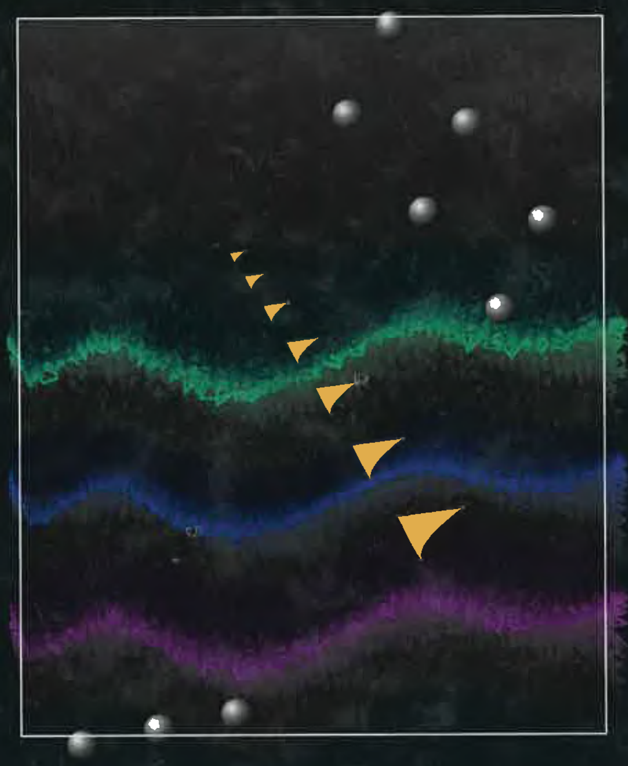
digital video processing



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PRENTICE HALL SIGNAL PROCESSING SERIES

Digital Video Processing

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Prentice Hall PTR
Upper Saddle River, NJ 07458

Tekalp, A. Murat.
Digital video processing / A. Murat Tekalp.
p. cm. -- (Prentice-Hall signal processing series)
ISBN 0-13-190075-7 (alk. paper)
1. Digital video. I. Title. II. Series.
TK6680.5.T45 1995
621.388'33--dc20 95-16650
CIP

Editorial/production supervision: **Ann Sullivan**
Cover design: **Design Source**
Manufacturing manager: **Alexis R. Heydt**
Acquisitions editor: **Karen Gettman**
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Printed on Recycled Paper

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Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN: 0-13-190075-7

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
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Prentice-Hall Hispanoamericana, S.A., *Mexico*
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Simon & Schuster Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

Chapter 18

LOSSLESS COMPRESSION

The need for effective data compression is evident in almost all applications where storage and transmission of digital images are involved. For example, an 8.5×11 in document scanned at 300 pixels/in with 1 bit/pixel generates 8.4 Mbits data, which without compression requires about 15 min transmission time over a 9600 baud line. A 35 mm film scanned at 12 micron resolution results in a digital image of size 3656 pixels $\times$ 2664 lines. With 8 bits/pixel per color and three color channels, the storage required per picture is approximately 233 Mbits. The storage capacity of a CD is about 5 Gbits, which without compression can hold approximately 600 pages of a document, or 21 color images scanned from 35 mm film. Several world standards for image compression, such as ITU (formerly CCITT) Group 3 and 4 codes, and ISO/IEC/CCITT JPEG, have recently been developed for efficient transmission and storage of binary, gray-scale, and color images.

Compression of image data without significant degradation of the visual quality is usually possible because images contain a high degree of i) spatial redundancy, due to correlation between neighboring pixels, ii) spectral redundancy, due to correlation among the color components, and iii) psychovisual redundancy, due to properties of the human visual system. The higher the redundancy, the higher the achievable compression. This chapter introduces the basics of image compression, and discusses some lossless compression methods. It is not intended as a formal review of the related concepts, but rather aims to provide the minimum information necessary to follow the popular still-image and video compression algorithms/standards, which will be discussed in the subsequent chapters. Elements of an image compression system as well as some information theoretic concepts are introduced in Section 18.1. Section 18.2 discusses symbol coding, and in particular entropy coding, which is an integral part of lossless compression methods. Finally, three commonly used lossless compression algorithms are presented in Section 18.3.

18.1 Basics of Image Compression

In this section, we first present the elements of a general image compression system, then summarize some results from the information theory which provide bounds on the achievable compression ratios and bitrates.

18.1.1 Elements of an Image Compression System

In information theory, the process of data compression by redundancy reduction is referred to as source encoding. Images contain two types of redundancy, statistical (spatial) and pyschovisual. Statistical redundancy is present because certain spatial patterns are more likely than others, whereas psychovisual redundancy originates from the fact that the human eye is insensitive to certain spatial frequencies. The block diagram of a source encoder is shown in Figure 18.1. It is composed of the following blocks:

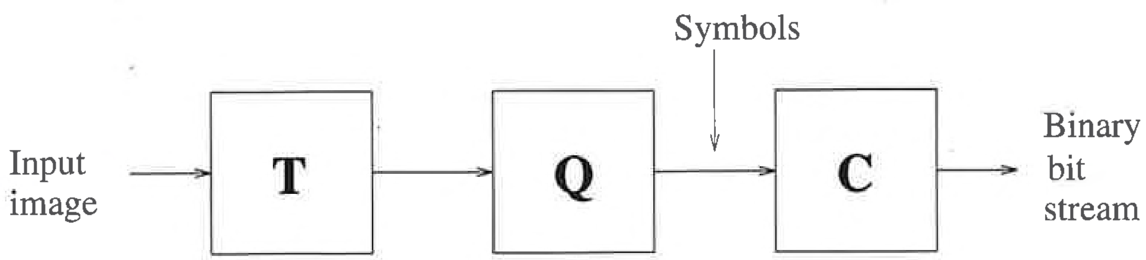

Figure 18.1: Block diagram of an image compression system.

i) Transformer (T) applies a one-to-one transformation to the input image data. The output of the transformer is an image representation which is more amenable to efficient compression than the raw image data. Typical transformations are linear predictive mapping, which maps the pixel intensities onto a prediction error signal by subtracting the predictible part of the pixel intensities; unitary mappings such as the discrete cosine transform, which pack the energy of the signal to a small number of coefficients; and multiresolution mappings, such as subband decompositions and the wavelet transform.
ii) Quantizer (Q) generates a limited number of symbols that can be used in the represention of the compressed image. Quantization is a many-to-one mapping which is irreversible. It can be performed by scalar or vector quantizers. Scalar quantization refers to element-by-element quantization of the data, whereas quantization of a block of data at once is known as vector quantization.
iii) Coder (C) assigns a codeword, a binary bitstream, to each symbol at the output of the quantizer. The coder may employ fixed-length or variable-length codes. Variable-length coding (VLC), also known as entropy coding, assigns codewords in such a way as to minimize the average length of the binary representation of the

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