---|---|---|
| 5.49 | The Overall detail results of the best 12 Wavelet Bases for 50 frames Suzie Video of QCIF size using the Periodic Extension and Level Dependent Threshold | 5.95 |
| 5.50 | For LVD of Level 1 of Mean Squared error (MSE), with m=100, CR=4:1, Density=6371, Periodic, Ten (10) Source Video Sequences in QCIF Format. | 5.96 |
| 5.51 | For LVD of Level 2 of Mean Squared error (MSE), with m=100, CR=15:1, Density=1638, Periodic, Ten (10) Source Video Sequences in QCIF Format. | 5.96 |
| 5.52 | For LVD of Level 3 of Mean Squared error (MSE), with m=100, CR=54:1, Density=463, Periodic, Ten (10) Source Video Sequences in QCIF Format. | 5.97 |
| 5.53 | For LVD of Level 4 of Mean Squared error (MSE), with m=100, CR=144:1, Density=175, Periodic, Ten (10) Source Video Sequences in QCIF Format. | 5.97 |
| 5.54 | For LVD of Level 5 of Mean Squared error (MSE), with m=100, CR=150:1, Density=168, Periodic, Ten (10) Source Video Sequences in QCIF Format. | 5.98 |
| 5.55 | The average Mean Squared Error (MSE) for LVD of Level 1 to 5 for 10 QCIF Video Sequences using Periodic Extensions. | 5.98 |
| 5.56 | Simulation results for Carphone sequences of QCIF size at 15fps decoded at average data rate of 64 kbps using the proposed algorithm with Biorthogonal filter | 5.100 |
| 5.57 | Simulation results for Carphone sequences of QCIF size at 15fps decoded at average data rate of 64 kbps using the proposed algorithm with Daubechies filter | 5.101 |
| 5.58 | Simulation results for Carphone sequences of QCIF size at 15fps decoded at average data rate of 64 kbps using the proposed algorithm with Coiflets filter | 5.102 |
| 5.59 | Simulation results for Carphone sequences of QCIF size at 15fps decoded at average data rate of 64 kbps using the proposed algorithm with Symlets filter | 5.103 |
| 5.60 | Simulation results for Carphone sequences of QCIF size at 15fps decoded at average data rate of 64 kbps using the proposed algorithm with the best Biorthogonal, Coiflets and Symlets filters | 5.104 |
| 5.61 | Simulation results for Miss America and Carphone Sequence of QCIF size, at 5 fps decoded at data rates of 16kbps and 64kbps respectively, using the proposed algorithm with bi-orthogonal filters, Daubechies, Coiflets and Symlets | 5.105 |

| | | |
|---|---|---|
| 5.62 | Simulation results for Foreman sequences of QCIF size 174x144 pixels, at 10 frames per second decoded at different data rates of 20,32,64,128 and 256 kbps respectively, using the proposed algorithm with bi-orthogonal filter of length 17/11 | 5.106 |
| 5.63 | Simulation results for Foreman sequences of QCIF size 174x144 pixels, at 15 frames per second decoded at different data rates of 20,32,64,128 and 256 kbps respectively, using the proposed algorithm with bi-orthogonal filter of length 17/11 | 5.106 |
| 5.64 | Overall Video Sequence Usage Ranking for the best Wavelet Filter Using Level Dependent Threshold Based Individual Video | 5.107 |
| 5.65 | Results of tested video sequences using the proposed video compression scheme with (1) Periodic Extension (2) Biorthogonal:4.4 (3) Level-dependent Threshold (4) Frame rate of 10fps | 5.109 |
| 5.66 | Results of MSE and PSNR values of the tested video sequences using the proposed video compression scheme, with (1) Periodic Extension (2) Biorthogonal:4.4 (3) Level-dependent Threshold (4) Frame rate of 10fps. | 5.111 |
| 5.67 | Results of PSNR values of the tested video sequences using the proposed video compression scheme, with (1) Periodic Extension (2) Biorthogonal:4.4 (3) Level-dependent Threshold (4) Frame rate of 10fps | 5.112 |
| 5.68 | Performance Evaluation of the proposed WVC compared to Ashourian (2001) in PSNR, Bitrate and Compression Ratio for the decoded Luminance Y of Claire, Miss America, salesman, Suzie and and Carphone video sequences in QCIF Resolutions | 5.127 |
| 5.69 | Performance Evaluation of the proposed WVC compared to Peter (1999) in PSNR, Bitrate and Compression Ratio for Miss America and Carphone of QCIF Resolution | 5.131 |
| 570 | Overall analysis of the 4 Color Images of 512x512 pixels off MSE/CR for the tested video using the proposed video compression scheme, with Periodic Extension, Bior-4.4, Level-dependent Threshold, 10fps | 5.134 |
| 5.71 | Overall analysis of the 10 QCIF Video Sequences of MSE/CR for the tested video using the proposed video compression scheme, with Periodic Extension, Bior-4.4, Level-dependent Threshold, 10fps | 5.135 |

