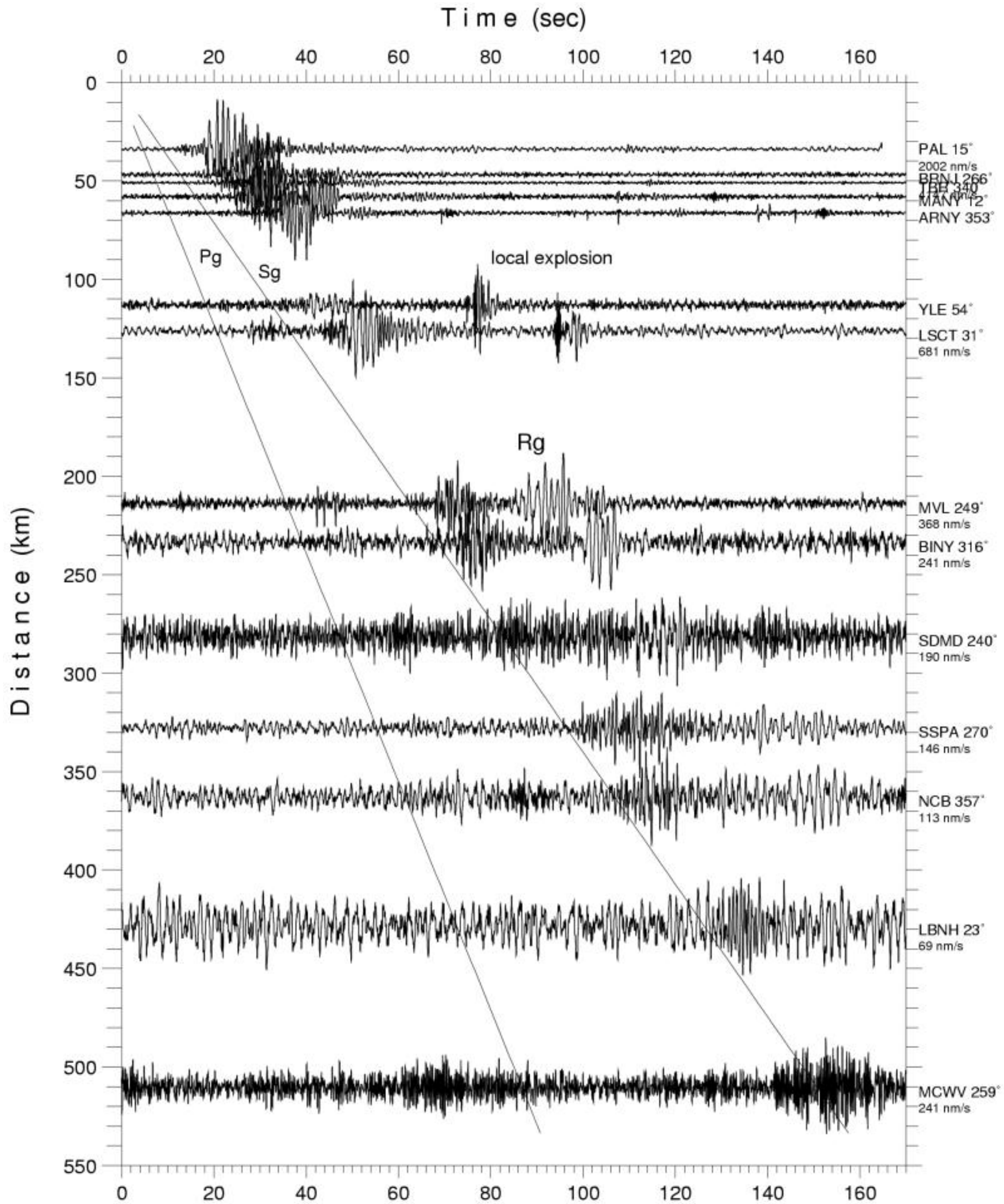
NUS-ISS
Intelligent Sensing and Sense Making

Introduction to signals

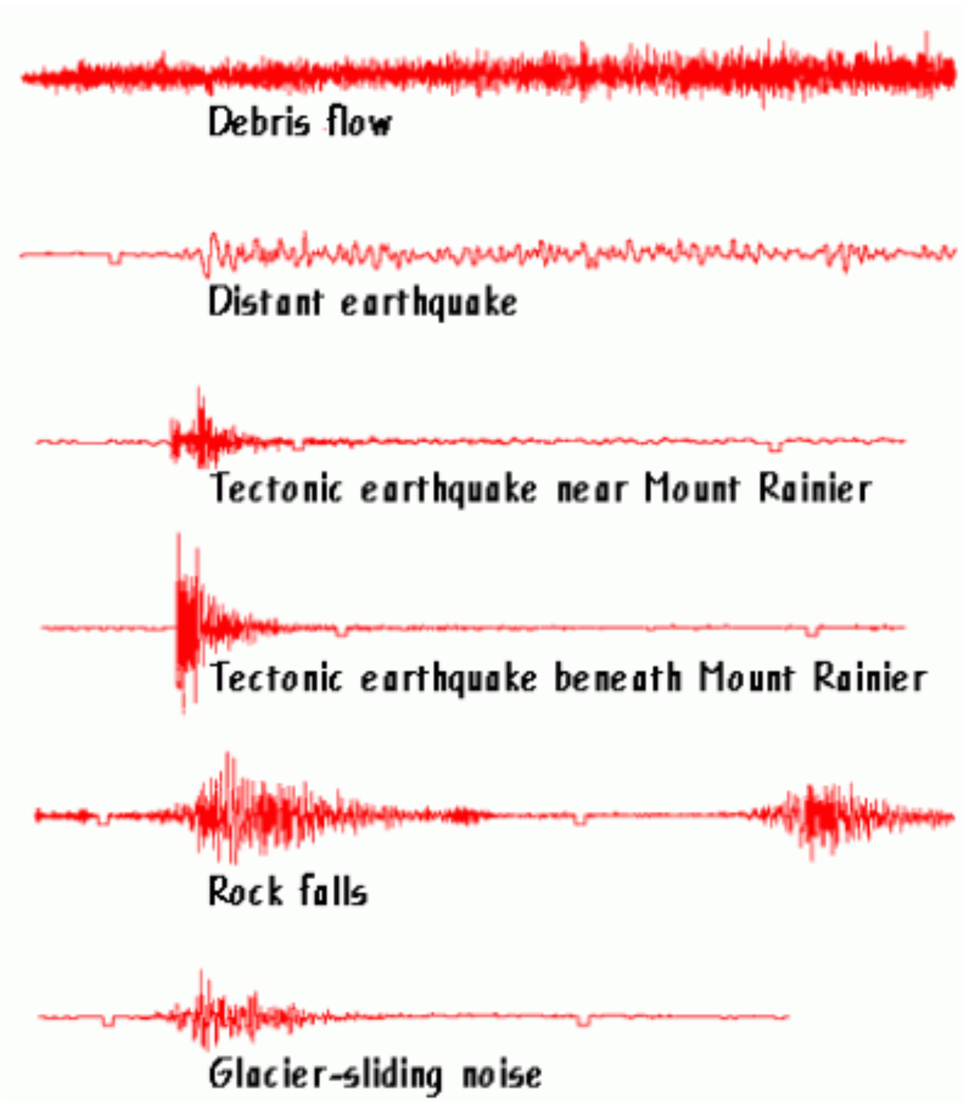
by Dr. Tan Jen Hong

Signals



Source: http://911research.wtc7.net/mirrors/guardian2/wtc/seismic/WTC_PENT_KIM.htm

What is signal?

