

Data Compression & Modeling

Data compression and modeling form an important, rigorous and yet practical, intersection of information theory and the discipline of signal modeling. This course is designed to acquaint the students with applications of information theory and rate-distortion theory, applications of statistical signal modeling in signal encoding and decoding, and algorithms and their theoretical justifications for practical coding methods currently used in many information systems such as digital telephony, digital television and multimedia Internet. It covers topics from foundations to applications.

Course Objective: Develop theoretical foundations of data compression, concepts and algorithms for lossy and lossless data compression, signal modeling and its extension to compression with applications to speech, image and video processing.

Course Description: The course covers the theory of quantization and basic concepts in source coding, and applications of the theory and concepts to systems that convert analog or high-rate digital signals into low-rate digital representations, with or without loss of fidelity. The concept of source coding is extended to general descriptions of a statistical information source where various data modeling techniques find useful applications. Related issues in signal classification and clustering, density estimation, and data complexity theory will be treated with a practical orientation for proper understanding of real data compression systems. Applications of the data compression fundamentals in speech and video coding, as well as image document processing, will be highlighted. Course format is interactive.

Text

- *Introduction to Data Compression*, K. Sayood. Morgan Kaufman, Second Edition, 2000. (Primary)
- *Vector Quantization and Signal Compression*, A. Gersho and R.M. Gray. Kluwer Academic Press, 1992. (Recommended)
- *Digital Compression for Multimedia, Principles and Standards*, Gibson, Berger, Lockbaugh, Lindbergh and Baker, Morgan Kaufman, 1998. (Recommended)

Credit Hours: 3

Level: Graduate Level

Prerequisites: Graduate standing

Tentative Course Outline

- Topic 1: Introduction
 - signal compression
 - lossless and lossy compression
 - communication systems and building blocks: sources, channels, and codes
 - issues - fixed rate and variable rate, robustness to channel errors, degradation and perceptual effects
- Topic 2: Quantization theory

- uniform quantization
- distortion and bit rates
- amplitude distribution and high-rate quantization theory
- Bennett approximations and optimal performance
- Lloyd's code optimality and algorithm
- elementary distortion-rate theory
- Topic 3: Architecture for data compression & introduction to data modeling
 - review of stochastic processes and information source
 - signal models & spectral analysis
 - quantization with memory: transform coding, subband coding, wavelet coding, predictive coding, vector quantization
 - fixed-rate vs. variable-rate code
 - entropy, estimated entropy, complexity and typical sequence of an ergodic source
 - variable rate quantization: lossless codes, prefix code
- Topic 4: Lossless Coding Techniques
 - Huffman coding
 - arithmetic coding
 - universal lossless codes: the Lempel-Ziv algorithm
 - adaptive and predictive lossless coding
- Topic 5: Distortion & Similarity Measures
 - sample difference, sum of squared deviations and Euclidean distance
 - Lp-norm, city-block distance, Mahalanobis distance
 - transformation and transformation invariant similarity measures
 - spectral distortion measures: Itakura distortion, Itakura-Saito distortion, model distortion, cepstral distance, non-uniform frequency warping
 - mutual-information, divergence, and Kullback-Liebler number
 - perceptual issues
- Topic 6: Coding algorithms – scalar quantization
 - clustering algorithms for quantizer design
 - the Lloyd algorithm and its generalization
 - entropy-constrained quantizers
- Topic 7: Coding algorithms - vector quantization (VQ)
 - sphere packing and optimal uniform lattice quantizers
 - Lloyd algorithm - revisited
 - progressive vector quantization
 - variations of vector quantization: tree-structured VQ, product VQ, predictive VQ, multistage VQ, hierarchical VQ
 - finite-state VQ and Markov models
 - tree and trellis encoding
- Topic 8: Applications – speech and audio coding
 - Waveform coders: pulse-coded modulation (PCM); adaptive PCM; differential PCM, adaptive differential PCM
 - Model-based coders: channel vocoder, linear prediction (LP) vocoder
 - Hybrid coders: residual LP coders, code-excited LP coders
 - Voice compression in communications: wireless and packet networks
 - MP3 audio coder
 - Noise masking and perceptual audio coders (PAC)
- Topic 9: Applications – image and video coding
 - JPEG still image compression algorithms
 - Transforms
 - Introduction to MPEG compression
 - Motion estimation and compensation
- Topic 10: Compression standards and formats