

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

# **Distributed Image and Video Coding**

**based on  
Compressed Sensing**

A thesis presented in partial fulfilment of the  
requirements for the degree of

Doctor of Philosophy  
in  
Computer Engineering  
at  
Massey University  
New Zealand.

**Muhammad Yousuf Baig**

2013



# Abstract

Conventional methods for encoding of images and videos is a complex process with high computational demands. They are designed for application scenarios where the signals concerned are encoded once and played back many times. However, new applications such as wireless video sensor networks demand low cost and low power cameras with limited computing resources. The focus of this thesis is on such image and video coding systems where the computational burden is shifted from the encoder to the decoder.

Three separate coding schemes have been developed – two for videos and one for images. Together they form a framework for distributed coding which is based on the theory of compressed sensing and distributed coding. Compressed sensing is a relatively new theory for the acquisition of sparse signals that allows the sampling rate to be much lower than the Nyquist limit. Distributed coding is based on the theorem by Slepian and Wolf, and Wyner and Ziv. It allows different correlated parts of a signal to be encoded independently without loss of coding efficiency. The decoding of these separately encoded parts are then decoded jointly in order to exploit the correlation between them. The main characteristics of the coding scheme proposed in this thesis are: (1) they do not require the use of traditional codecs; (2) only compressed sensing measurements are used for encoding and decoding; (3) no motion estimation and compensation are involved for videos.

The first proposed coding scheme is for the encoding of whole video frames. The compressed sensing measurement of individual frames are separately encoded. These frames are divided into key and non-key frames with the key frames encoded at a higher

rate than non-key ones. While the key frames are decoded independently, the non-key ones are decoded with the help of side information generated from the measurements of the key frames. The most important part of the decoder is a simple, yet effective, side information generation method which requires only minimal computation. The side information generated is simply added to the measurements of the non-key frames for use with any compressed sensing reconstruction algorithm. The other two coding schemes are block-based coding methods. Each image or frame is divided into non-overlapping image blocks in a similar way it is done in some existing coding standards. The coding of the blocks are performed in a distributed manner by classifying them into key blocks and non-key blocks. An adaptive encoding strategy based on block similarity is also developed. Experimental analyses using publicly available test images and videos show that the performances of the simpler codecs proposed are better than other existing compressed sensing based codecs. The video codecs also out-perform conventional distributed video codec in terms of simplicity, compression ratio and decoding complexity.

The basis of these coding methods is on the correlation of frames or blocks. This correlation is established through experimental analyses. These analyses also showed that the minimum square error between any pair of them can be effectively used as a measure of correlation. In conjunction with the development of the codecs, a quantization scheme that is tailored to the statistics of CS measurements has also been proposed. This scheme yields better results than a uniform quantizer and those used for JPEG. The quantizer is also robust against different statistics of individual images. Separate experimental evaluations also show that structurally random matrices are the best sensing matrices for acquiring images and the sparse reconstruction by separable approximation (SpaRSA) algorithm produces the best reconstructed image quality.

# Acknowledgments

I am profoundly grateful to my supervisor Associate Professor Edmund Lai for his constant support and guidance throughout my PhD study. There were many occasions in this journey when things were not going in a right direction but Edmund's encouragements and endless patience has helped me to finish this thesis. Edmund's knowledge and inspiring research insights were always fruitful and without him, this endeavour could have never been completed.

I am also thankful to my co supervisor Dr Amal Punchihewa for his valuable comments, suggestions and feedback throughout my research. This PhD thesis could not be completed without a financial support and scholarship from Higher Education Commission, Pakistan. I am thankful for their support and appreciate their effort for educational reforms. I am also thankful to Mehran University for granting me study leave to pursue PhD study.

I want to express my gratitude to my parents for their prayers and support. I am thankful to my wife Sana for her love, understanding and endless support despite all the difficulties. Finally love to my children, Maryam and Taha who always brings smiles back in a long and hard day