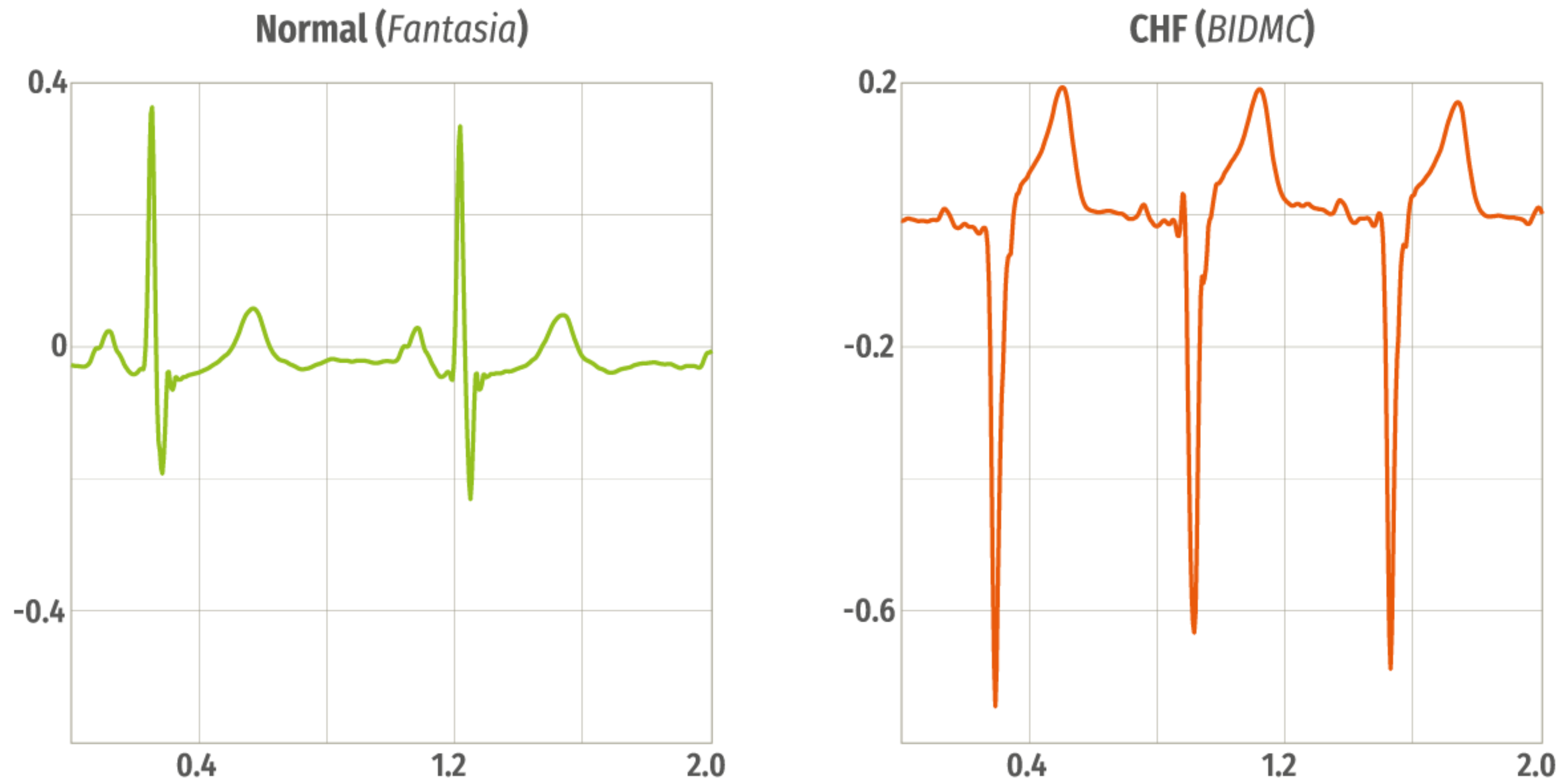


Source: https://volcanoes.usgs.gov/vhp/seismic_signals.html

- A set/series of data
- Any kind of physical variable subjected to variations represents a signal
- Independent variable, physical variable can be either scalar or vector
- Independent variable: time (t), position (x,y,z)