## LIST OF FIGURES


| Figure | | Page |
|---|---|---|
| 1.1 | Future DVB-X Receiver | 1.2 |
| 2.1 | The Encoder and decoder in a vector quantizer | 2.4 |
| 2.2 | 1- D cosine basis functions | 2.10 |
| 2.3 | 2-DCT basis functions | 2.10 |
| 2.4 | JPEG Picture Coder Architecture | 2.12 |
| 2.5 | H.261 Video Coder Architecture | 2.14 |
| 2.6 | MPEG-1/2 frame encoding | 2.16 |
| 2.7 | H.263 PB-frame encoding | 2.16 |
| 2.8 | Windowed Fourier Transform Domain | 2.22 |
| 2.9 | Two dimensional decomposition | 2.23 |
| 2.10 | Wavelet Transform Binary Graph | 2.24 |
| 2.11 | Wavelet Packet Transform binary graph, fully decomposed | 2.25 |
| 2.12 | Two level Wavelet Dyadic Horizontal and Vertical Filtering | 2.26 |
| 2.13 | Two dimensional Tree Structured Decomposition | 2.26 |
| 2.14 | Parent-Child Dependencies of Subbands | 2.32 |
| 2.15 | An 11 sub-bands tree-structured spatio-temporal decomposition | 2.34 |
| 2.16 | Template for displaying the 11-band decomposition | 2.35 |
| 2.17 | For the comparison of quality Average PSNR versus bitrate for several QCIF video sequences, at 10 and 30fps | 2.39 |
| 2.18 | For the comparison of quality Average PSNR versus Compression Ratio for several QCIF video sequences, at 10 and 30fps | 2.40 |
| 2.19 | Forward and inverse integer transform | 2.45 |
| 3.1 | Multi-resolution Representation | 3.9 |
| 3.2 | Multi-resolution Representation of L Sq R | 3.11 |

| | | |
|---|---|---|
| 3.3 | Decomposition of signal using analysis filters | 3.13 |
| 4.1 | Proposed Wavelet Image Compression | 4.3 |
| 4.2 | Proposed 2D Wavelet Video Compression | 4.7 |
| 4.3 | Proposed 3D Wavelet Video Compression | 4.9 |
| 4.4 | (a) The original Lena Image, (b) Level 5 decomposition of Lena image, (c) Histogram plot of the original Lena image, (d) Frequency response after level 5 decomposition of Lena image | 4.13 |
| 4.5 | The Original, Y, Cb and Cr components for the Akiyo QCIF Sequence | 4.16 |
| 4.6 | The Original, Y , Cb and Cr components for the News CIF Sequence | 4.16 |
| 4.7 | The Original, Y , Cb and Cr components for the Stefan SIF Sequence | 4.17 |
| 4.8 | Decomposition of QCIF size Suzie Video Sequence | 4.18 |
| 4.9 | Wavelet decomposition of Average and Difference frame and the corresponding histogram plot for the 1st. frame of Akiyo video sequence | 4.19 |
| 4.10 | Level one of 2-D DWT applied on an image | 4.21 |
| 4.11 | Level one of 2-D DWT of High-pass and Low-pass | 4.21 |
| 4.12 | Level Three Dyadic DWT scheme used for Image Compression | 4.22 |
| 4.13 | High-Pass Temporal and Low-Pass Temporal for Video sequences Compression | 4.22 |
| 4.14 | Scaling and Wavelets functions of Bior-2.2 | 4.28 |
| 4.15 | Original Mesh of Lena | 4.38 |
| 4.16 | Mesh of Lena using Zero-padding | 4.39 |
| 4.17 | Mesh of Lena using Symmetrization | 4.40 |
| 4.18 | Mesh of Lena using Smooth Padding | 4.41 |
| 4.19 | Mesh of Lena using Periodic Padding | 4.41 |
| 5.1 | (a) Original QCIF of Miss America, (b) Mesh plot of original Miss America, (c) Histogram of original Miss America, and (d) Histogram of decoded Miss America at 32kbps/5fps, using Zero Padding. | 5.6 |
| 5.2 | Mesh plots of Miss America,(a) Periodic Extension, (b) Symmetric Extension, (c) Smooth-Padding, and (d) Zero-Padding. | 5.7 |

