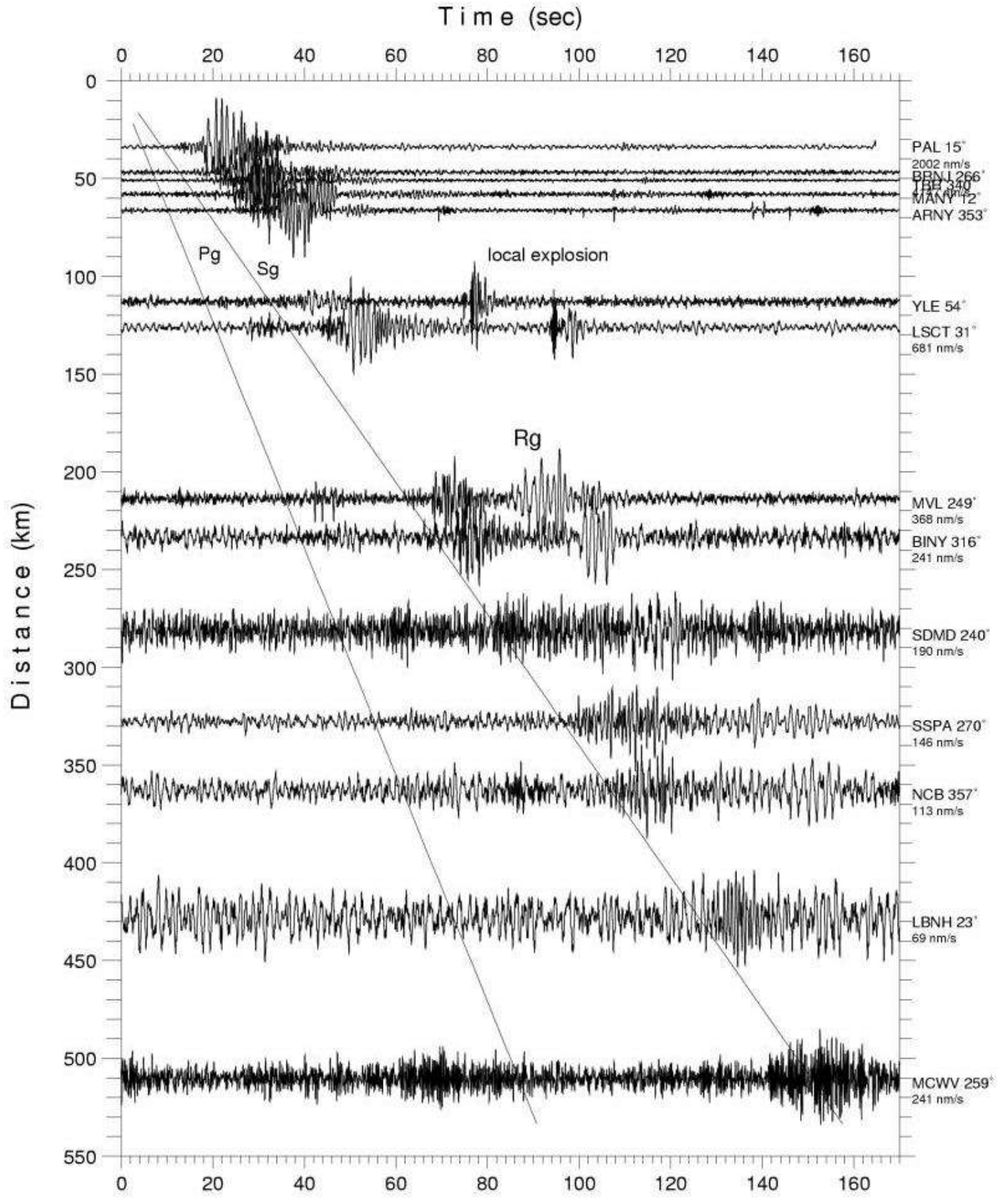
NUS-ISS
Intelligent Sensing and Sense Making

