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HST.582J / 6.555J / 16.456J Biomedical Signal and Image Processing  
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**INTRODUCTION TO BIOMEDICAL SIGNAL AND IMAGE  
PROCESSING**

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## **Signals convey information**

A *signal* is a function of one or several variables that carries useful information. A signal is said to be *biological* if it is recorded from a living system, and conveys information about the state or behavior of that system. For example, the temperature record of a patient, the voltage recorded by an electrode placed on the scalp, and the spatial pattern of X-ray absorption obtained from a CT scan are biological signals. Signals can be either one-dimensional, if they depend on a single variable such as time, or multidimensional if they depend on several variables such as spatial coordinates. The first part of these notes will be concerned with one-dimensional signals. In the second part, concepts used in processing one-dimensional signals will be extended to multidimensional signals such as images and volumetric data. Often, signals are functions of time, but this is not necessarily so as the case of images illustrates. Mathematically, it does not matter whether the signal variable is time or some other coordinate. For the purpose of making things concrete, we will assume in these notes that one-dimensional signals are functions of time.

## **Signal processing selectively eliminates information**

More often than not, a signal conveys irrelevant information as well as the information of interest. For example, the electroencephalogram (EEG) recorded from the scalp of a volunteer may be contaminated by the electrophysiological activity of the heart and the ubiquitous 60-Hz power-line signal. What constitutes information of interest depends on the specific application. For example, a speech signal contains both linguistic information (what was said) and information about the speaker (who said it). The former would be of interest in an automatic speech recognition system, while the latter would matter for a speaker identification system. The purpose of *signal processing* is to selectively eliminate irrelevant information from a signal so as to make the information of interest more easily accessible to a human observer or a computer system. The reason for this negative definition is that it is never possible to add information to a given signal, only to eliminate it. (This fundamental limitation is related to the second law of thermodynamics.)

## **Stages in biomedical signal processing**

In a typical biomedical application, signal processing may include four stages (see Figure 1): data acquisition, signal conditioning, feature extraction, and decision making. The goal of *data*

*acquisition* is to capture the signal and encode in a form suitable for computer processing. At this stage, the main concern is to avoid losing information about the signal. The goal of *signal conditioning* is to eliminate or reduce extraneous components such as noise from the signal. Often, this done using linear filters, sometimes in combination with nonlinear operators. A major theme of this course is how to design filters that best separate signal from noise. *Feature extraction* means identifying and measuring a small number of parameters or features that best characterize the information of interest in a signal. The distinction between feature extraction and signal conditioning is not a rigid one in that both selectively eliminate irrelevant information. It is primarily one of dimensionality: Whereas the result of conditioning typically has the same dimensionality as the input signal, the set of extracted features should have much lower dimensionality so as to facilitate storage, processing and visualization. In addition, feature extraction techniques are often signal- and application-specific, while conditioning methods can be very general. Examples of feature extraction techniques covered in these notes are analysis of speech by linear prediction and edge detection in image processing. The last stage of signal processing, *decision making*, a.k.a. *hypothesis testing* is particularly important in clinical applications where a course of action has to be taken. It aims at answering questions such as "Does the patient have a tumor based on a brain scan?" or "Does patient show a specific pathology in heart beats based on the electrocardiogram?" In these notes, we will briefly introduce some general statistical techniques for making such decisions as reliably as possible.

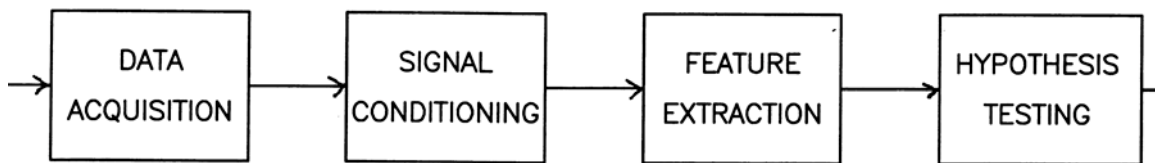


Figure 1: