

Lecture 1: Data Acquisition and Signal Conditioning

Instructor: Dr. Lalitha Vadlamani

Signals describe a wide variety of physical phenomenon, for example

- The patterns of variations of source and capacitor voltages.
- Human vocal mechanism, which produces speech by creating fluctuations in acoustic pressure.
- Pattern of variations in brightness across an image.

Signals must be processed to facilitate extraction of information. Signals are represented mathematically as functions of one or more independent variables.

1.1 Types of Signals

- Continuous-time and discrete-time signals: The independent variable of the mathematical representation of a signal may be either continuous or discrete. Continuous-time signals are signals that are defined at a continuum of times and thus are represented by continuous variable functions. Discrete-time signals are defined at discrete times and thus the independent variable takes on only discrete values; i.e., discrete-time signals are represented as sequences of numbers. Continuous-time signals are denoted by $x(t), t \in \mathbb{R}$ and discrete-time signals are denoted by $x(n), n \in \mathbb{Z}$.
- Analog and digital signals: Continuous-time, continuous amplitude signals are called analog signals. Digital signals are those for which both time and amplitude are discrete.
- Periodic and aperiodic signals: A signal $x(t)$ is periodic with period T if $x(t+T) = x(t)$ for all t . Note that if $x(t)$ is periodic with period T , then it is also periodic with period nT , where n is any positive integer. The smallest time interval for which $x(t)$ is periodic is termed as fundamental period T_0 .

1.2 Examples of Signals

1.2.1 1-D Signals

- Speech Signal: The speech signal, as it emerges from a speaker's mouth, nose and cheeks, is a one-dimensional function (air pressure) of time. Microphones convert the fluctuating air pressure into electrical signals.
- ECG Signal: The ECG signal is a record of the potential differences produced by the electrical activity of the heart cells. The body by itself acts as a giant conductor of electric current and any two points in the body can be connected by electrical electrodes to record an ECG or monitor the heart's rhythm. The trace measured and recorded using suitable equipment refers to the electrical activity of the heart and forms a series of waves and complexes that have been arbitrarily called P wave, QRS complex, T wave and U wave. The waves or deflections are separated by regular intervals.

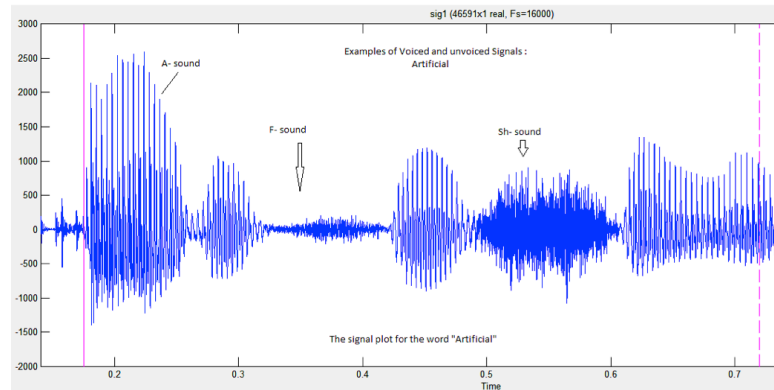


Figure 1.1: Speech Signal.