Module 1 - Introduction to intelligent sensing system

by Nicholas Ho

Let’s take at a look at some signals

Signals



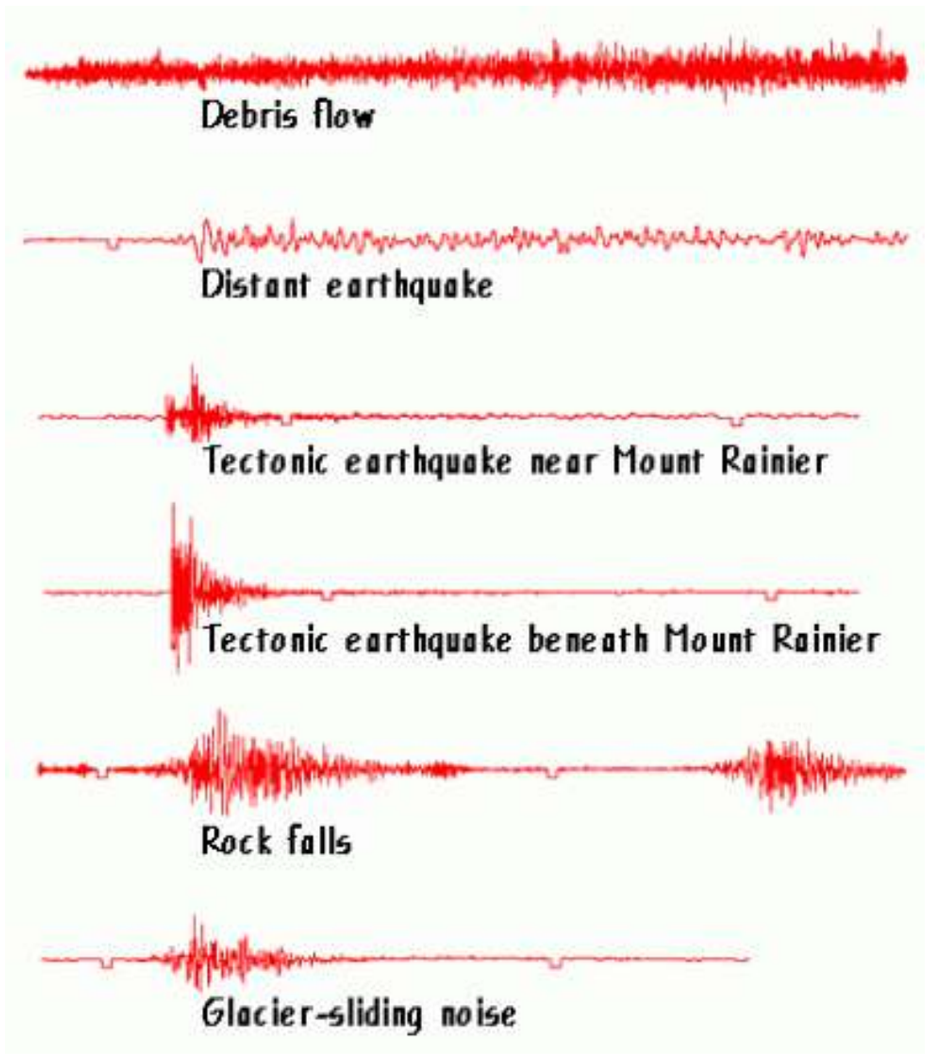
Source:
http://911research.wtc7.net/mirrors/guardian2/wtc/seismic/WTC_PENT_KIM.htm

What is signal?

- In signal processing, signal is a function that conveys information about a phenomenon

- A signal can also be defined as an observable change in a quantity (property)

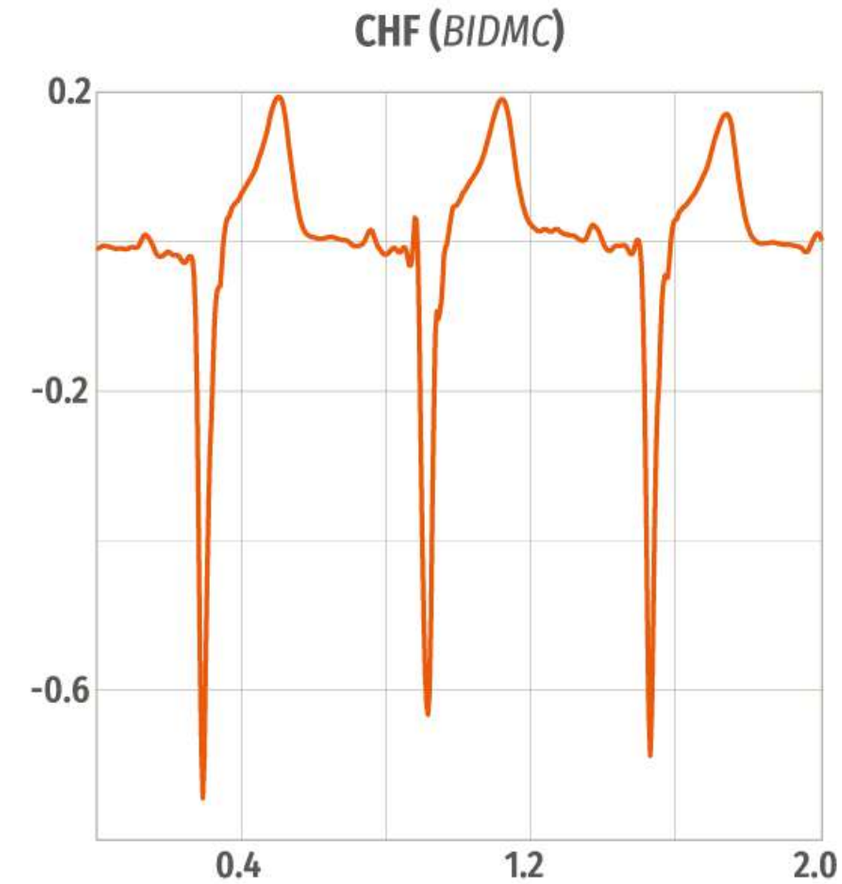
- Any physical quantity that exhibits variation in space or time can be a signal



