Chapter VI

Subband Coding of Signals

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In this chapter we deal with subband coding of signals. We begin with an introduction to rate-distortion theory, and after that we discuss subband compression schemes in general. We then describe popular still image and video coding algorithms using subband decompositions, including DCT and wavelet-based methods. R-D optimization-based techniques such as wavelet packets are also described. We finish the chapter with a brief account of subband-based audio compression schemes.

INTRODUCTION

The compression of signals is one of the main applications of digital signal processing. In this chapter we focus on the compression of signals using the subband decomposition approach. In this scheme, a signal is transformed by an analysis filter bank prior to compression. Then some data compression method is applied to the output of the channels of the filter bank. Although the compression can be done directly on the input data, it is usually easier to efficiently compress the output of the filter bank. One of the main reasons for this is that for most natural signals, despite the statistics of the filter bank’s outputs varying a great deal from band to band, each band tends to have a much more well-behaved statistic than the original signal. Therefore, a specific compressor can be designed for each band, which tends to increase the overall coding efficiency.
In the section named *Rate-Distortion Theory* we present a formal definition of the compression problem and basic results from rate-distortion theory. The section *The Subband Compression Scheme* contains a description of a general subband coding system and its properties. The *Popular Still-Image and Video Coding Algorithms* section describes popular subband compression algorithms. We also discuss their compression performance and complexity. In the section named *R-D Techniques* we study R-D optimization techniques, and in the *Audio Compression* section we deal with audio compression using multirate systems. Finally, we present a summary of the chapter.

**RATE-DISTORTION THEORY**

The problem of data compression emerges naturally in many applications. Whenever we have to deal with large amounts of data, we value methods that provide efficient signal representations. The main question here is how much one can compress a particular signal. The answer to this question usually depends on the accuracy level of the representation we need, that is, is it really necessary to reproduce an exact copy of the input data, or is it sufficient to have an approximate reproduction? In other words, we want to know how many bits are required to describe a source of data within a given reproduction quality.

**The R(D) Function**

The rate-distortion theory (Berger, 1971) studies the compression of a source subject to a fidelity criterion. In this theory a source is characterized by its statistical properties. Over the last 50 years, rate-distortion theory studies have focused to a large extent on the derivation of performance bounds for the tradeoff between coding rate and achievable distortion for a given source. This tradeoff is called R(D) function of the source, where R is the average rate required to describe any output produced by the source with average distortion at most D. One can show that the R(D) function of any source is a decreasing and convex function defined over the interval [0, D\text{max}] (Blahut, 1988). D\text{max} is the smallest average distortion that can be obtained using zero bits to describe the source (at zero rate we always use the same pattern to approximate the actual output produced by the source). In other words, if we want more quality we have to pay the cost of using more bits. The R(D) function defines the achievable performance of any compression code, that is, the rate of any compression code must satisfy R ≤ R(D).

For example, a Gaussian source is a random variable (rv) (Papoulis, 1984) x with a Gaussian function as its probability density function. The R(D) function for a Gaussian source, when the mean squared error is the fidelity criterion, is:
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