IMAGE PROCESSING AND PATTERN RECOGNITION

Fundamentals and Techniques

FRANK Y. SHIH

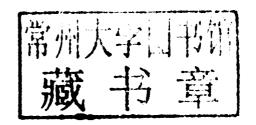




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FUNDAMENTALS



INTRODUCTION

An image is a subset of a signal. A *signal* is a function that conveys information generally about the behavior of a physical system or attributes of some phenomenon. A simple example is the traffic signal that uses three universal color codes (red, yellow, and green) signaling the moment to stop, drive, or walk. Although signals can be represented in many ways, in all cases the information is contained in a pattern of variations of some form, and with that information is typically transmitted and received over a medium. Electrical quantities such as current and voltage are called *electrical signals*, which are often used in radio, radar, sonar, telephone, television, and many other areas. An acoustic wave signal can convey speech or music information, in which people often speak of a strong or weak signal when the sound is referred to its clarity and audibility. A thermocouple can convey temperature, and a pH meter can convey the acidity of a solution.

A signal may take a form of time variations or a spatially varying pattern. Mathematically speaking, signals are represented as functions of one or more independent variables that can be either continuous or discrete. *Continuous-time* signals are defined at a continuum of the time variable. *Discrete-time* signals are defined at discrete instants of time. *Digital* signals are those for which both time and amplitude are discrete. The continuous-time and continuous-amplitude signals are called *analog* signals. Analog signals that have been converted to digital forms can be processed by a computer or other digital devices.

Signal processing is the process of extracting information from the signal. Digital signal processing (DSP) is concerned with the representation of signals by sequences of numbers or symbols and processing of these sequences. It was initiated in the seventeenth century and has become an important modern tool in the tremendously diverse fields of science and technology. The purpose of such processing is to estimate characteristic parameters of a signal or to transform a signal into a form that is more sensible to human beings. DSP includes subfields such as digital image processing, video processing, statistical signal processing, signal processing for communications, biomedical signal processing, audio and speech signal processing, sonar and radar signal processing, sensor array processing, spectral estimation, and so on.

Human beings possess a natural signal processing system. "Seeing" takes place in the visual system and "hearing" takes place in the auditory system. Human visual system (HVS) plays an important role in navigation, identification, verification, gait, gesture, posture, communication, psychological interpretation, and so on. Human

4 CHAPTER 1 INTRODUCTION

auditory system converts sound waves into nerve impulses, to analyze auditory events, remember and recognize sound sources, and perceive acoustic sequences. As the speed, capability, and economic advantages of modern signal processing devices continue to increase, there is simultaneously an increase in efforts aimed at developing sophisticated, real-time automatic systems capable of emulating human abilities. Because of digital revolution, digital signals have been increasingly used. Most household electronic devices are based entirely or almost entirely upon digital signals. The entire Internet is a network of digital signals, as is modern mobile phone communication.

1.1 THE WORLD OF SIGNALS

The world is filled with many kinds of signals; each has its own physical meaning. Sometimes the human body is incapable of receiving a special signal or interpreting (decoding) a signal, so the information that the signal intends to convey cannot be captured. Those signals are not to be said nonsense or insignificant, but conversely they are exactly what people are working very hard to understand. The more we learn from the world's signals, the better living environment we can provide. Furthermore, some disaster or damage can be avoided if a warning signal can be sensed in advance. For example, it was recorded historically that animals, including rats, snakes, and weasels, deserted the Greek city of Helice in droves just days before a quake devastated the city in 373 B.C. Numerous claims have been made that dogs and cats usually behave strangely before earthquake by barking, whining, or showing signs of nervousness and restlessness.

The characteristics of a signal may be one of a broad range of shapes, amplitudes, time durations, and perhaps other physical properties. Based on the sampling of time axis, signals can be divided into continuous-time and discrete-time signals. Based on the sampling of time and amplitude axes, signals can be divided into analog and digital signals. If signals repeat in some period, they are called periodic signals; otherwise, aperiodic or nonperiodic signals. If each value of a signal is fixed by a mathematical function, it is called a deterministic signal; otherwise, a random signal that has uncertainty about its behavior. In the category of dimensionality, signals are divided into one-dimensional (1D), two-dimensional (2D), three-dimensional (3D), and multidimensional signals, which are further explained below.

1.1.1 One-Dimensional Signals

A 1D signal is usually modeled as an ensemble of time waveforms, for example, x(t) or f(t). One-dimensional signal processing has a rich history, and its importance is evident in such diverse fields as biomedical engineering, acoustics (Beranek, 2007), sonar (Sun et al., 2004), radar (Gini et al., 2001), seismology (Al-Alaoui, 2001), speech communication, and many others. When we use a telephone, our voice is converted to an electrical signal and through telecommunication systems circulates around the Earth. The radio signals, which are propagated through free space and by radio receivers, are converted into sound. In speech transmission and recognition, one