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

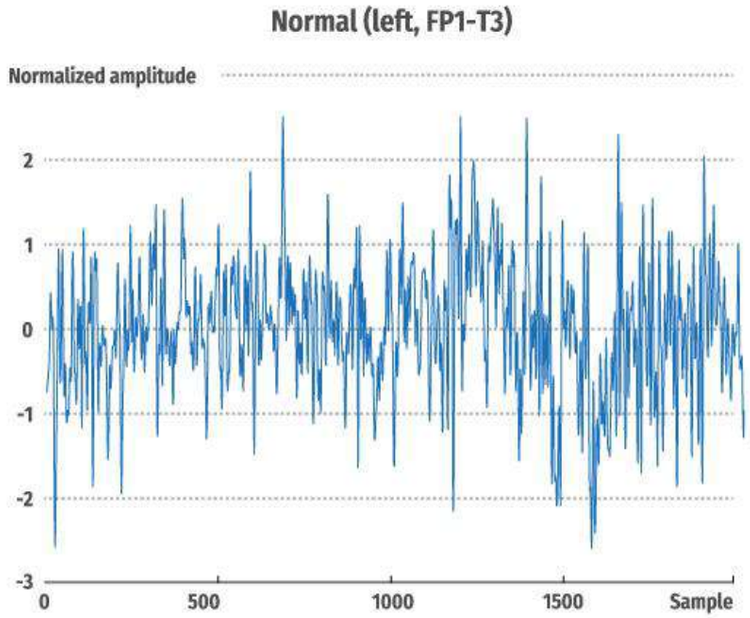
Signals

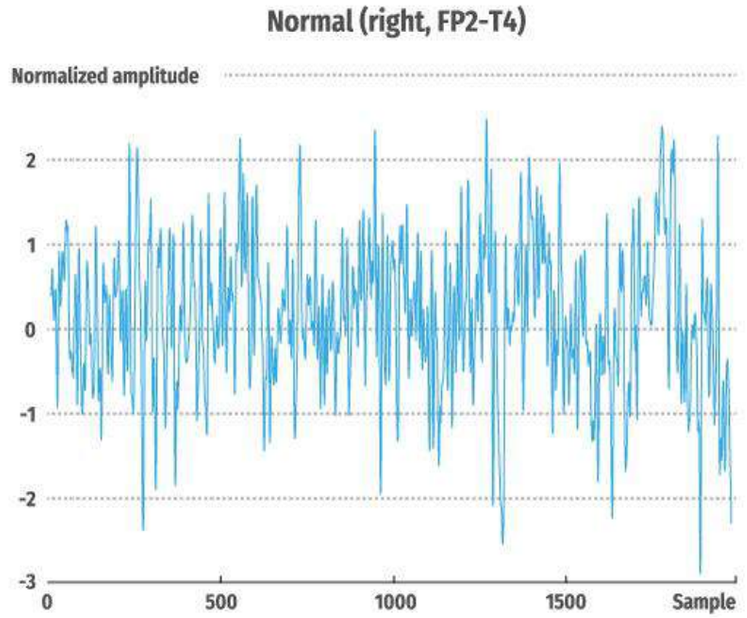
Example: ECG