# Contents

|                                                  |          |
|--------------------------------------------------|----------|
| <b>Abstract</b> . . . . .                        | i        |
| <b>Acknowledgments</b> . . . . .                 | iii      |
| <b>List of Figures</b> . . . . .                 | x        |
| <b>List of Tables</b> . . . . .                  | xiv      |
| <b>List of Abbreviations</b><br>. . . . .        | xv       |
| <b>1 Introduction</b>                            | <b>1</b> |
| 1.1 Background and Motivation . . . . .          | 1        |
| 1.2 Scope and Objectives . . . . .               | 3        |
| 1.3 Original Contributions . . . . .             | 4        |
| 1.4 Organization of the Thesis . . . . .         | 5        |
| <b>2 An Overview of Compressed Sensing</b>       | <b>7</b> |
| 2.1 Key Elements of Compressed Sensing . . . . . | 7        |
| 2.1.1 Sparsity . . . . .                         | 8        |
| 2.1.2 Incoherence . . . . .                      | 10       |
| 2.1.3 CS Measurement Acquisition . . . . .       | 10       |



|          |                                                              |           |
|----------|--------------------------------------------------------------|-----------|
| 2.1.4    | CS Reconstruction . . . . .                                  | 13        |
| 2.2      | Potential Applications . . . . .                             | 15        |
| 2.3      | Summary . . . . .                                            | 18        |
| <b>3</b> | <b>A Review of Compressed Sensing Image and Video Coding</b> | <b>19</b> |
| 3.1      | Compressed Sensing Image Coding . . . . .                    | 19        |
| 3.1.1    | Full Image Coding . . . . .                                  | 19        |
| 3.1.2    | Block Based Coding . . . . .                                 | 20        |
| 3.1.3    | Multi-scale Coding . . . . .                                 | 22        |
| 3.1.4    | Distributed Coding . . . . .                                 | 24        |
| 3.2      | Compressed Sensing Video Coding . . . . .                    | 29        |
| 3.2.1    | 3D Transform Coding . . . . .                                | 29        |
| 3.2.2    | Distributed Coding . . . . .                                 | 31        |
| 3.2.3    | Dictionary-based Coding . . . . .                            | 35        |
| 3.2.4    | Residue-based Coding . . . . .                               | 37        |
| 3.2.5    | Adaptive Coding . . . . .                                    | 41        |
| 3.2.6    | Scalable Coding . . . . .                                    | 45        |
| 3.3      | Conventional Distributed Video Coding . . . . .              | 46        |
| 3.3.1    | Transform Domain Wyner-Ziv Video Coding . . . . .            | 47        |
| 3.3.2    | The PRISM Video Codec . . . . .                              | 47        |
| 3.3.3    | The DISCOVER Video Codec . . . . .                           | 49        |
| 3.3.4    | Comparison of DVC Architectures . . . . .                    | 50        |
| 3.4      | Summary . . . . .                                            | 52        |

|                                                                                                  |           |
|--------------------------------------------------------------------------------------------------|-----------|
| <b>4 Sensing Matrix, Quantization Matrix and Reconstruction Algorithms for Image Compression</b> | <b>53</b> |
| 4.1 Choice of Sensing Matrices . . . . .                                                         | 55        |
| 4.1.1 Experimental Results . . . . .                                                             | 56        |
| 4.2 Choice of Reconstruction Algorithms . . . . .                                                | 61        |
| 4.2.1 Greedy Algorithms . . . . .                                                                | 63        |
| 4.2.2 Gradient based Algorithms . . . . .                                                        | 64        |
| 4.2.3 Iterative Shrinkage Thresholding Algorithms . . . . .                                      | 67        |
| 4.2.4 Experimental Results . . . . .                                                             | 68        |
| 4.3 Design of Quantizer . . . . .                                                                | 72        |
| 4.3.1 Distribution of CS Measurements . . . . .                                                  | 73        |
| 4.3.2 Proposed Quantization Scheme . . . . .                                                     | 75        |
| 4.4 Summary . . . . .                                                                            | 77        |
| <b>5 Distributed Inter-frame Video Compressed Sensing</b>                                        | <b>79</b> |
| 5.1 Proposed DCVS Codec . . . . .                                                                | 80        |
| 5.1.1 Encoder . . . . .                                                                          | 81        |
| 5.1.2 Decoder . . . . .                                                                          | 82        |
| 5.1.3 Correlation Analysis of CS Measurements . . . . .                                          | 83        |
| 5.1.4 Correlation and Mean Square Error . . . . .                                                | 86        |
| 5.2 Side Information Generation . . . . .                                                        | 86        |
| 5.2.1 Motion Compensated Interpolation . . . . .                                                 | 88        |
| 5.2.2 Proposed SI Generation Method . . . . .                                                    | 90        |