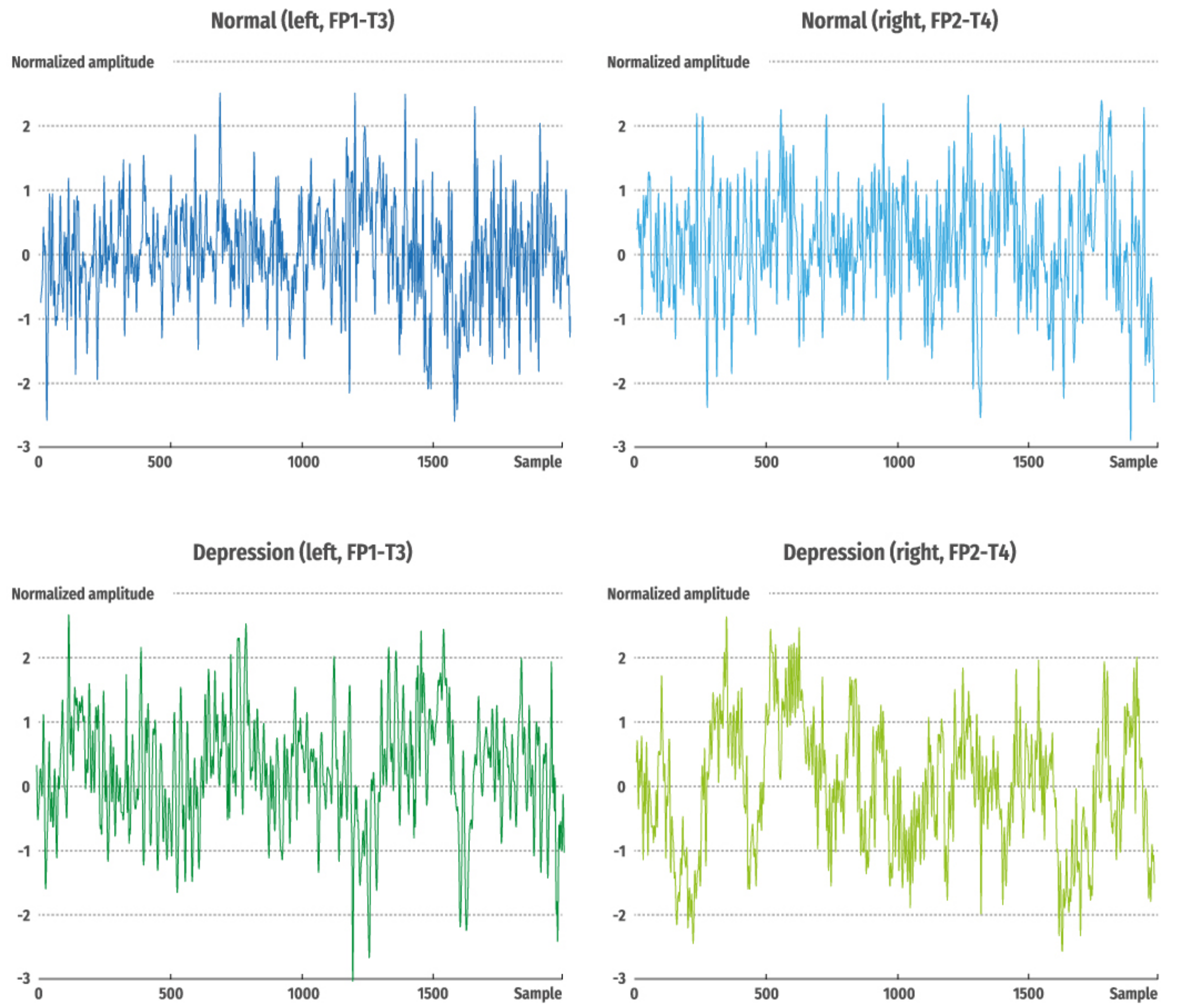
Signals

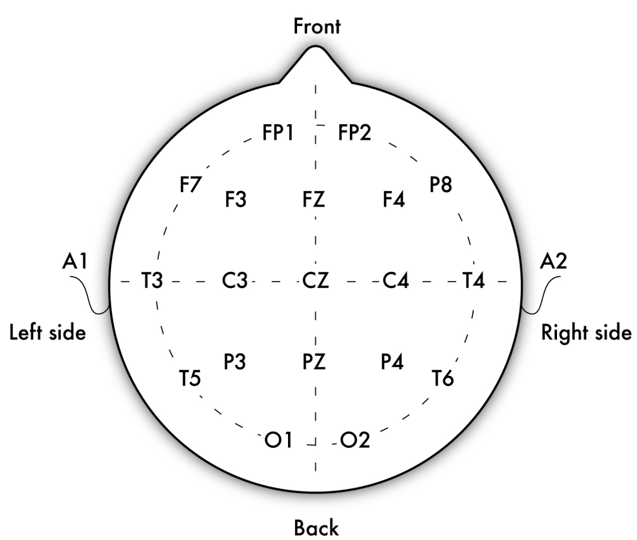
Example: ECG



Signals

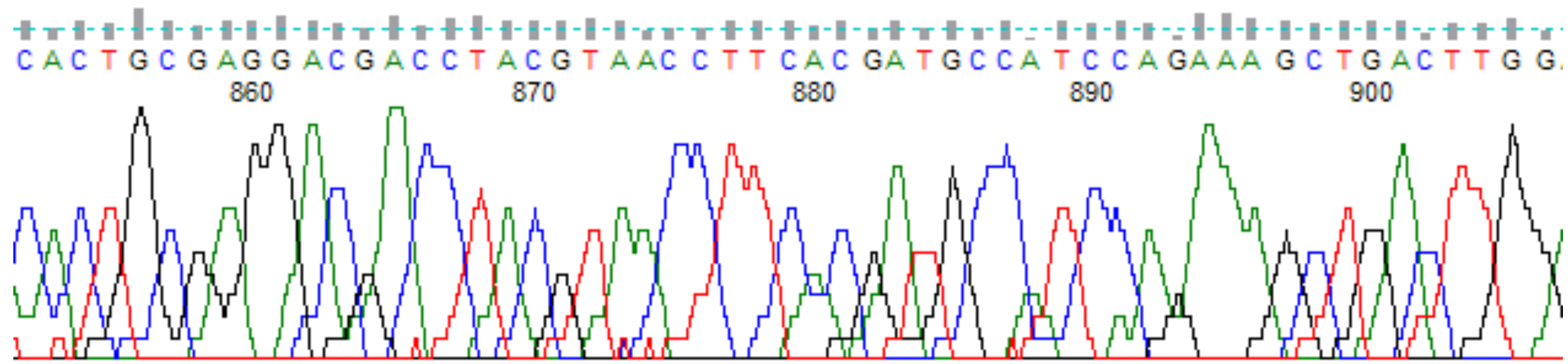
Example: EEG

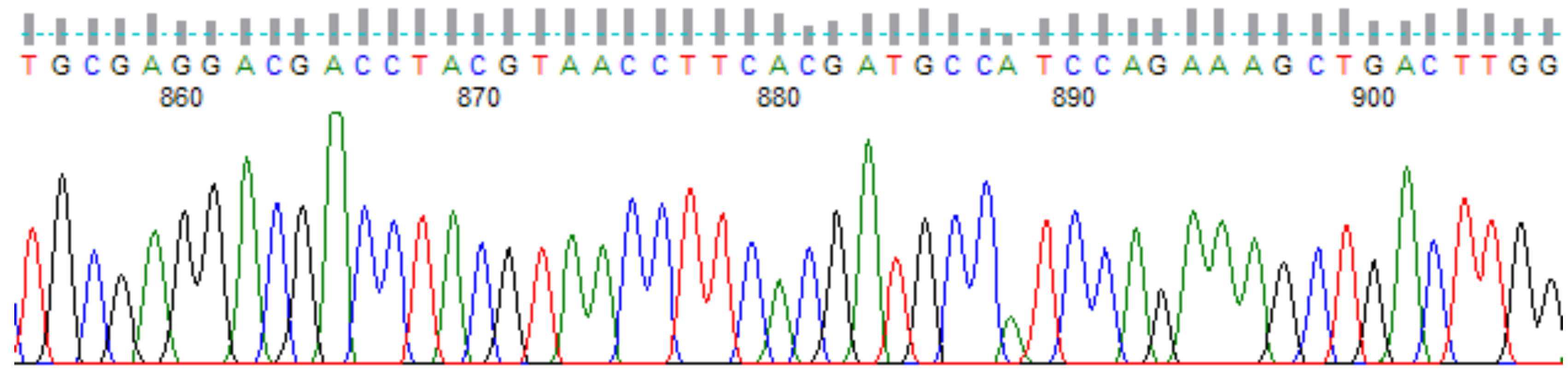




Signals

Example: Electropherogram

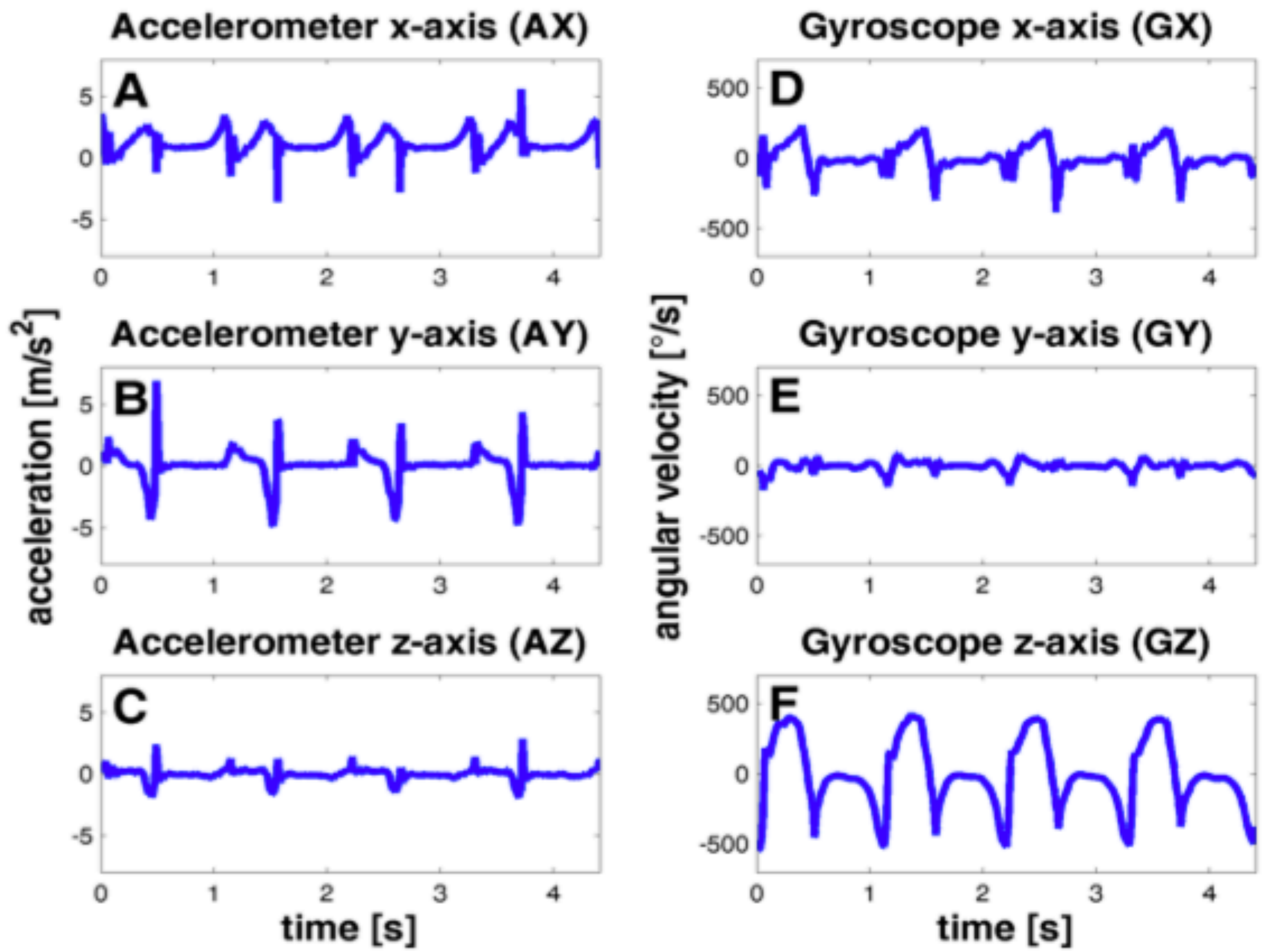




Source: https://www.nucleics.com/peaktrace/peaktrace-box-overview.html

Signals

