

Exercise Problems: Information Theory and Coding

Prerequisite courses: Mathematical Methods for CS; Probability

Overview and Historical Origins: Foundations and Uncertainty. Why the movements and transformations of information, just like those of a fluid, are law-governed. How concepts of randomness, redundancy, compressibility, noise, bandwidth, and uncertainty are intricately connected to information. Origins of these ideas and the various forms that they take.

Mathematical Foundations; Probability Rules; Bayes' Theorem. The meanings of probability. Ensembles, random variables, marginal and conditional probabilities. How the formal concepts of information are grounded in the principles and rules of probability.

Entropies Defined, and Why They Are Measures of Information. Marginal entropy, joint entropy, conditional entropy, and the Chain Rule for entropy. Mutual information between ensembles of random variables. Why entropy is a fundamental measure of information content.

Source Coding Theorem; Prefix, Variable-, & Fixed-Length Codes. Symbol codes. Binary symmetric channel. Capacity of a noiseless discrete channel. Error correcting codes.

Channel Types, Properties, Noise, and Channel Capacity. Perfect communication through a noisy channel. Capacity of a discrete channel as the maximum of its mutual information over all possible input distributions.

Continuous Information; Density; Noisy Channel Coding Theorem. Extensions of the discrete entropies and measures to the continuous case. Signal-to-noise ratio; power spectral density. Gaussian channels. Relative significance of bandwidth and noise limitations. The Shannon rate limit and efficiency for noisy continuous channels.

Fourier Series, Convergence, Orthogonal Representation. Generalized signal expansions in vector spaces. Independence. Representation of continuous or discrete data by complex exponentials. The Fourier basis. Fourier series for periodic functions. Examples.

Useful Fourier Theorems; Transform Pairs. Sampling; Aliasing. The Fourier transform for non-periodic functions. Properties of the transform, and examples. Nyquist's Sampling Theorem derived, and the cause (and removal) of aliasing.

Discrete Fourier Transform. Fast Fourier Transform Algorithms. Efficient algorithms for computing Fourier transforms of discrete data. Computational complexity. Filters, correlation, modulation, demodulation, coherence.

The Quantized Degrees-of-Freedom in a Continuous Signal. Why a continuous signal of finite bandwidth and duration has a fixed number of degrees-of-freedom. Diverse illustrations of the principle that information, even in such a signal, comes in quantized, countable, packets.

Gabor-Heisenberg-Weyl Uncertainty Relation. Optimal "Logons." Unification of the time-domain and the frequency-domain as endpoints of a continuous deformation. The Uncertainty Principle and its optimal solution by Gabor's expansion basis of "logons." Multi-resolution wavelet codes. Extension to images, for analysis and compression.

Kolmogorov Complexity and Minimal Description Length. Definition of the algorithmic complexity of a data sequence, and its relation to the entropy of the distribution from which the data was drawn. Shortest possible description length, and fractals.

Recommended book:

Cover, T.M. & Thomas, J.A. (1991). *Elements of Information Theory*. New York: Wiley.

Exercise Problems Information Theory And Coding

Joacim Rocklöv



Exercise Problems Information Theory And Coding:

Decoding **Exercise Problems Information Theory And Coding**: Revealing the Captivating Potential of Verbal Expression

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