|          |                                                                 |            |
|----------|-----------------------------------------------------------------|------------|
| 5.3      | CS Reconstruction with Side Information . . . . .               | 92         |
| 5.4      | Experimental Results . . . . .                                  | 93         |
| 5.4.1    | Reconstruction Complexity Evaluation . . . . .                  | 95         |
| 5.4.2    | Rate Distortion Evaluation . . . . .                            | 95         |
| 5.4.3    | Performance Comparison with Distributed and Conventional Codecs | 103        |
| 5.5      | Summary . . . . .                                               | 112        |
| <b>6</b> | <b>Distributed CS Image Compression</b>                         | <b>113</b> |
| 6.1      | Block Based Encoding and Decoding . . . . .                     | 114        |
| 6.1.1    | Recovery Methods . . . . .                                      | 114        |
| 6.1.2    | Impact of Block Size . . . . .                                  | 116        |
| 6.2      | Block Similarity Analysis . . . . .                             | 118        |
| 6.3      | Proposed Distributed Image Codec . . . . .                      | 120        |
| 6.3.1    | Encoder . . . . .                                               | 121        |
| 6.3.2    | Decoder . . . . .                                               | 124        |
| 6.4      | Experimental Results . . . . .                                  | 125        |
| 6.5      | Summary . . . . .                                               | 131        |
| <b>7</b> | <b>Distributed Block-based Video Compressed Sensing</b>         | <b>133</b> |
| 7.1      | Block Correlation Analysis . . . . .                            | 133        |
| 7.1.1    | Intra-frame Block Correlation . . . . .                         | 134        |
| 7.1.2    | Inter-frame Block Correlation . . . . .                         | 137        |
| 7.2      | Proposed Adaptive Block-based Video Codec . . . . .             | 137        |

|          |                                                                              |            |
|----------|------------------------------------------------------------------------------|------------|
| 7.2.1    | Encoder . . . . .                                                            | 140        |
| 7.2.2    | Decoder . . . . .                                                            | 142        |
| 7.3      | Experimental Results . . . . .                                               | 143        |
| 7.3.1    | Measurement Rate Reduction . . . . .                                         | 146        |
| 7.3.2    | Reconstruction Complexity Evaluation . . . . .                               | 146        |
| 7.3.3    | Rate Distortion Evaluation . . . . .                                         | 148        |
| 7.3.4    | Performance Comparison with DISCOVER and Other Conventional Codecs . . . . . | 154        |
| 7.4      | Summary . . . . .                                                            | 162        |
| <b>8</b> | <b>Conclusions and Future Work</b>                                           | <b>167</b> |
| 8.1      | Conclusions . . . . .                                                        | 167        |
| 8.2      | Further Research . . . . .                                                   | 169        |
| 8.2.1    | Multi-view Image/Video Coding . . . . .                                      | 169        |
| 8.2.2    | Hyperspectral Imaging . . . . .                                              | 169        |
| <b>A</b> | <b>List of Publications</b>                                                  | <b>171</b> |
|          | <b>References</b>                                                            | <b>173</b> |

# List of Figures

|      |                                                                        |    |
|------|------------------------------------------------------------------------|----|
| 2.1  | Key Elements of Compressed Sensing . . . . .                           | 9  |
| 2.2  | CS Camera, [Image Courtesy, InView Corporation [41]] . . . . .         | 16 |
| 3.1  | Multi Scale Image Coding Scheme [59]. . . . .                          | 23 |
| 3.2  | Wyner-Ziv Image Coding Scheme [68]. . . . .                            | 25 |
| 3.3  | Wyner-Ziv Image Coding Architecture [69]. . . . .                      | 26 |
| 3.4  | Architecture of Adaptive Distributed Image Sensing [71]. . . . .       | 28 |
| 3.5  | Architecture of Distributed Compressed Video Sensing [13]. . . . .     | 31 |
| 3.6  | Distributed CS Encoder/ Decoder [14] . . . . .                         | 33 |
| 3.7  | CS based Video Coder [17]. . . . .                                     | 36 |
| 3.8  | Residual CS Encoder/ Decoder [89]. . . . .                             | 39 |
| 3.9  | $k$ - $t$ FOCUSS with ME/MC [78]. . . . .                              | 40 |
| 3.10 | Block based Video Codec [15]. . . . .                                  | 42 |
| 3.11 | Adaptive Block based Video Codec [79]. . . . .                         | 43 |
| 3.12 | Transform Domain Wyner-Ziv video Coding architecture [99]. . . . .     | 46 |
| 3.13 | PRISM Video Coding Architecture [101] . . . . .                        | 48 |
| 3.14 | Block diagram of the DISCOVER video coding architecture [103]. . . . . | 49 |