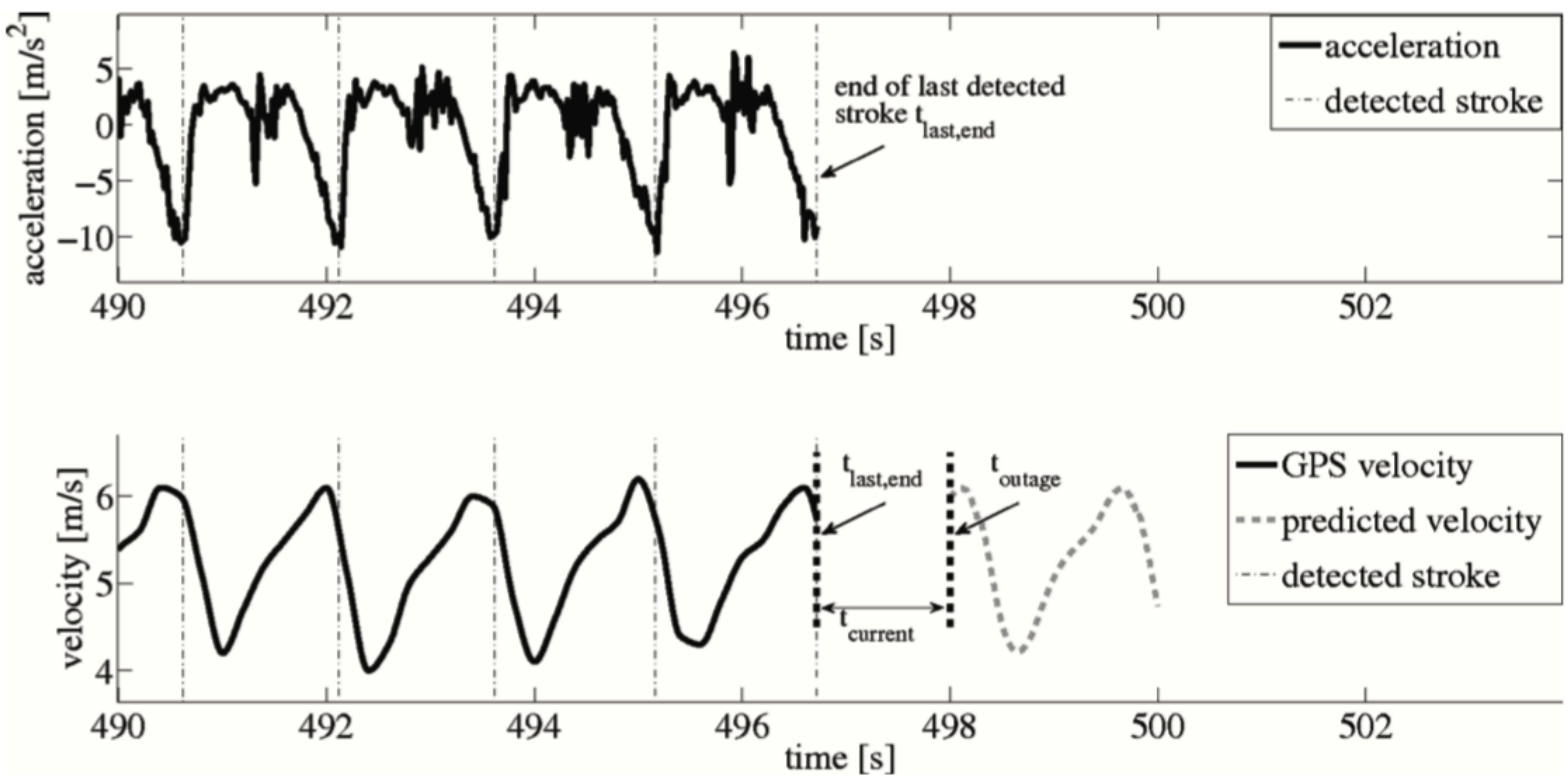
Example: 4 walking strides from an elderly



Source: doi:10.3390/s150306419

Signals

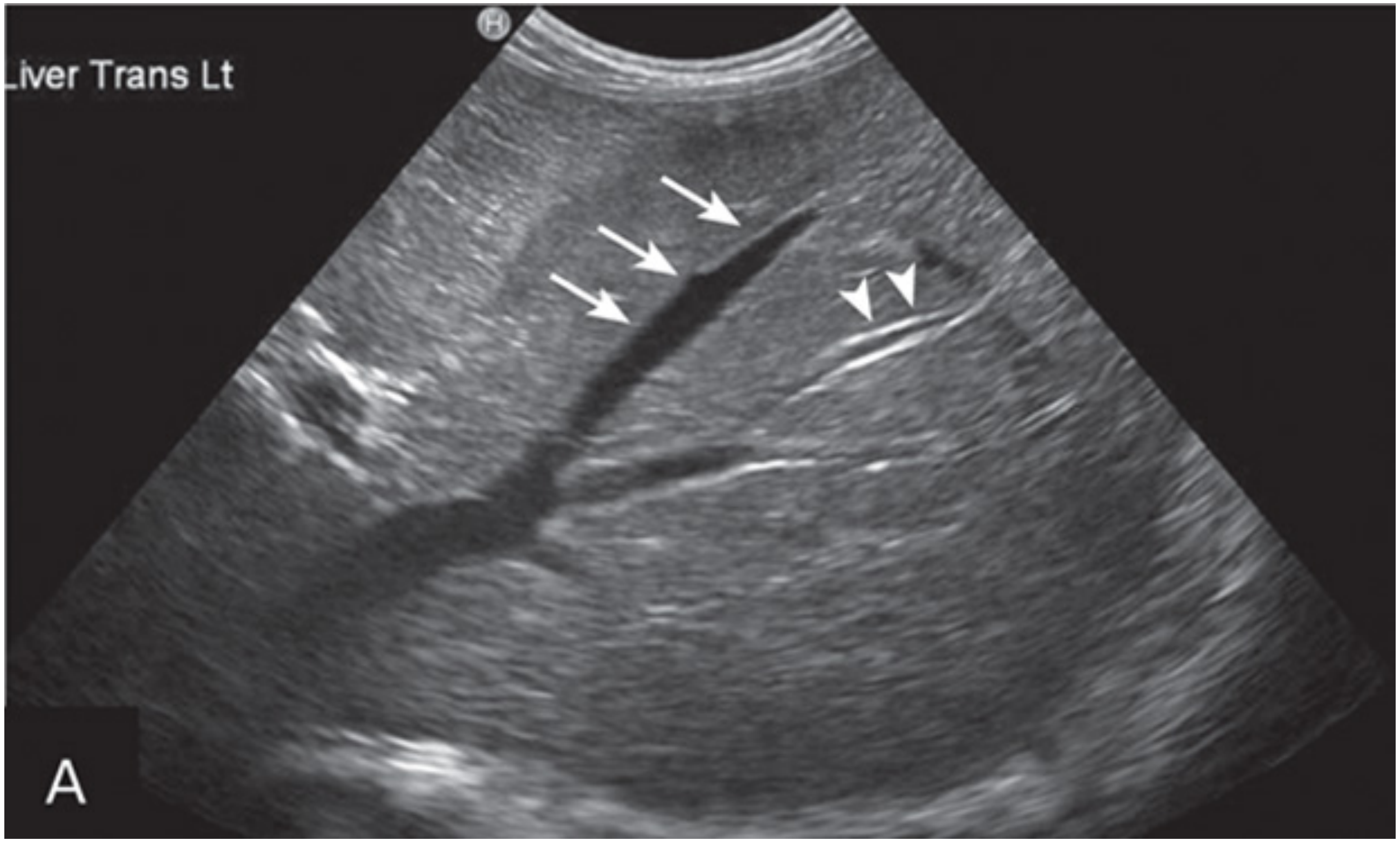
Example: Movement prediction in rowing based on stroke detection



Source: DOI: 10.1109/ISSNIP.2014.6827684

Signals

Example: Ultrasound image



Source: https://www.cliniciansbrief.com/article/liver-ultrasound-guided-fine-needle-aspiration

