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It is certified that the work contained in the thesis titled ***"Some Approaches For Hyperspectral Image Compression"*** by ***Yaman Dua*** has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

It is further certified that the student has fulfilled all requirements of Comprehensive Examination, Candidacy, and SOTA for the award of Ph.D. Degree.

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DECLARATION BY THE CANDIDATE

I, ***Yaman Dua***, certify that the work embodied in this Ph.D. thesis is my own bonafide work carried out by me under the supervision of ***Dr. Ravi Shankar Singh*** from ***July 2018*** to ***October 2021*** at ***Department of Computer Science and Engineering***, Indian Institute of Technology (BHU) Varanasi. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not willfully copied any other's work, paragraphs, text, data, results, *etc.* reported in journals, books, magazines, reports, dissertations, theses, *etc.*, or available at websites and have not included them in this thesis and have not cited as my own work.

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ACKNOWLEDGEMENT

This thesis would not have been possible without the guidance, inspiration and support of my supervisor, Dr. Ravi Shankar Singh. I have been very fortunate to have a talented supervisor, who always has brilliant ideas, who cared about my work and who responded to my questions and queries with endless patience. The study has extensive useful discussions and brainstorming sessions, especially during the difficult conceptual development stage. I feel very privileged to have worked with him.

I would like to express my gratitude to the Ph.D. committee members, Professor Sanjay Kumar Singh, Dr. Ravi Shankar Singh, and Dr. Rajeev, for their constructive comments and guidance during my candidature. Special thanks to Prof. Sanjay Kumar Singh for helping me improve my research skills, for his invaluable guidance and advice, and for his suggestions on improving my work. I would also like to thank all the past and current members of the High-Performance Computing (HPC) Lab, at the Indian Institute of Technology, BHU for their friendship and support. In particular, I thank Dr. Shri Prakash Dwivedi, Mr. Naveen Mani Upadhyay, Mrs. Swati Gupta, Mr. Vinod Kumar, and Mr. Rambabu Medara.

I would like to acknowledge IIT(BHU) and Government of India for giving me the opportunity to carry out my doctoral research and for their financial support. I am forever indebted for the study opportunities and to have such an outstanding academic environment for research that has made my study life a wonderful journey.

I thank my parents, my brother, and my sister for being a loving, caring, and supportive family away from home. Finally, I would like to thank my beloved friend, Nistha Dubey, for her selflessness, unconditional, endless support, and for the words of praise when they were most needed. I would like to acknowledge my friends Garvit Bajpai and Syambrij for always believing in me, and for encouraging me to achieve every step of this difficult journey. I thank my father for being an exceptional role model, for teaching me the meaning of perseverance and hard work, and for his words of advice and caring love.

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Abbreviations

Abbreviation	Description
4D	Four Dimensional
AA	Average Accuracy
AAC	Adaptive Arithmetic Coder
AE	Absolute error
ALS	adaptive least square
ANN	Apply Artificial Neural Network
API	Application Programming Interface
ASWDR	Adaptively Scanned Wavelet Difference Reduction
AVIRIS	Airborne visible/infrared imaging spectrometer
BIP-MLPNN	Block-based Inter-Band Predictor using Multi-Layer Propagation Neural Network
BPPPB	bits per pixel per band
BRCCBH	Band Reordering based on Consecutive Continuity Breakdown Heuristics
BRSB	Based on Segmented of Bands
BRWCH	Band Reordering based on Weighted-Correlation Heuristic
CALIC	Context Based Adaptive Lossless Image Coder
CASI	Compact Airborne Spectrographic Imager
CCSDS	Consultative Committee for Space Data Systems
CDF	Cohen, Daubechies and Feauveau
CLMS	Correntropy Least Mean Square
CNN	Convolution Neural Network
CPPCA	Compressive-projection principal component analysis
CPU	Central Processing Units
CR	Compression Ratio
CUDA	Compute Unified Device Architecture

Abbreviation	**Description**
CV	Correlation Vector
DAIS	Digital Airborne Imaging Spectrometer
DBN	Deep Belief Network
DCT	Discrete Cosine Transform
DFT	Discrete Fourier Transform
DPCM	Differential Pulse Code Modulation
DWT	Discrete Wavelet Transform
EnMAP	Environmental Mapping and Analysis Program
EPI	Edge Preservation Index
ERDC	U.S. Army Engineer Research and Development Center
FAST-RLS-ALP	Fast Recursive Least Square Adaptive Length Prediction
FPGA	Field Programmable Gate Arrays
FrWF	Fractional wavelet filter
GA	Genetic Algorithm
GBRBM	Gaussian–Bernoulli Restricted Boltzmann Machine
GBs	GigaBytes
GD	Gradient Descent
GFT	Graph Fourier Transform
GIC	Computational Intelligence Groups
GoB	Group of Bands
GPU	Graphics Processing Units
GRC	Golomb Rice Coding
HICO	Hyperspectral Imager for the Coastal Ocean
HISUI	Hyperspectral Imager SUIte
HPC	High Performance Computing
HSI	Hyperspectral Image
HSV	Hue Saturation Value
HypXIM	Hyperspectral X Imagery
HyspIRI	Hyperspectral InfraRed Imager
ICA	Independent Component Analysis
IDWT	Inverse discrete wavelet transform
IMEC	Interuniversity Microelectronics Centre
IoT	Internet Of Things