|      |                                                                                             |     |
|------|---------------------------------------------------------------------------------------------|-----|
| 4.1  | CS Image Compression . . . . .                                                              | 54  |
| 4.2  | Sensing Matrix Acquisition Time . . . . .                                                   | 57  |
| 4.3  | Sensing Matrix Reconstruction Time . . . . .                                                | 59  |
| 4.4  | Sensing Matrix Rate Distortion Performance . . . . .                                        | 60  |
| 4.5  | Reconstruction Times for CS Reconstruction Algorithms . . . . .                             | 69  |
| 4.6  | Number of Iterations Required for CS Reconstruction . . . . .                               | 70  |
| 4.7  | Rate-Distortion Performance of CS Reconstruction Algorithms . . . . .                       | 71  |
| 4.8  | CS Measurements and DCT Coefficients Histogram for Test Images . . . . .                    | 74  |
| 4.9  | Quantization Matrix Rate-Distortion Performance . . . . .                                   | 76  |
| 4.10 | Reconstruction visual quality for Lena . . . . .                                            | 78  |
| 5.1  | Proposed Video Codec . . . . .                                                              | 81  |
| 5.2  | Correlation Analysis for CS Measurements . . . . .                                          | 84  |
| 5.3  | Correlation of CS Measurements of WZ frames with Key frames . . . . .                       | 85  |
| 5.4  | Correlation and MSE Comparison of CS Measurements of WZ frames with<br>Key frames . . . . . | 87  |
| 5.5  | DVC Side Information Generation . . . . .                                                   | 89  |
| 5.6  | Motion Compensated Interpolation . . . . .                                                  | 90  |
| 5.7  | Median of Laplacian Distribution Parameter for Two Types of SI . . . . .                    | 92  |
| 5.8  | Reconstruction complexity comparison of Video Sequences . . . . .                           | 97  |
| 5.9  | Rate Distortion Curve for GOP Size 3 . . . . .                                              | 103 |
| 5.10 | Rate Distortion Curve for GOP Size 5 . . . . .                                              | 104 |
| 5.11 | Rate Distortion Curve for GOP Size 8 . . . . .                                              | 105 |

|      |                                                                                                                                                                      |     |
|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 5.12 | Visual Reconstruction Quality of News 89th Frame for GOP Size 3 . . . .                                                                                              | 106 |
| 5.13 | Visual Reconstruction Quality of Container 56th Frame for GOP Size 3 . .                                                                                             | 107 |
| 5.14 | Bit Rate vs Compression Ratio for Video Sequences - GOP Size 3 . . . . .                                                                                             | 109 |
| 5.15 | Bit Rate vs PSNR for Video Sequences - GOP Size 3 . . . . .                                                                                                          | 110 |
| 5.16 | Reconstruction Time Complexity Comparison with DISCOVER . . . . .                                                                                                    | 111 |
| 6.1  | Block Based CS Reconstruction Comparison . . . . .                                                                                                                   | 115 |
| 6.2  | Rate Distortion Performance of Block Size (64, 32, 16, and 8) . . . . .                                                                                              | 117 |
| 6.3  | Block Similarity Analysis of Original Pixel Data and CS measurements<br>with Correlation Coefficient and MSE . . . . .                                               | 119 |
| 6.4  | Percentage of Similar Blocks for Block Size (64, 32, 16 and 8) . . . . .                                                                                             | 120 |
| 6.5  | Proposed Distributed Intra Image Codec . . . . .                                                                                                                     | 122 |
| 6.6  | Test Images used. . . . .                                                                                                                                            | 126 |
| 6.7  | Rate-Distortion Performance for Test Images . . . . .                                                                                                                | 128 |
| 6.8  | SSIM Index for Test Images . . . . .                                                                                                                                 | 129 |
| 6.9  | Compression Efficiency for Test Images . . . . .                                                                                                                     | 130 |
| 7.1  | Intra Block Correlation of Original Pixel Data and CS measurements with<br>MSE and Correlation Coefficient . . . . .                                                 | 135 |
| 7.2  | Percentage of Similar Blocks for Block Size (64, 32, 16 and 8) . . . . .                                                                                             | 136 |
| 7.3  | Inter Block Correlation of Original Pixel Data and CS measurements be-<br>tween 1st and 2nd frame of Foreman video with MSE and Correlation<br>Coefficient . . . . . | 138 |