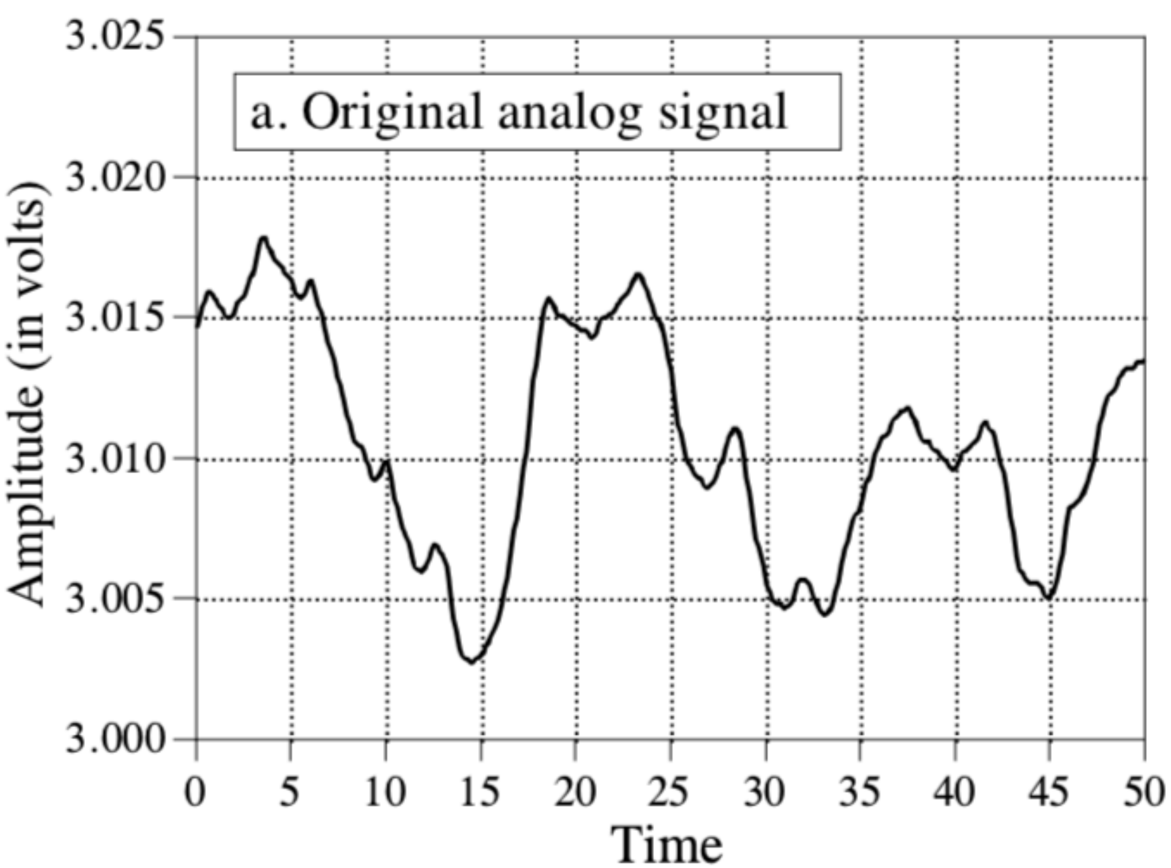
Signal as function
Real - Real

- Continuous function of real indepedent variables

- 1 dimensional: $z = f(x)$

- 2 dimensional: $z = f(x, y)$

$$z, x, y \in R$$



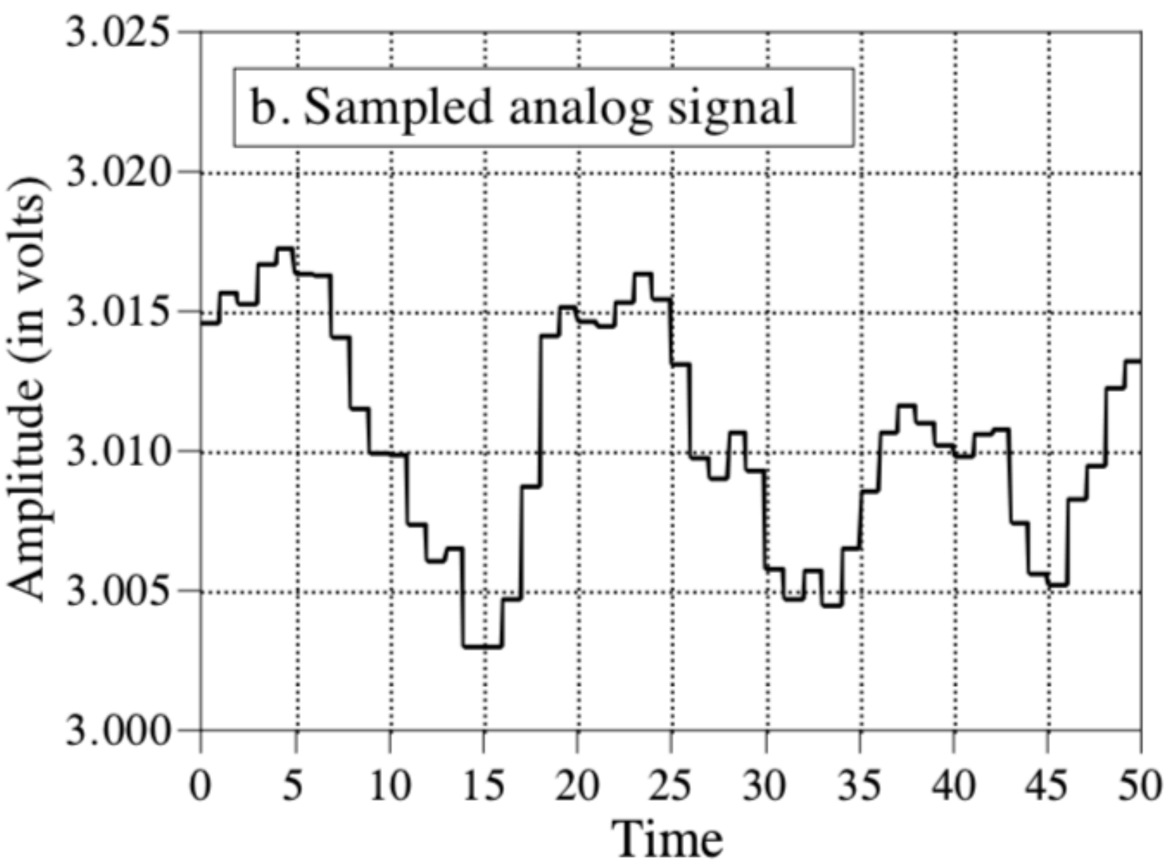
Source: "The scientist and engineer's guide to digital signal processing", by Steven W. Smith

Signal as function

Real - Discrete

- Continuous function of real indepedent variables
- 1 dimensional: $z = f[i]$
- 2 dimensional: $z = f[i, j]$