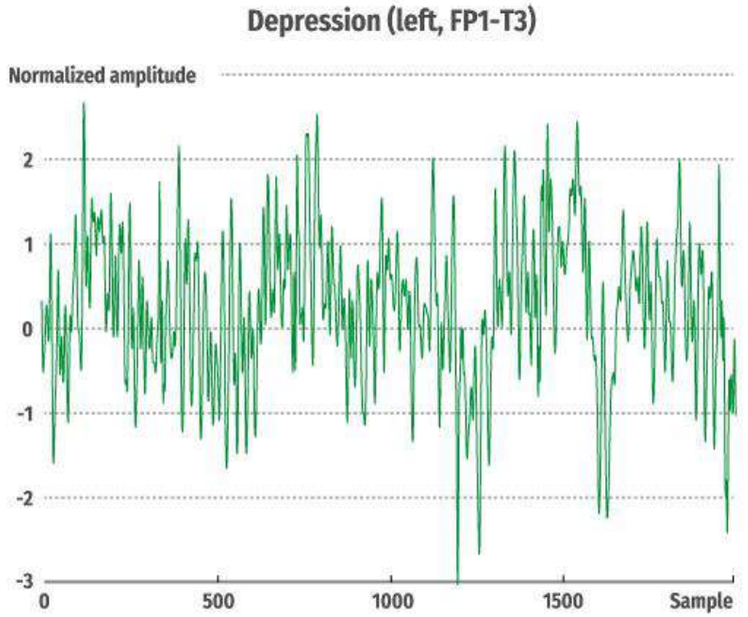


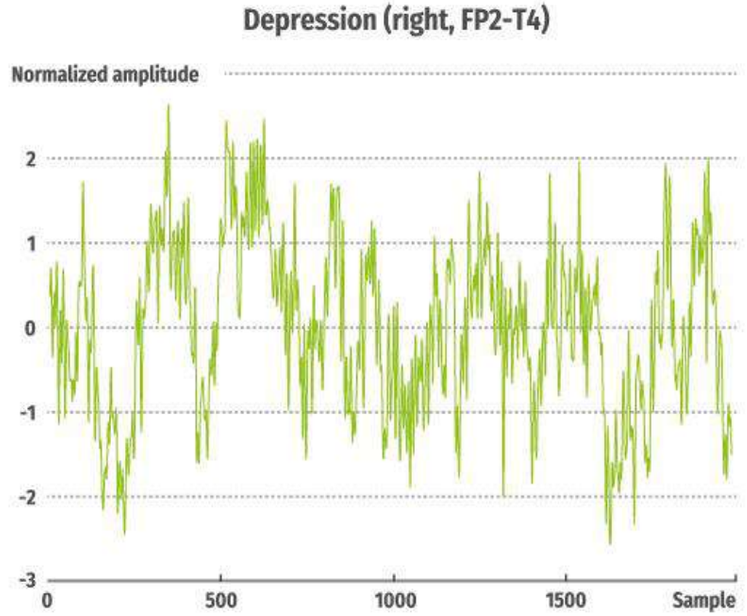
Signals

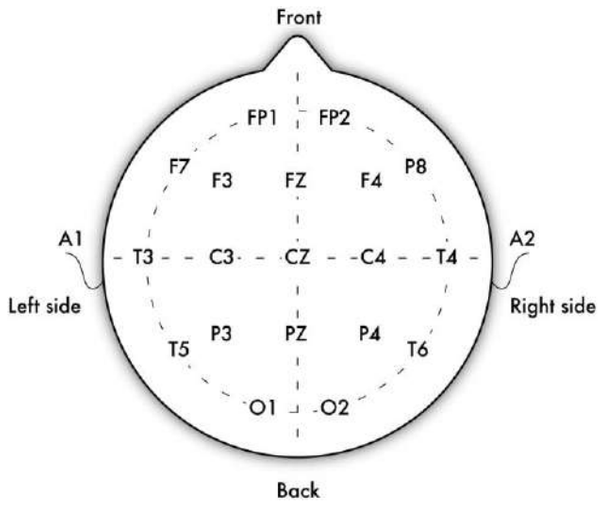
Example: EEG