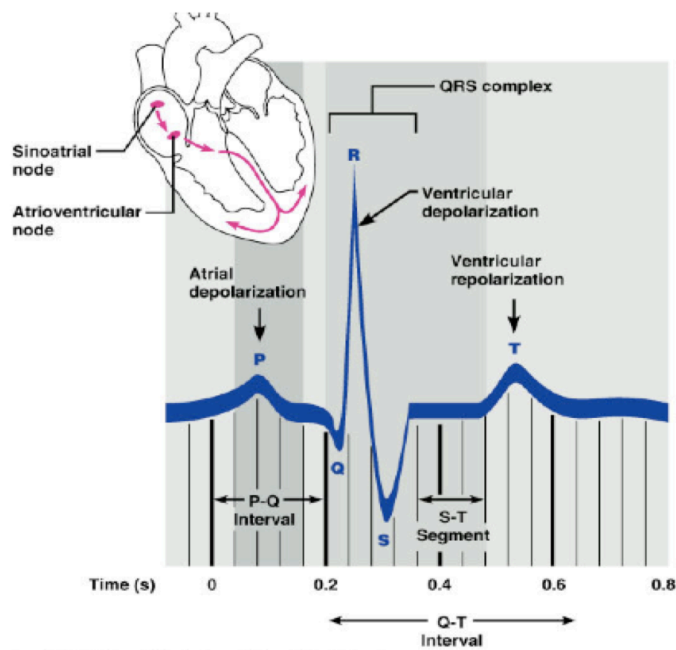


Figure 1.2: ECG Signal.

- **Financial Data:** The basic information from financial markets is the price: price of share, commodity price, currency price, bond price etc. The prices are monitored in certain time frequency and create time series.
- **Temperature Data:** The device used to measure temperature is a temperature sensor which is essentially a resistance temperature detector. The principle used here is the resistance of the sensor changes with respect to the temperature of the surroundings. Therefore when the voltage around the RTD is measured, this forms a function of the surrounding temperature in degrees.

Question: Is text a signal?

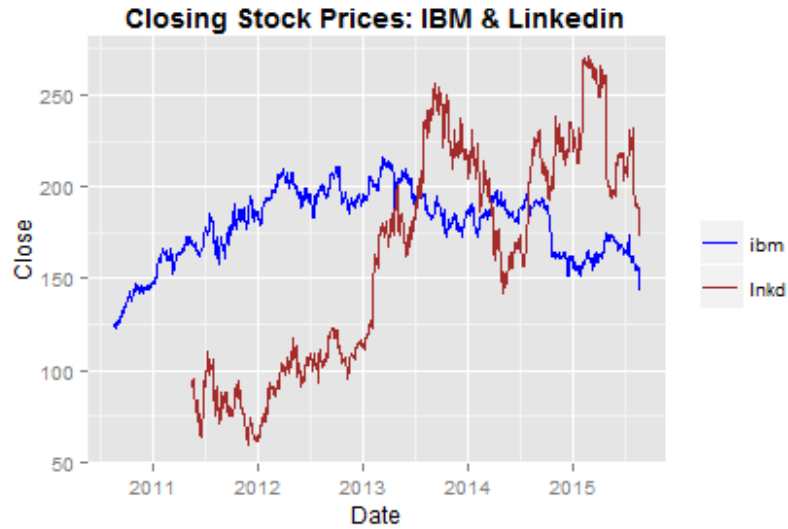


Figure 1.3: Financial time series.

1.2.2 Ideal Signals and Related Examples

- Sinusoid: A sinusoid is characterized completely by its amplitude, frequency and phase. Its given by

$$s(t) = A \sin(2\pi ft + \phi). \quad (1.1)$$

Examples of sinusoid include music tones, alternating current.

- Unit Step Function: A unit step function is given by

$$u(t) = \begin{cases} 0, & t < 0 \\ 1, & t \geq 0 \end{cases}. \quad (1.2)$$

An example of a unit step function is when a switch changes state from OFF to ON.

- Unit Impulse Function: Consider the following function

$$\delta(t) = \begin{cases} 0 & t \neq 0 \\ \infty & t = 0 \end{cases} \quad (1.3)$$

With $\int_{-\infty}^{\infty} \delta(t) dt = 1$. This function is obtained as a limiting case of box function $B_{\Delta}(t)$. The function $B_{\Delta}(t)$ is defined as follows:

$$B_{\Delta}(t) = \begin{cases} \frac{1}{\Delta} & 0 \leq t \leq \Delta \\ 0 & \text{elsewhere} \end{cases} \quad (1.4)$$

The family of box functions for all Δ have area 1. As Δ gets smaller, the box gets taller and thinner. The impulse function is defined as

$$\delta(t) = \lim_{\Delta \rightarrow 0} B_{\Delta}(x). \quad (1.5)$$

Note that the above definition is only one of the many ways in which impulse function can be defined.