$$z \in R \qquad i, j \in Z^+$$



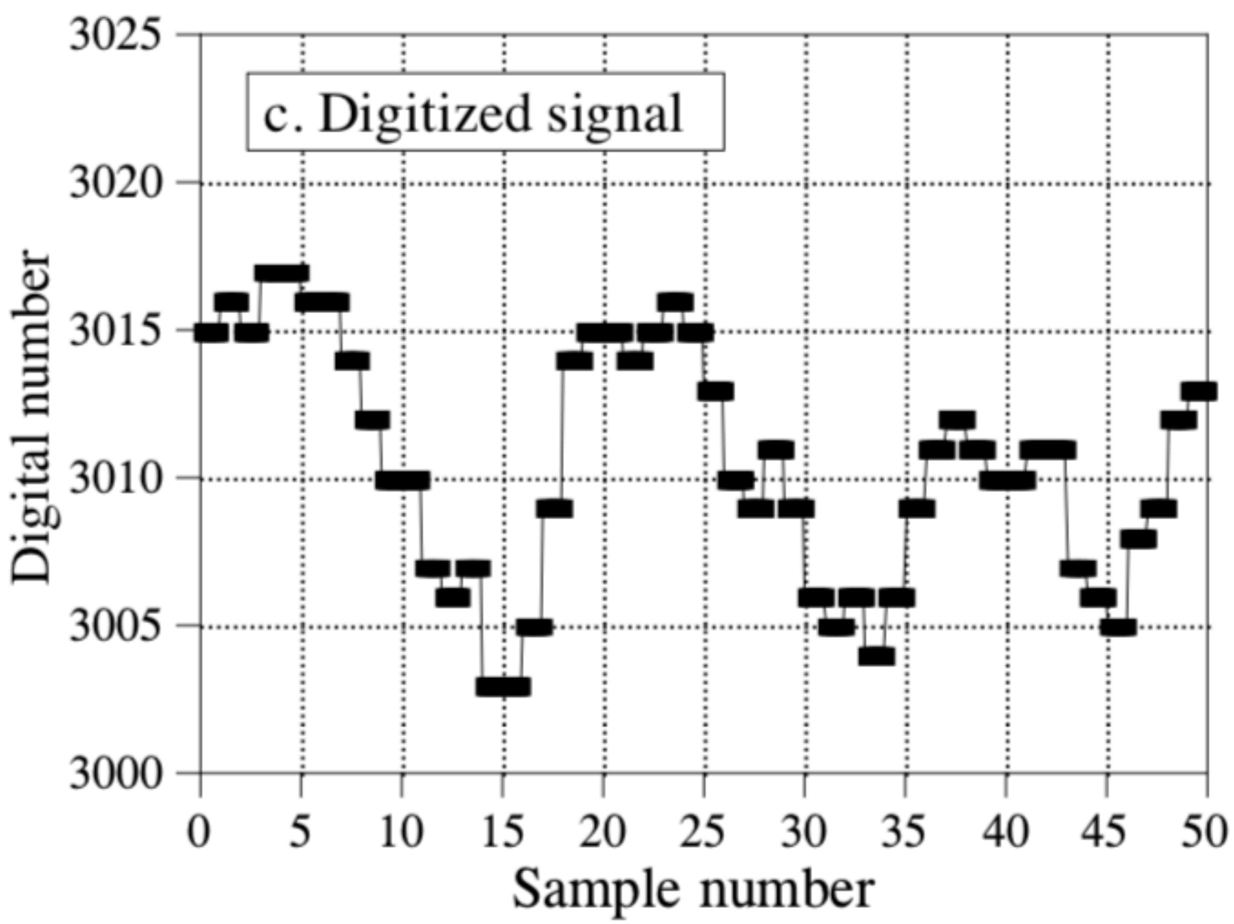
Source: "The scientist and engineer's guide to digital signal processing", by Steven W. Smith

Signal as function

Discrete - Discrete

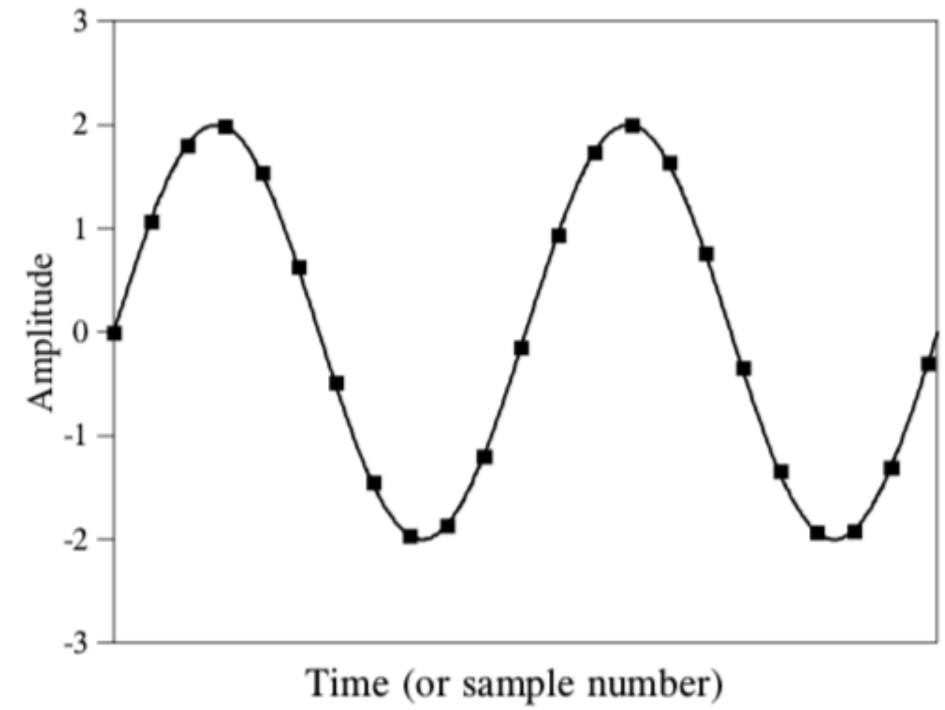
- Continuous function of real indepedent variables
- 1 dimensional: $z = f[i]$
- 2 dimensional: $z = f[i, j]$

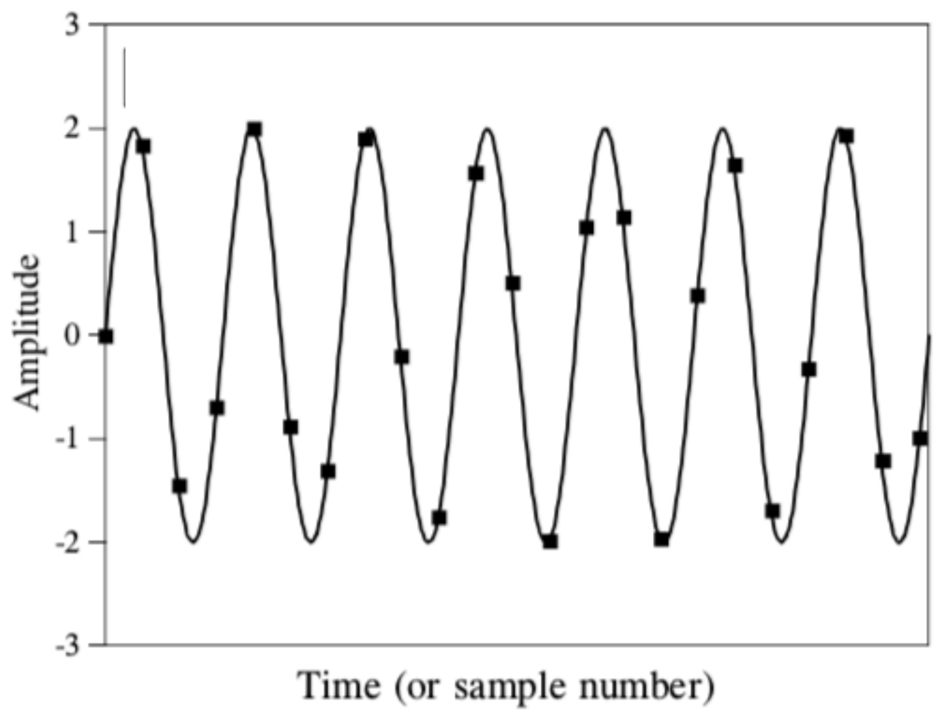
$$z \in Z \qquad i, j \in Z^{+}$$

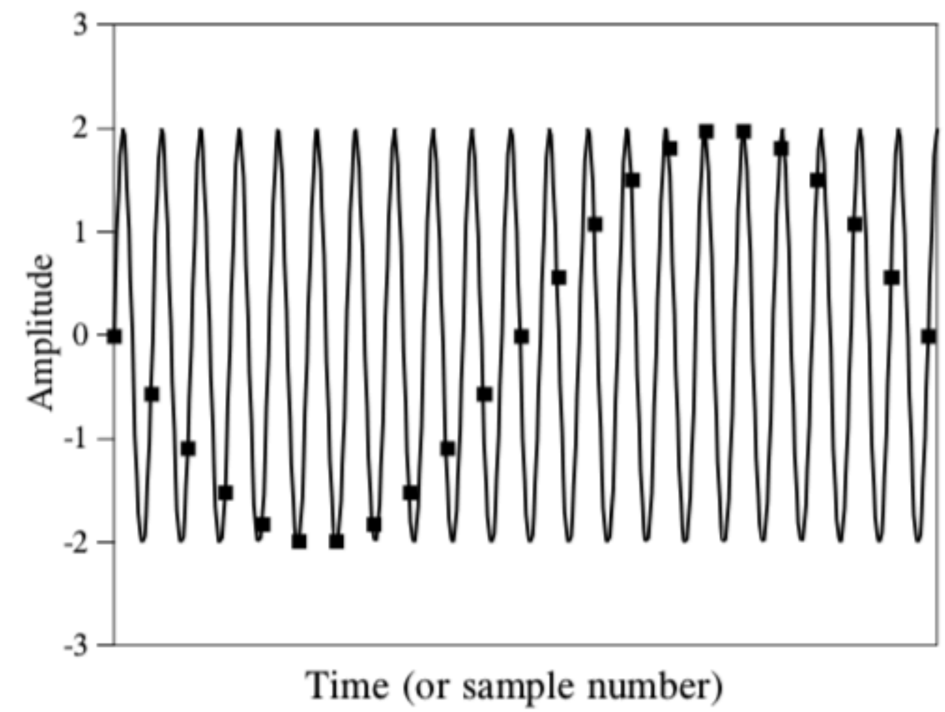


Source: "The scientist and engineer's guide to digital signal processing", by Steven W. Smith