Abbreviation	**Description**
JPEG-LS	Joint Photographic Experts Group-Lossless
JPL	Jet Propulsion Laboratory
KA	Kappa Accuracy
KLT	Karhunen-Loeve Transform
KNN	k-nearest neighbor
LCPLC	Low Complexity Predictive Lossy Compression
LMBTC	Low Memory Block Tree Coding
LMP	Linearized Median Predictor
LMS	Least mean squares
LPGPU	Low Power Graphical Processing Unit
LZMA	Lempel Ziv Markov chain algorithm
LZW	Lempel Ziv Welch
MBLP	Multi Band Linear Predictor
MBs	MegaBytes
MBSRDL	Multidimensional Block-Sparse Representation and Dictionary Learning
MHDC	Multi/Hyperspectral Data Compression
MPI	Message Passing Interface
MSE	Mean Square Error
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NTD	Non-Negative Tucker Decomposition
OA	Overall Accuracy
OPB	Optimal Prediction Band
PCA	Principal Component Analysis
PDF	Probability Distribution Function
PRISMA	PRecursore IperSpettrale della Missione Applicativa
PSNR	Peak Signal to Noise Ratio
PSO	Particle Swarm Optimization
RE	Relative error
RELU	rectified linear unit
RLE	Run Length Encoder
RLPHCS	Re-weighted Laplace prior based HCS
RLS	Recursive Least Square
RLS	Recursive Least Square

Abbreviation	**Description**
RLS-ALP	RLS- Adaptice Length Prediction
RoI	Region Of Interests
RWA-C	Regression wavelet analysis-clustered
SAD	Spectral Angle Distance
SAM	Spectral Angle Mapper
SAR	Synthetic Aperture Radar
SB-DSC	Skip block based distributed source coding
SBS	Superpixel Based Segmentation
SHALOM	Space-borne Hyperspectral Applicative Land and Ocean Mission
SHSIR	Sparsification of HSI and Reconstruction
SNR	Signal to Noise Ratio
SPECK	3D-Set Partitioning Embedded Block
SPIHT	Set Partitioning in Hierarchical Trees
SSASR	Spectral-Spatial Adaptive Sparse Representation
SSHBCS	Structured Sparsity
SSIM	Structural SIMilarity
STW	Spatial-oriented Tree Wavelet
SUW	Suwanee natural reserve
SVM	Support Vector Machine
SVR	Support Vector Regression
SWIR	Short Wave Infrared
TANH	Hyperbolic Tangent
TBs	Tera Bytes
VCA	Vertex component analysis
VNIR	Visible and near-infrared range
VQ	Vector Quantization
VQPCA	Vector Quantization Principal Component Analysis
WBTC	Wavelet Block Tree Coding
WDR	Wavelet Difference Reduction
WPCA	Weighted Principal Component Analysis

Abstract

The recent advancement in the field of electronics has led to the development of sensors that capture the image of an area or object in spectral-domain with spatial information. Spectral signatures of these images provides reflectance, texture, moisture content, and other external quality characteristics of diverse samples far beyond human vision. Hyperspectral Image (HSI) finds its applications in many domains such as agriculture, astronomy, biomedical imaging, Earth observation, track military movements & operations, molecular biology, mineral identification, monitoring natural disasters, identification of disease in the medical industry, physics, and surveillance. The rate of production of hyperspectral data is increasing rapidly due to increment in the acquisition capacity of such devices and success of specialized missions by various space organizations. The large size and high scale acquisition of HSIs has increased the demand for a more efficient compression strategy that is effective against multidimensional data and different from traditional algorithms.

In this work, we categorized state of the art algorithms into eight broad categories namely transform based, prediction based, vector quantization based, compressive sensing based, tensor decomposition based, sparse representation based, multi-temporal based, and learning based algorithms. The main purpose of this thesis is to study and implement existing compression methods, thus mentioning their merits and demerits through close analysis. An in-depth analysis of the existing techniques deduced the need for a system that can eliminate redundant information as much as possible to reach ideal compression, improve the performance of existing compression techniques, and reduce the execution time of compression for real-time streaming.

This research endeavors developing an optimized compression scheme addressing three different problems of HSI compression. A lossless prediction-based compression technique for multitemporal images is developed. It removes temporal correlations along with spatial and spectral correlation, reduces the size of time-lapse hyperspectral images significantly. Prediction-based techniques suffer from high complexity and high run time due to pixel-wise operations. We propose a parallelization scheme to reduce the runtime in a high performance computing environment. It consists of a general framework of multilevel parallelism for lossless compression techniques. The results justify the efficiency of proposed work upon increasing number of cores of supercomputer having negligible impact on the compression performance.

This work also utilizes deep learning algorithms for the compression of HSIs applications due to the flexibility of deep networks. More complex functions can be accomplished by adding more units in a layer or multiple layers within a network. The computational complexity of deep networks is a hurdle in its general acceptance besides high performance in most applications. We utilize the most popular solution to accelerate training using GPUs by exploiting the multilevel parallelism existing in the training process and massive floating-point operations. We propose a lossy hyperspectral image compression algorithm based on the concept of autoencoders.

Lastly, we propose a model that combines a traditional transform-based decorrelation method with a convolution network model to improve reconstructed image quality. It reduces the dimensions of the input image by a significant level utilizing the benefits of max-pooling and convolution layer. The effect of compression on classification has also been evaluated in these two experiments using a state-of-the-art classification algorithm. A negligible difference in classification accuracy was obtained that proves the effectiveness of the proposed algorithm.