5.3 The decoded Miss America at 32kbps/5fps using (a) Periodic Extension: 37.46dB, (b) Symmetric Extension: 36.79dB,(c) Smooth-Padding: 36.19 dB, and (d) Zero-Padding: 33.88 dB 5.8

5.4 The plots of the 100 frames Miss America at 32kbps/5fps using (a) Periodic Extension: 37.46dB, (b) Symmetric Extension: 36.79 dB, (c) Smooth-Padding: 36.19dB, and (d) Zero-Padding: 33.88dB. The PSNR difference between (a) and (d - which is the default setting) is 3.58dB 5.9

5.5 Plot for 100 frames of Salesman sequences of QCIF size at 5fps decoded at average data rate of 32kbps using the proposed algorithm with bior-4.4 5.10

5.6 Plot for 100 frames of Carphone sequences of QCIF size at 5fps decoded at average data rate of 32kbps using the proposed algorithm with bior-4.4 5.11

5.7 Plot for 100 frames of Claire sequences of QCIF size at 5fps decoded at average data rate of 32kbps using the proposed algorithm bior-4.4. 5.12

5.8 Plot of Foreman sequences of QCIF size at 5fps decoded at average data rate of 32kbps using the proposed algorithm with bior-4.4. 5.13

5.9 Plot of Suzie sequences of QCIF size at 5fps decoded at average data rate of 32kbps using the proposed algorithm with bior-4.4. 5.13

5.10 Decoded Miss America Sequence with (Average video bit-rate of 62 kbps, 7.5 fps Periodic Extensions, and using bior-4.4) average PSNR of 41.5 5.14

5.11 Decoded Miss America Sequence with (Average video bit-rate of 62 kbps, 7.5 fps, Symmetric Extensions, and using bior-4.4) average PSNR of 39.0 dB 5.15

5.12 Decoded Miss America Sequence with (Average video bit-rate of 62 kbps, 15 fps Symmetric Extensions, and using bior-4.4) average PSNR of 34.0 dB. 5.16

5.13 Decoded Miss America Sequence with (Average video bit-rate of 62 kbps, 15 fps Symmetric Extensions, and using bior-4.4) average PSNR of 34.0 dB 5.17

5.14 The Plot of PSNR against Global Threshold values for Stefan SIF Video sequences decoded using the four boundary strategies, and bior-4.4 5.18

5.15 The Plot of Compression Ratio against Global Threshold values for Stefan SIF Video sequences decoded using the four boundary strategies, and bior-4.4 5.18

5.16 Plot of PSNR Vs Number of Miss America Video Frames using Symlets wavelet family, Periodic Extensions and Global Threshold 5.22

5.17 Plot of Compression Ratio Vs Number of Miss America Video Frames using Symlets wavelet family, Periodic Extensions and Global Threshold 5.23