Sampling







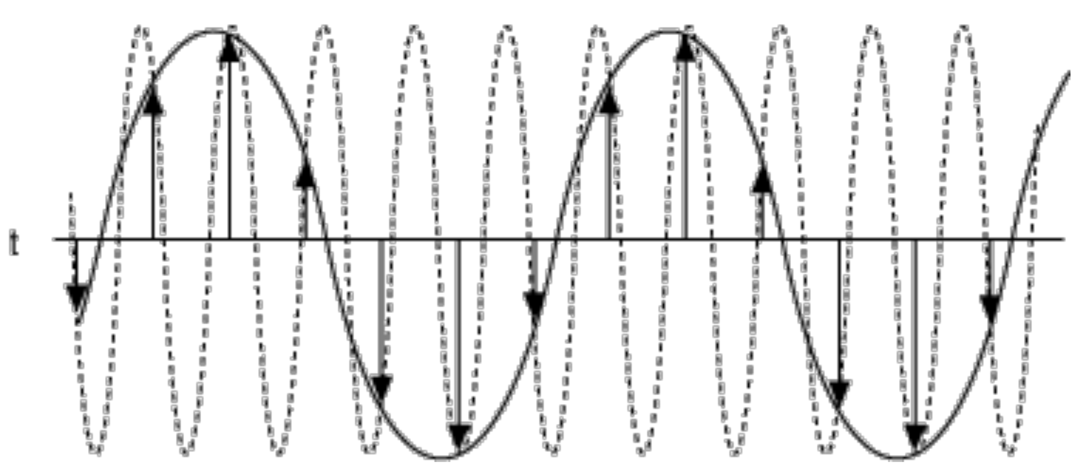
Source: "The scientist and engineer's guide to digital signal processing",
by Steven W. Smith

Nyquist-Shannon theorem

- Suppose the highest frequency component, in hertz, for a given analog signal is f_{max}.

- According to the Nyquist-Shannon theorem, the sampling rate must be at least $2f_{max}$, or twice the highest analog frequency component.

- If the sampling rate is less than $2f_{max}$, some of the ***highest frequency components*** in the analog input signal will not be correctly represented in the digitized output



Source: http://www.writeopinions.com/nyquist-ndash-shannon-sampling-theorem

Source: https://whatis.techtarget.com/definition/Nyquist-Theorem

Sampling

Example

- Wheel of a forward-moving car is seemed rotating backward when by right it should rotate forward

- Can be explained by under-sampling. If movie is filmed at 24 frames per second, but wheel rotates more than 12 times per second, under-sampling likely creates the impression of backward rotation

Source: https://www.howitworksdaily.com/question-of-the-day-why-do-car-wheels-look-like-they-are-spinning-backwards-at-high-speed/

Question

- A telephone company digitize voice by assuming a maximum frequency of 4000 Hz

- What should be the sampling rate?

Question

- A complex signal has a bandwidth of 200 kHz.

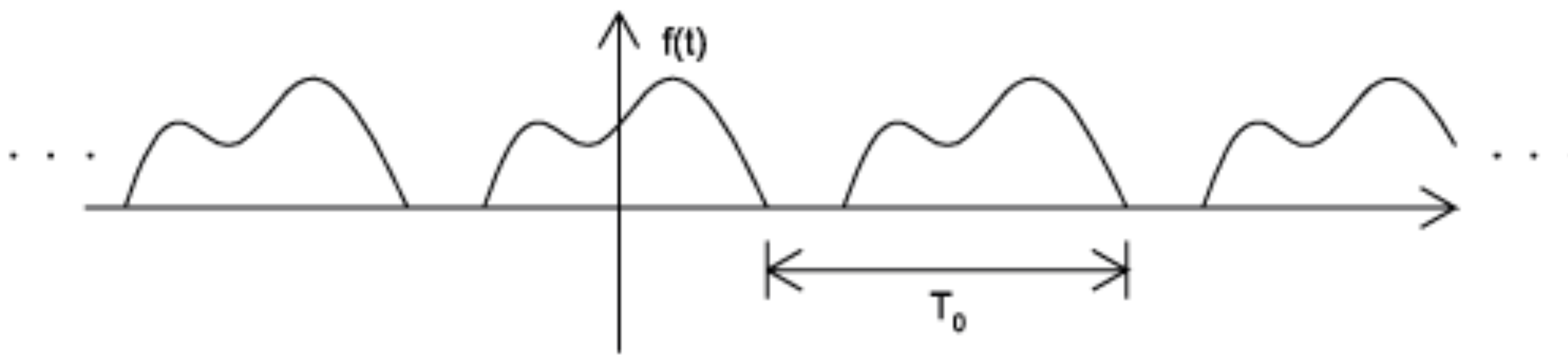
- What is the minimum sampling rate for this signal?

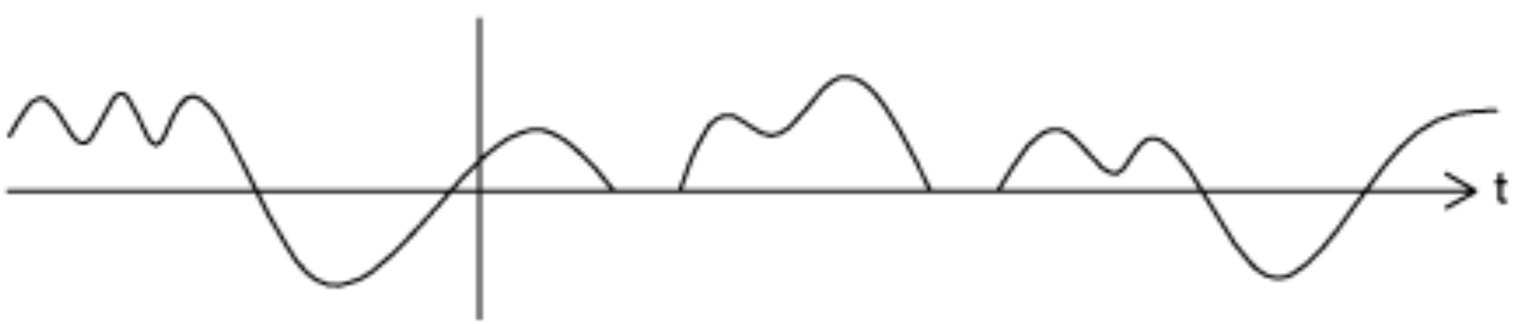
Signal types

Periodic | Aperiodic

- A signal is periodic if there exists a positive constant T_0 such that

$$f(t + T_0) = f(t) \qquad \forall t$$





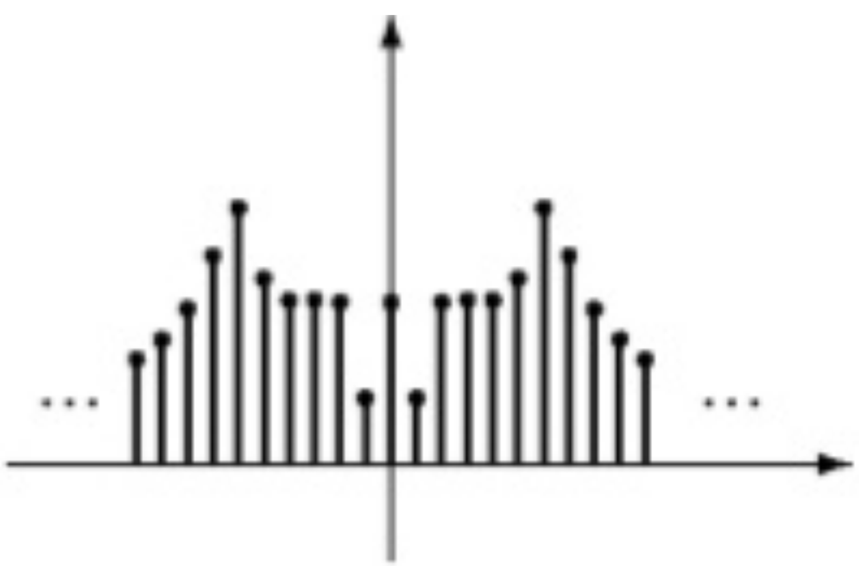
Source: http://pilot.cnxproject.org/content/collection/col10064/latest/module/m10057/latest