|      |                                                                                                                                                                 |     |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 7.4  | Inter Block Correlation of Original Pixel Data and CS measurements between 1st and 3rd frame of Foreman video with MSE and Correlation Coefficient . . . . .    | 138 |
| 7.5  | Inter Block Correlation of Original Pixel Data and CS measurements between 1st and 2nd frame of Coastguard video with MSE and Correlation Coefficient . . . . . | 139 |
| 7.6  | Inter Block Correlation of Original Pixel Data and CS measurements between 1st and 3rd frame of Coastguard video with MSE and Correlation Coefficient . . . . . | 139 |
| 7.7  | Proposed Distributed Block-based Video Codec . . . . .                                                                                                          | 141 |
| 7.8  | Test Videos . . . . .                                                                                                                                           | 144 |
| 7.9  | Reconstruction complexity comparison for GOP Size 3, 5 and 8 . . . . .                                                                                          | 150 |
| 7.10 | Rate Distortion Curve for GOP Size 3 . . . . .                                                                                                                  | 151 |
| 7.11 | Rate Distortion Curve for GOP Size 5 . . . . .                                                                                                                  | 153 |
| 7.12 | Rate Distortion Curve for GOP Size 8 . . . . .                                                                                                                  | 154 |
| 7.13 | SSIM Index for GOP Size 3 . . . . .                                                                                                                             | 156 |
| 7.14 | SSIM Index for GOP Size 5 . . . . .                                                                                                                             | 157 |
| 7.15 | SSIM Index for GOP Size 8 . . . . .                                                                                                                             | 158 |
| 7.16 | Visual Reconstruction Quality of Akiyo 123rd Frame for GOP Size 3 . . .                                                                                         | 159 |
| 7.17 | Visual Reconstruction Quality of Mother Daughter 24th Frame for GOP Size 3 . . . . .                                                                            | 160 |
| 7.18 | Bit Rate vs Compression Ratio for Video Sequences - GOP Size 3 . . . . .                                                                                        | 162 |
| 7.19 | Bit Rate vs PSNR for Video Sequences - GOP Size 3 . . . . .                                                                                                     | 163 |
| 7.20 | Reconstruction Time Complexity Comparison with DISCOVER . . . . .                                                                                               | 164 |



# List of Tables

|     |                                                                                             |     |
|-----|---------------------------------------------------------------------------------------------|-----|
| 4.1 | Performance Comparison of Quantization Schemes, in PSNR(dB) . . . . .                       | 77  |
| 5.1 | Video Test Sequences . . . . .                                                              | 94  |
| 5.2 | Average Reconstruction Time (in Seconds) of Video Sequences . . . . .                       | 96  |
| 5.3 | Rate Distortion Performance (in dB) of Video Sequences for GOP Size 3                       | 99  |
| 5.4 | Rate Distortion Performance (in dB) of Video Sequences for GOP Size 5                       | 100 |
| 5.5 | Rate Distortion Performance (in dB) of Video Sequences for GOP Size 8                       | 101 |
| 5.6 | Average SSIM Index Performance of Video Sequences for GOP Size 3, 5<br>and 8 . . . . .      | 102 |
| 6.1 | Performance Evaluation of Test Images . . . . .                                             | 127 |
| 7.1 | Percentage of Measurement Rate Reduction in Adaptive Encoding . . . . .                     | 147 |
| 7.2 | Average Reconstruction Time (in Seconds) of Video Sequences . . . . .                       | 149 |
| 7.3 | Average Rate Distortion Performance of Video Sequences for GOP Size 3,<br>5 and 8 . . . . . | 152 |
| 7.4 | Average SSIM Index Performance of Video Sequences for GOP Size 3, 5<br>and 8 . . . . .      | 155 |