| | | |
|---|---|---|
| 5.18 | Plot of PSNR Vs Number of Akiyo Video Frames using Symlets wavelet family, Periodic Extensions and Global Threshold | 5.23 |
| 5.19 | Plot of Compression Ratio Vs Number of Akiyo Video Frames using Symlets wavelet family, Periodic Extensions and Global Threshold | 5.24 |
| 5.20 | Plot of PSNR Vs Number of Miss America Video Frames using Symlets wavelet family, Periodic Extensions and Level-Dependent Threshold | 5.26 |
| 5.21 | Plot of Compression Ratio Vs Number of Miss America Video Frames using Symlets wavelet family, Periodic Extensions and Level-Dependent Threshold | 5.26 |
| 5.22 | Plot of Density Vs Number of Miss America Video Frames using Symlets wavelet family, Periodic Extensions and Level-Dependent Threshold | 5.27 |
| 5.23 | Plot of MAE Vs Number of Miss America Video Frames using Symlets wavelet family, Periodic Extensions and Level-Dependent Threshold | 5.27 |
| 5.24 | Plot of MSE Vs Number of Miss America Video Frames using Symlets wavelet family, Periodic Extensions and Level-Dependent Threshold | 5.28 |
| 5.25 | Plot of PSNR Vs Number of Akiyo Video Frames using Symlets wavelet family, Periodic Extensions and Level-Dependent Threshold | 5.28 |
| 5.26 | Plot of MAE Vs Number of Akiyo Video Frames using Symlets wavelet family, Periodic Extensions and Level-Dependent Threshold | 5.29 |
| 5.27 | Plot of Density Vs Number of Akiyo Video Frames using Symlets wavelet family, Periodic Extensions and Level-Dependent Threshold | 5.29 |
| 5.28 | Plot of Compression Ratio Vs Number of Akiyo Video Frames using Symlets wavelet family, Periodic Extensions and Level-Dependent Threshold | 5.30 |
| 5.29 | Color image of size 1280x720, using Bi-Orthogonal of length 5/3 (bior-2.2), at Level 1 Wavelet Decomposition, Threshold value of 100, gives PSNR value of 26.46 dB, Compression Ratio of 4:1, MAE=119.6 and MSE=146.6. | 5.32 |
| 5.30 | The decoded color video sequence of Akiyo at average Compression Ratio of 1,407:1 when Level-Dependent Threshold at Penetration depth of 7, giving the overall decoded PSNR of only 22.66dB | 5.35 |
| 5.31 | The decoded color video sequence of Akiyo at average Compression Ratio of 11,650:1 when Level-Dependent Threshold at Penetration depth of 7, giving the overall decoded PSNR of only 19.44dB | 5.36 |
| 5.32 | The Plot for Average PSNR for Wavelet Packet and Discrete Wavelet Transform of using the best eight types of wavelet filters and Global threshold of 10 | 5.38 |

5.33 The Plot for Average PSNR for Wavelet Packet and Discrete Wavelet Transform of using the best eight types of wavelet filters and Global threshold of 20 5.39

5.34 The Plot for Average PSNR for Wavelet Packet and Discrete Wavelet Transform of using the best eight types of wavelet filters and Global threshold of 45 5.40

5.35 The Plot for Average PSNR for Wavelet Packet and Discrete Wavelet Transform of using the best eight types of wavelet filters and Global threshold of 85 5.41

5.36 The Plot for Average PSNR for Wavelet Packet and Discrete Wavelet Transform of using the best eight types of wavelet filters and Global threshold of 125 5.42

5.37 Plot of Density Versus Penetration Depth of Lena of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with bi-orthogonal filters 5.46

5.38 Plot of Compression Ratio Versus Penetration Depth of Lena of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with bi-orthogonal filters 5.46

5.39 Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Lena of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with bi-orthogonal filters 5.47

5.40 Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Lena of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with Coiflets filters 5.47

5.41 Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Lena of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters 5.48

5.42 Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Lena of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters 5.48

5.43 Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Barbara of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters 5.50

5.44 Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Barbara of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters 5.50

5.45 Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Barbara of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters 5.51

| | | |
|---|---|---|
| 5.46 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Barbara of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters | 5.51 |
| 5.47 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Goldhill of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with bi-orthogonal Wavelet filters | 5.53 |
| 5.48 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Goldhill of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters | 5.53 |
| 5.49 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Goldhill of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters | 5.54 |
| 5.50 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Goldhill of size 512x512 pixels using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters | 5.54 |
| 5.51 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Akiyo of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters | 5.56 |
| 5.52 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Akiyo of QCIF size using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters | 5.56 |
| 5.53 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Akiyo of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters | 5.57 |
| 5.54 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Penetration Depth of Akiyo of QCIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters | 5.57 |
| 5.55 | The original Lena (a) and the decoded images of Lena at 1.0 bpp, 0.5 bpp and 0.4 bpp using the proposed algorithm. | 5.60 |
| 5.56 | The decoded images of Lena at 0.3bpp, 0.25bpp, 0.125bpp ,and 0.0625bpp using the proposed algorithm. | 5.61 |
| 5.57 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Akiyo Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters | 5.66 |
| 5.58 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Akiyo Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Coiftels Wavelet filters. | 5.66 |