Signal types

Even | Odd

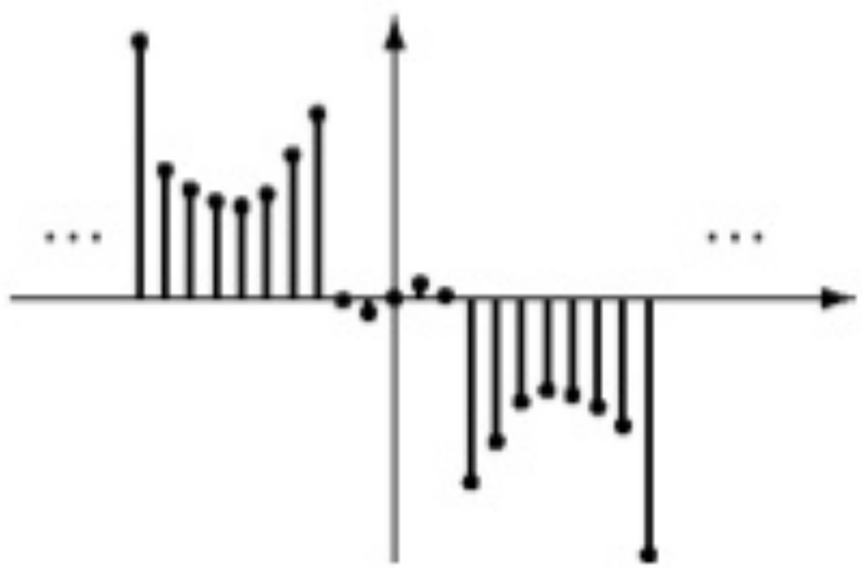
- Even signals can be easily spotted as they are symmetric around vertical axis

$$f(t) = f(-t)$$



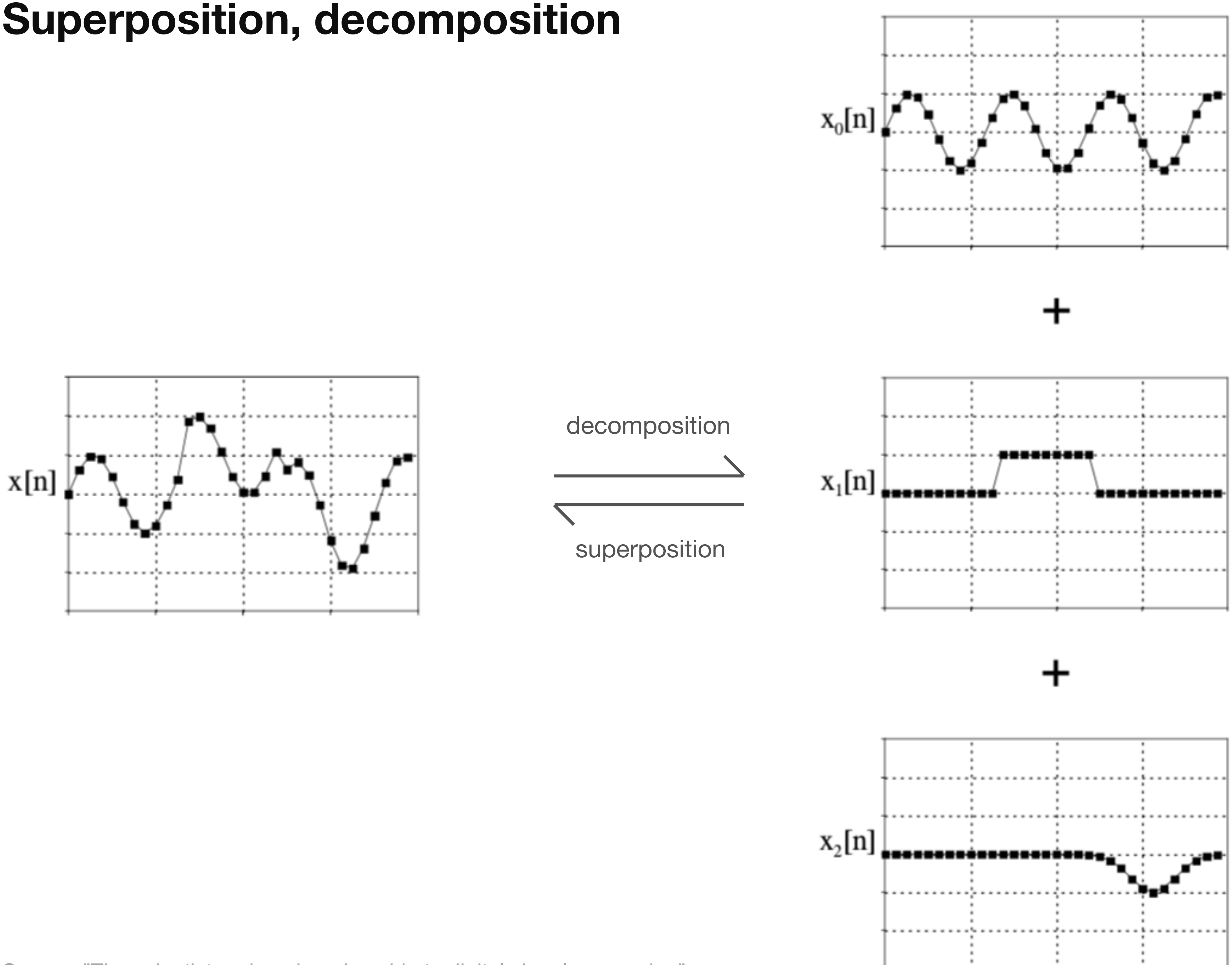
- An odd signal is a signal such that

$$f(t) = -f(-t)$$



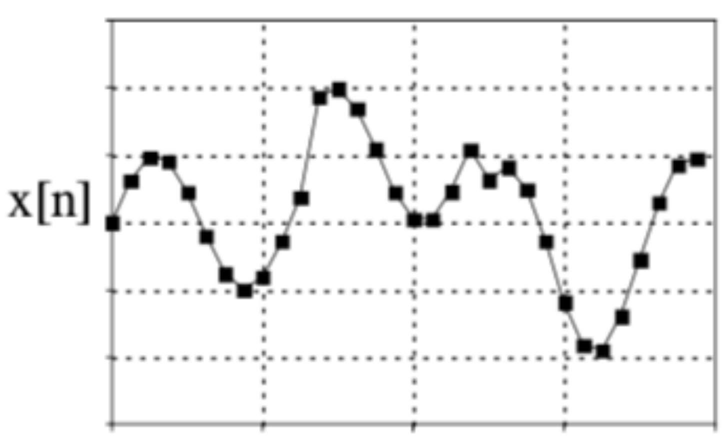
Source: https://www.slideshare.net/mihirkjain/ch1-46505880

Superposition, decomposition



Source: "The scientist and engineer's guide to digital signal processing", by Steven W. Smith

Superposition, decomposition



Source: "The scientist and engineer's guide to digital signal processing", by Steven W. Smith

- When dealing with linear systems, signals can only be combined by scaling and adding, no signal-signal multiplication
- Synthesis: The process of combining signals through scaling and addition
- The beauty of superposition: Instead of trying to understand how complicated signals behave as a whole, we study the individual components, which are simpler signals