# List of Abbreviations

|                   |                                                    |
|-------------------|----------------------------------------------------|
| <b>AVC</b>        | Advanced Video Coding                              |
| <b>BCH Codes</b>  | Bose Chaudhuri Hocquenghem Codes                   |
| <b>BCQP</b>       | Bounded Constraint Quadratic Program               |
| <b>BCS</b>        | Bayesian Compressive Sensing                       |
| <b>BM</b>         | Block Matching                                     |
| <b>BP</b>         | Basis Pursuit                                      |
| <b>BPDN</b>       | Basis Pursuit Denoising                            |
| <b>CoSaMP</b>     | Compressive Sampling Matching Pursuit              |
| <b>CRC</b>        | Cyclic Redundancy Check                            |
| <b>CS</b>         | Compressed Sensing                                 |
| <b>DCT</b>        | Discrete Cosine Transform                          |
| <b>DCVS</b>       | distributed compressed video coding                |
| <b>DISCOS</b>     | Distributed Compressed Video Sensing               |
| <b>DISCOVER</b>   | DistributedCoding forVideo Services                |
| <b>DSC</b>        | Distributed Source Coding                          |
| <b>DVC</b>        | Distributed Video Coding                           |
| <b>Ffmpeg</b>     | Fast Foraward MPEG                                 |
| <b>GOB</b>        | Group of Blocks                                    |
| <b>GOP</b>        | Group of Picture                                   |
| <b>GPSR</b>       | Gradient Projection for Sparse Reconstruction      |
| <b>ISAR</b>       | Inverse Synthetic Aperture Radar                   |
| <b>ITU-T</b>      | International Telecommunication Union              |
| <b>JPEG</b>       | Joint Picture Expert Group                         |
| <b>k-t FOCUSS</b> | Focal Under Determined System Solver in k-t Space  |
| <b>LASSO</b>      | Least Aboslute Shrinkage and Selecion Operator     |
| <b>LDPC</b>       | Low Density Parity Check                           |
| <b>LDPCA</b>      | Low Density Parity Check Accumulate                |
| <b>LIMAT</b>      | Lifting-based Invertible Motion Adaptive Transform |
| <b>LP</b>         | Linear Programming                                 |
| <b>MC</b>         | Motion Compensation                                |
| <b>MCFI</b>       | Motion Compensated Frame Interpolation             |
| <b>MCI</b>        | Motion Compensated Interpolation                   |
| <b>ME</b>         | Motion Estimation                                  |
| <b>MP</b>         | Matching Pursuit                                   |
| <b>MPEG</b>       | Motion Picture Expert Group                        |
| <b>MR</b>         | Measurement Rate                                   |
| <b>MRI</b>        | Magnetic Resonance Imaging                         |
| <b>MSE</b>        | Mean Square Error                                  |
| <b>NESTA</b>      | Nesterov's Algorithm                               |

|               |                                                                            |
|---------------|----------------------------------------------------------------------------|
| <b>NP</b>     | Non-deterministic Polynomial-time                                          |
| <b>OMP</b>    | Orthogonal Matching Pursuit                                                |
| <b>PCA</b>    | Principle Component Analysis                                               |
| <b>PFT</b>    | Partial Fourier Transform                                                  |
| <b>PL</b>     | Projected Landweber                                                        |
| <b>PRISM</b>  | Power-efficient, Robust, hIgn compression Syndrome based Multimedia coding |
| <b>PSNR</b>   | Peak Signal to Noise Ratio                                                 |
| <b>QCIF</b>   | Quad Common Interchange Format                                             |
| <b>RD</b>     | Rate Distortion                                                            |
| <b>RDO</b>    | Rate Distortion Optimization                                               |
| <b>RIP</b>    | Restricted Isometry Property                                               |
| <b>SBHE</b>   | Scrambled Block Hadamard Ensemble                                          |
| <b>SFE</b>    | Scrambled Fourier Ensemble                                                 |
| <b>SI</b>     | Side Information                                                           |
| <b>SpaRSA</b> | Sparse Reconstruction by Seperable Approximation                           |
| <b>SPL</b>    | Smoothed Projected Landweber                                               |
| <b>SRM</b>    | Structurally Random Matrices                                               |
| <b>SSIM</b>   | Structure Similarity Index                                                 |
| <b>STD</b>    | Standard Deviation                                                         |
| <b>StOMP</b>  | Stagewise Orthogonal Matching Pursuit                                      |
| <b>SVC</b>    | Scalable Video Coding                                                      |
| <b>SVD</b>    | Singular Value Decomposition                                               |
| <b>TV</b>     | Total Variation                                                            |
| <b>TwIST</b>  | Two-Step Iterative Shrinkage Thresholding                                  |
| <b>TWR</b>    | Through-the-wall Radar                                                     |
| <b>WT</b>     | Wavelet Transform                                                          |
| <b>WZ</b>     | Wyner Ziv                                                                  |