5.59 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Akiyo Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters 5.67

5.60 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Akiyo Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters 5.67

5.61 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Claire Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters. 5.69

5.62 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Claire Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters. 5.69

5.63 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Claire Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters 5.70

5.64 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Claire Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters. 5.70

5.65 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Carphone Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters. 5.72

5.66 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Carphone Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters. 5.72

5.67 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Carphone Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters. 5.73

5.68 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Carphone Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters. 5.73

5.69 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Foreman Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters 5.75

5.70 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Foreman Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters 5.75

5.71 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Foreman Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters 5.76

5.72 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Foreman Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters 5.76

5.73 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Grandma Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters 5.78

5.74 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Grandma Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters 5.78

5.75 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Grandma Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters 5.79

5.76 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Grandma Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters 5.79

5.77 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Miss America Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters 7.81

5.78 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Miss America Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters 7.81

5.79 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Miss America Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters 7.82

5.80 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Miss America Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters 7.82

5.81 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Mother & Daughter Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters 5.84

5.82 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Mother & Daughter Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters 5.84

5.83 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Mother & Daughter Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters 5.85

5.84 Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Mother & Daughter Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters 5.85

| | | |
|---|---|---|
| 5.85 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of News Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-Orthogonal Wavelet filters | 5.87 |
| 5.86 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of News Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters | 5.87 |
| 5.87 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of News Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters | 5.88 |
| 5.88 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of News Video Frames of CIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters | 5.88 |
| 5.89 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Salesman Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters | 5.90 |
| 5.90 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Salesman Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters | 5.90 |
| 5.91 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Salesman Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters | 5.91 |
| 5.92 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Salesman Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters | 5.91 |
| 5.93 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Suzie Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Bi-orthogonal Wavelet filters | 5.93 |
| 5.94 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Suzie Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Coiflets Wavelet filters | 5.93 |
| 5.95 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Suzie Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Daubechies Wavelet filters | 5.94 |
| 5.96 | Plot of Peak Signal to Noise Ratio (PSNR) Versus Number of Suzie Video Frames of QCIF size using the Periodic Extension and Level Dependent Threshold with Symlets Wavelet filters | 5.94 |
| 5.97 | Bi-orthogonal Filter-bank Performance for 100 frames of QCIF format, Miss America @ 16 kbps/ 5fps | 5.99 |

5.98 Plot for 100 frames of Carphone sequences of QCIF size at 15fps decoded at data rate of 64 kbps using the proposed algorithm with bi-orthogonal filters 5.101

5.99 Plot for 100 frames of Carphone sequences of QCIF size at 15fps decoded at data rate of 64 kbps using the proposed algorithm with Daubechiesl filters 5.102

5.100 Plot for 100 frames of Carphone sequences of QCIF size at 15fps decoded at data rate of 64 kbps using the proposed algorithm with Coiflets filters 5.103

5.101 Plot for 100 frames of Carphone sequences of QCIF size at 15fps decoded at data rate of 64 kbps using the proposed algorithm with Symlets filters 5.104

5.102 Plot for 100 frames of Carphone sequences of QCIF size at 15fps decoded at data rate of 64 kbps using the proposed algorithm with the best Biorthogonal, Coiflets and Symlets filters 5.105

5.103 Results of PSNR values of the tested video sequences using the proposed video compression scheme against the video data rate (1) 686 kbps (2) 195kbps (3) 74kbps (4) 53kbps (5) 41kbps (6) 21 kbps, with Periodic Extension; Biorthogonal:4.4; Level-dependent Threshold ; Frame rate of 10fps 5.111

5.104 Results of PSNR values of the tested video sequences using the proposed video compression scheme against the Video Data Rates in kbps, with Periodic Extension; Biorthogonal:4.4; Level-dependent Threshold ; Frame rate of 10fps 5.112

5.105 Results of PSNR values of the tested video sequences using the proposed video compression scheme against the Compression Ratio, with Periodic Extension; Biorthogonal:4.4 ; Level-dependent Threshold ; Frame rate of 10fps 5.112