Sifting Property of Impulse Function: We integrate the box function with an arbitrary function $f(t)$. The mean value theorem of integrals states that we can find some average height $f(c)$ for some

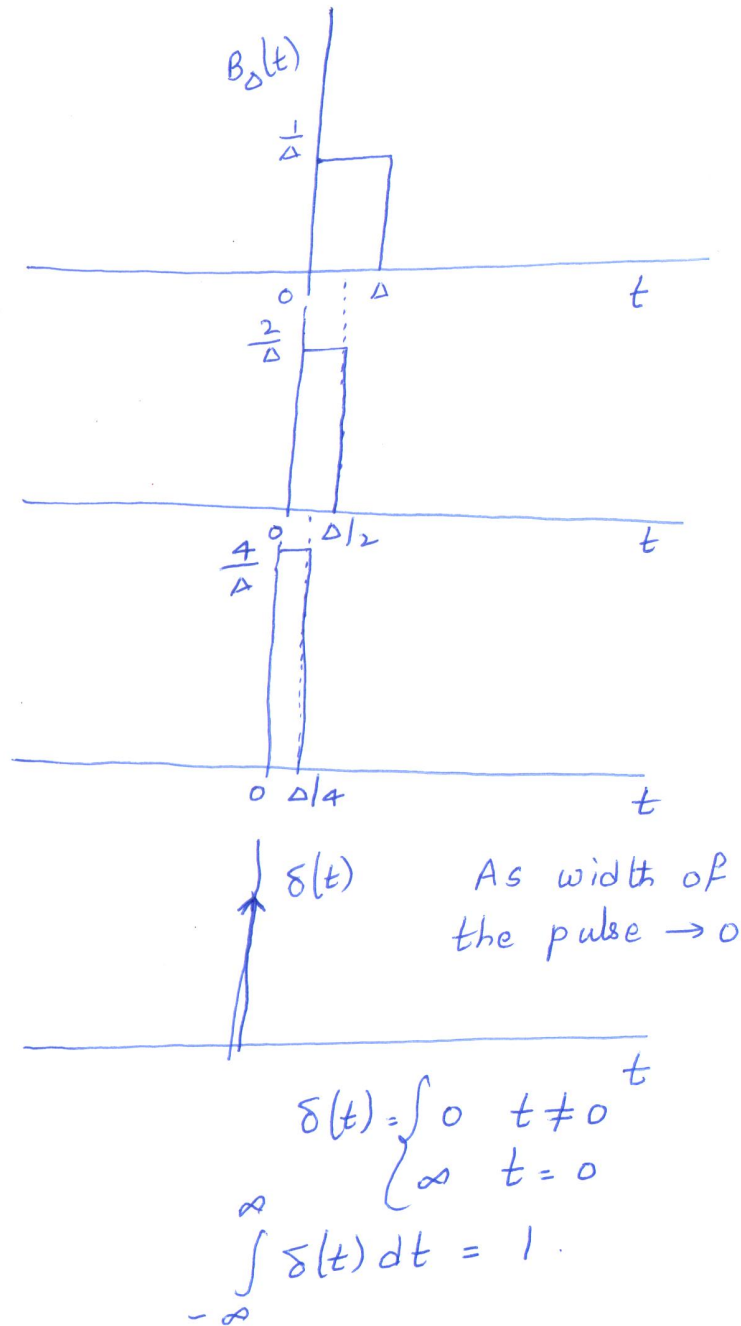


Figure 1.4: Impulse function as limiting function of rectangular pulses.

$t = c, 0 \leq c \leq \Delta$ such that $f(c)\Delta$ is the area under the curve. Thus, applying mean value theorem, we have

$$\int_{-\infty}^{\infty} B_{\Delta}(t)f(t)dt = \frac{1}{\Delta}f(c)\Delta = f(c) \quad (1.6)$$

As $\Delta \rightarrow 0$, $c \rightarrow 0$.

$$\lim_{\Delta \rightarrow 0} \int_{-\infty}^{\infty} B_{\Delta}(t) f(t) dt = \lim_{\Delta \rightarrow 0} f(c) = f(0). \quad (1.7)$$

Hence, we have

$$\int_{-\infty}^{\infty} \delta(t) f(t) dt = f(0). \quad (1.8)$$

Examples of impulse function include movie clap shot.