Preface

Signal processing is the means and methodology of handling, manipulating, and converting signals for the purposes of recording, analysis, transmission, and storage. Signals, particularly in the context of the biomedical field, are recorded for the presentation and often the quantification of some physical phenomena for the purposes of directly or indirectly obtaining information about the phenomena. There may not be a medical specialty that relies on the acquisition, recording, and displaying of signals more than cardiology. We have come a long way from the days when stethoscopes and blood pressure cuffs were the only diagnostic equipment available to assess the cardiovascular system of a patient. Imagine modern cardiology without electrocardiograms, continuous blood pressure monitoring, intracardiac electrograms, echocardiograms, and MRIs. In fact, these technologies have become so ubiquitous that interpretation of these signals is often performed with little understanding of how these signals are obtained and processed.

Why then would the understanding of signal and image processing be important for a clinician, nurse, or technician in cardiology? Electrocardiograms, for example, can be practically performed with a touch of a button providing a near instantaneous report. Why does it matter how the machine was able to come to the conclusion that the patient had a heart rate of 65 beats/min or a QT interval of 445 ms? The effects of signal processing can appear mysterious and it is tempting to consider that this aspect is best left for engineers and researchers who have technical and mathematical backgrounds. One reason why a better understanding of signal processing would be beneficial is that these technologies used in cardiology all have their own strengths and limitations. For example, a surface electrocardiogram signal may look "noisy" because of motion artifact or poor electrode contact. Changing filter settings can make a signal look much cleaner. These settings, however, may also result in distortion or loss of important information from the signal of interest. Understanding of filters and the frequency content of signals may help determining the proper balance between acceptable noise and the acceptable amount of distortion of the waveform. This is only one example of the importance of understanding the process of obtaining the signal or image, as judging signal quality is often more important than how "clean" a signal or image looks.

More advanced signal processing is also essential in cardiovascular imaging and a variety of advanced electrocardiographic techniques, such as heart rate variability, signal-averaged ECGs, and T-wave alternans. The role of processing is to enhance, embellish, or uncover the signal of interest among a variety of other signals, both physiologic and non-physiologic. By definition, the more a signal is processed, the more deviation there will be from the raw signal. The interpreter must therefore be able to assess whether this deviation is desirable or undesirable. Understanding the signal processing used in these methods will allow the interpreter to understand the issues that are created with signal processing.

The aim of this book is to provide those in the cardiology field an opportunity to learn the basics of signal and image processing without requiring extensive technical or mathematical background. We feel that the saying "a picture is worth a thousand words" is particularly applicable for the purposes of this book. Therefore most of the concepts will be conveyed through illustrative examples. Although this book is geared towards the clinical cardiologist, a beginner in the biomedical engineering field may also find the review of concepts useful before requiring a more in-depth signal processing text. Signal processing is an extremely interesting and thought-provoking subject.

The first half of the book is an overview of general signal processing concepts. In Chap. 1, the architecture of a digital physiologic recording system will be described. The reader will understand the commonality in how all the main cardiology diagnostic systems are put together. In Chap. 2, the fundamentals of analog and digital signals, the reasons why we use them, and the advantages and disadvantages of both will be discussed. In Chap. 3, we will go through what it means to analyze signals in the time domain and frequency domain. In Chap. 4, we will discuss filters, why they are so important to recording systems, and the interpretation of signals. Chapters 5 and 6 discuss ways to detect events such as the heart beat and how the rate of events can be estimated. Chapter 7 then describes the technique of signal averaging, a common method used to improve signal quality. The topic of Chap. 8 is compression, which describes the methods by which digital data can be reduced in size to facilitate storage and transmission. And finally, Chap. 9 shows how the previously described concepts and techniques can be applied to two-dimensional images.

The second half of the book is devoted to discussions on how signal and image processing is used in the specific modalities of cardiac instrumentation. The modalities which utilize one-dimensional signals include the electrocardiogram, invasive and noninvasive blood pressure measurement, pulse oximetry, intracardiac electrograms, and stethoscope. The two (or three)-dimensional modalities include coronary angiograms, ultrasound, magnetic resonance imaging, nuclear imaging, and computed tomography.

We hope that this text will not only enhance the reader's knowledge for clinical and research purposes, but also provide an enjoyable reading experience.

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