5.106 The decoded SIF of Flower Garden Using Extension: Periodic, and Filter : Bior4.4,Level Dependent Threshold, fps=10, for CR of 3:1, 10:1,and 12:1 5.113

5.107 The decoded SIF of Flower Garden Using Extension: Periodic, and Filter : Bior4.4,Level Dependent Threshold, fps=10, for CR of 27:1, 38:1, 48:1 and 100:1 5.114

5.108 The decoded SIF Format of Football Sequences Using Extension: Periodic, and Filter : Bior4.4,Level Dependent Threshold, fps=10, for CR of 3:1, 10:1,and 12:1 5.115

5.109 The decoded SIF of Flower Garden Using Extension: Periodic, and Filter : Bior4.4,Level Dependent Threshold, fps=10, for CR of 27:1, 38:1, 48:1 and 100:1 5.116

| | | |
|---|---|---|
| 5.110 | The decoded Mobile sequences of CIF size at 10fps at average data rate of about 3Mbps using the proposed algorithm with Haar filter | 5.117 |
| 5.111 | The plot of PSNR Vs Number of Miss America sequences of QCIF size at 10fps at average data rate of about 177bps using the proposed 2D and 3D algorithms | 5.119 |
| 5.112 | plot of Compression Ratio Vs Number of Miss America sequences of QCIF size at 10fps at average data rate of about 177bps using the proposed 2D and 3D algorithms | 5.119 |
| 5.113 | The plot of MSE Vs Number of Miss America sequences of QCIF size at 10fps at average data rate of about 177bps using the proposed 2D and 3D algorithms | 5.120 |
| 5.114 | The plot of PSNR Vs Number of Foreman sequences of QCIF size at 10fps at average data rate of about 177bps using the proposed 2D and 3D algorithms | 5.121 |
| 5.115 | The plot of Compression Ratio Vs Number of Foreman sequences of QCIF size at 10fps at average data rate of about 177bps using the proposed 2D and 3D algorithms | 5.121 |
| 5.116 | The plot of MSE Vs Number of Foreman sequences of QCIF size at 10fps at average data rate of about 177bps using the proposed 2D and 3D algorithms | 5.122 |
| 5.117 | The plot of PSNR Vs Number of Akiyo sequences of QCIF size at 10fps at average data rate of about 177bps using the proposed 2D and 3D algorithms | 5.123 |
| 5.118 | The plot of Compression Ratio Vs Number of Akiyo sequences of QCIF size at 10fps at average data rate of about 168kbps using the proposed 2D and 3D algorithms | 5.123 |
| 5.119 | The plot of MSE Vs Number of Akiyo sequences of QCIF size at 10fps at average data rate of about 168kbps using the proposed 2D and 3D algorithms | 5.124 |
| 5.120 | The plot of PSNR Vs Number of Carphone sequences of QCIF size at 10fps at average data rate of about 168kbps using the proposed 2D and 3D algorithms using Sym5 | 5.125 |
| 5.121 | The plot of Compression Ratio Vs Number of Carphone sequences of QCIF size at 10fps at average data rate of about 168kbps using the proposed 2D and 3D algorithms | 5.125 |
| 5.122 | The plot of MSE Vs Number of Carphone sequences of QCIF size at 10fps at average data rate of about 177kbps using the proposed 2D and 3D algorithms | 5.126 |

5.123 The plot of Y-Video Bitrate Vs Number of Carphone sequences of QCIF size at 10fps at average data rate of about 62, 113 and 355kbps using the proposed 3D WVC algorithms 5.128

5.124 The plot of Y-PSNR Vs Number of Carphone sequences of QCIF size at 10fps at average data rate of about 62, 113 and 355kbps using the proposed 3D WVC algorithms 5.128

5.125 The plot of Y-Compression Ratio Vs Number of Carphone sequences of QCIF size at 10fps at average data rate of about 62, 113 and 355kbps using the proposed 3D WVC algorithms. 5.129

5.126 The plot of Video Bitrates Vs Number of Video Frames of Miss America QCIF size at 10fps at average data rate of 20, 50, 100 and 500kbps using the proposed 3D-WVC algorithms 5.131

5.127 The plot of PSNR Vs Number of Video Frames of Miss America QCIF size at 10fps at average data rate of 20, 50, 100 and 500kbps using the proposed 3D-WVC algorithms 5.131

5.128 The plot of Video Bitrate Vs Number of Video Frames of Carphone QCIF size at 10fps at average data rate of 20, 50, 100 and 500kbps using the proposed 3D-WVC algorithms 5.132

5.129 The plot of PSNR Vs Number of Video Frames of Carphone QCIF size at 10fps at average data rate of 20, 50, 100 and 500kbps, using the proposed 3D-WVC algorithms 5.132

## LIST OF ABBREVIATIONS

| | |
|---|---|
| ADC | Analog to Digital Converter |
| ATM | Asynchronous Transfer Mode |
| AVC | Advanced Video Coding |
| AWPT | Adaptive Wavelet Packet Transform |
| bpp | Bit-per-pixel |
| CCIR | Comite Consultatif International de Radiodiffusion |
| CCITT | International Consultative Committee for Telephone and Telegraph |
| CDF | Cumulative distribution function |
| CD-I | Compact Disk - Interactive |
| CD-ROM | Compact Disk - Read Only Memory |
| CIF | Common Intermediate Format |
| codec | compressor/decompressor |
| CPU | Central Processing Unit |
| CR | Compression Ratio |
| CWT | Continuous wavelet transform |
| DAC | Digital to Analogue Converter |
| DCT | Discrete Cosine Transform |
| DFT | Discrete Fourier Transform |
| DPCM | Differential Pulse Code Modulation |
| DTFT | Discrete Time Fourier Transform |
| DVD | Digital Versatile Disk |
| DWT | Discrete Wavelet Transform |
| FBI | Federal bureau investigations |

| | |
|---|---|
| EZW | Embedded zerotree wavelets |
| FFT | Fast Fourier Transform |
| FIR | Finite impulse response |
| FT | Fourier Transform |
| GOF | Group of Frames |
| GOP | Group of Pictures |
| GGD | Generalized Gaussian distribution |
| HDTV | High Definition Television |
| HVS | Human Visual System |
| HPT | High-Pass Temporal |
| i.i.d. | Independent and identically distributed |
| ISDN | Integrated Services Distributed Network |
| ISO | International Standard Organisation |
| ITU | International Telecommunications Union |
| JPEG | Joint Photographic's Expert Group |
| kb | kilobit (1024 bits) |
| KLT | Karhunen-Loeve Transform |
| LOT | Lapped orthogonal transform |
| LPT | Low-Pass Temporal |
| LVQ | Lattice vector quantization |
| MAE | Mean absolute error |
| MSE | Mean Squared Error |
| Mb | Megabit (1024 kb) |
| MBps | MegaByte per second |
| MHz | MegaHertz |

| | |
|---|---|
| MPEG | Motion Picture's Expert Group |
| MRA | Multiresolution analysis |
| MSE | Mean Square Error |
| NVOD | Near Video of Demand |
| PDF | Probability density function |
| PLVQ | Pyramid lattice vector quantization |
| PR | Perfect Reconstruction |
| PSD | Power spectral density |
| PSNR | Peak Signal to Noise Ratio |
| QMF | Quadrature Mirror Filter |
| QCIF | Quarter Common Intermediate Format |
| SBC | Subband Coding |
| SBD | Subband Decomposition |
| SIF | Standard Interchange Format |
| SLCCA | Significance-linked connected component analysis |
| SNR | Signal--to--noise ratio |
| SPIHT | Set Partitioning In Hierarchical Trees |
| SQ | Scalar Quantisation |
| STFT | Short Time Fourier Transform |
| SVC | Scalable Video Coding |
| TCG | Transform Coding Gain |
| VCR | Video Cassette Recorder |
| VLBR | Very Low Bit rate Video |
| VLSI | Very Large Scale Integration |
| VOD | Video of Demand |

| | |
|---|---|
| VOP | Video Object Plane |
| VQ | vector quantization |
| WFT | Windowed Fourier Transform (same as STFT) |
| WPT | Wavelet Packet Transform |
| WSQ | Wavelet/scalar quantization |
| WSS | Wide sense stationary |
| WT | Wavelet transform |
| Y | Luminance or intensity plane of a picture |