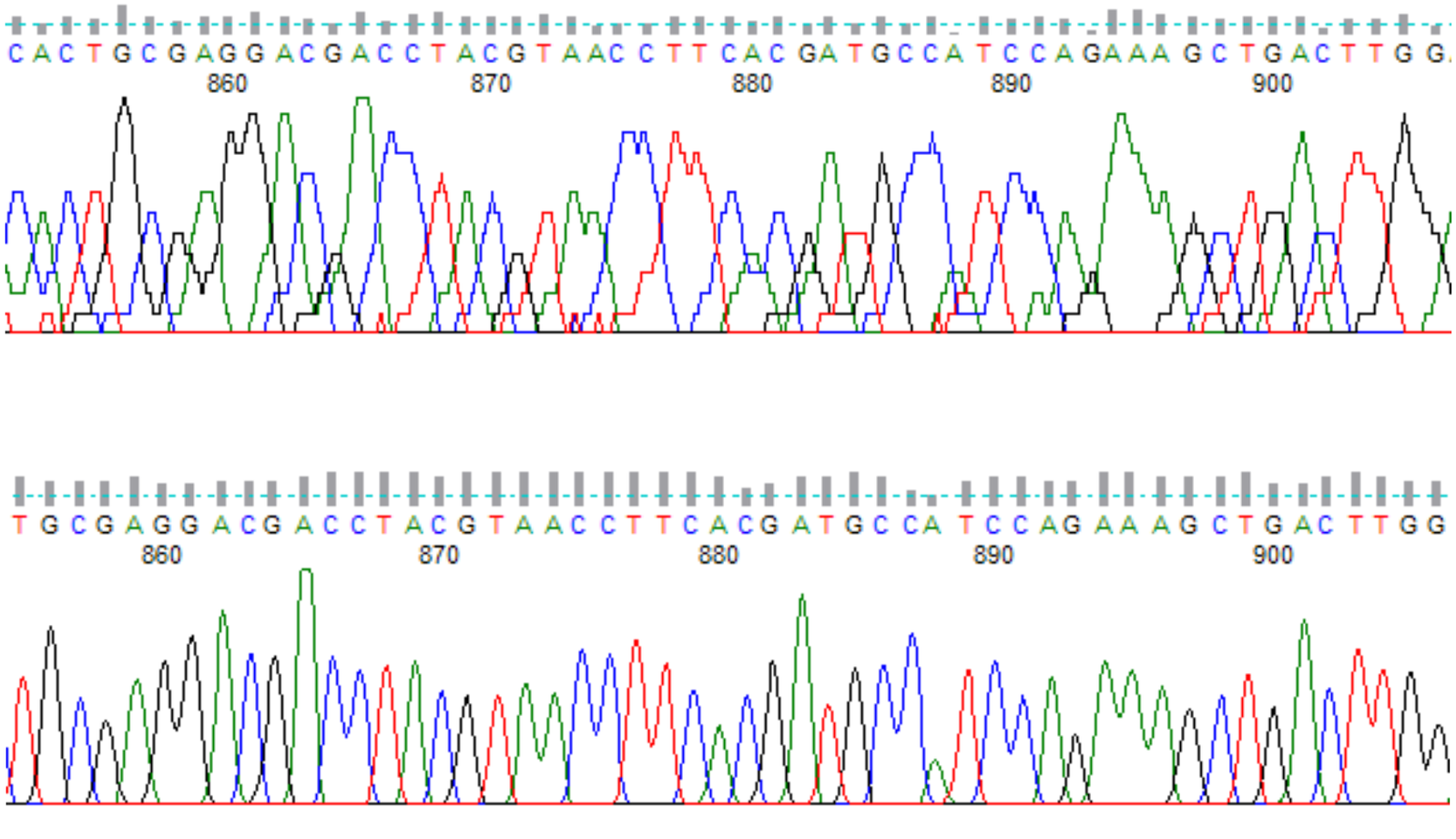






Signals

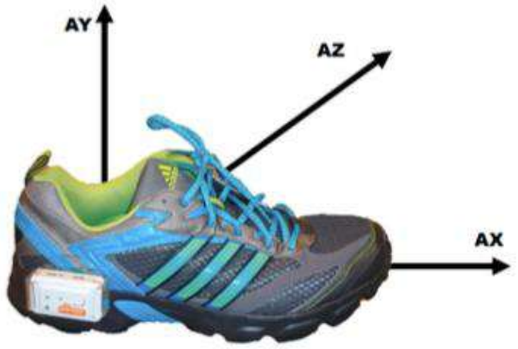
Example:
Electropherogram

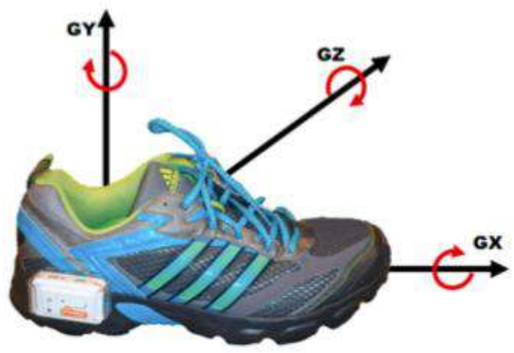


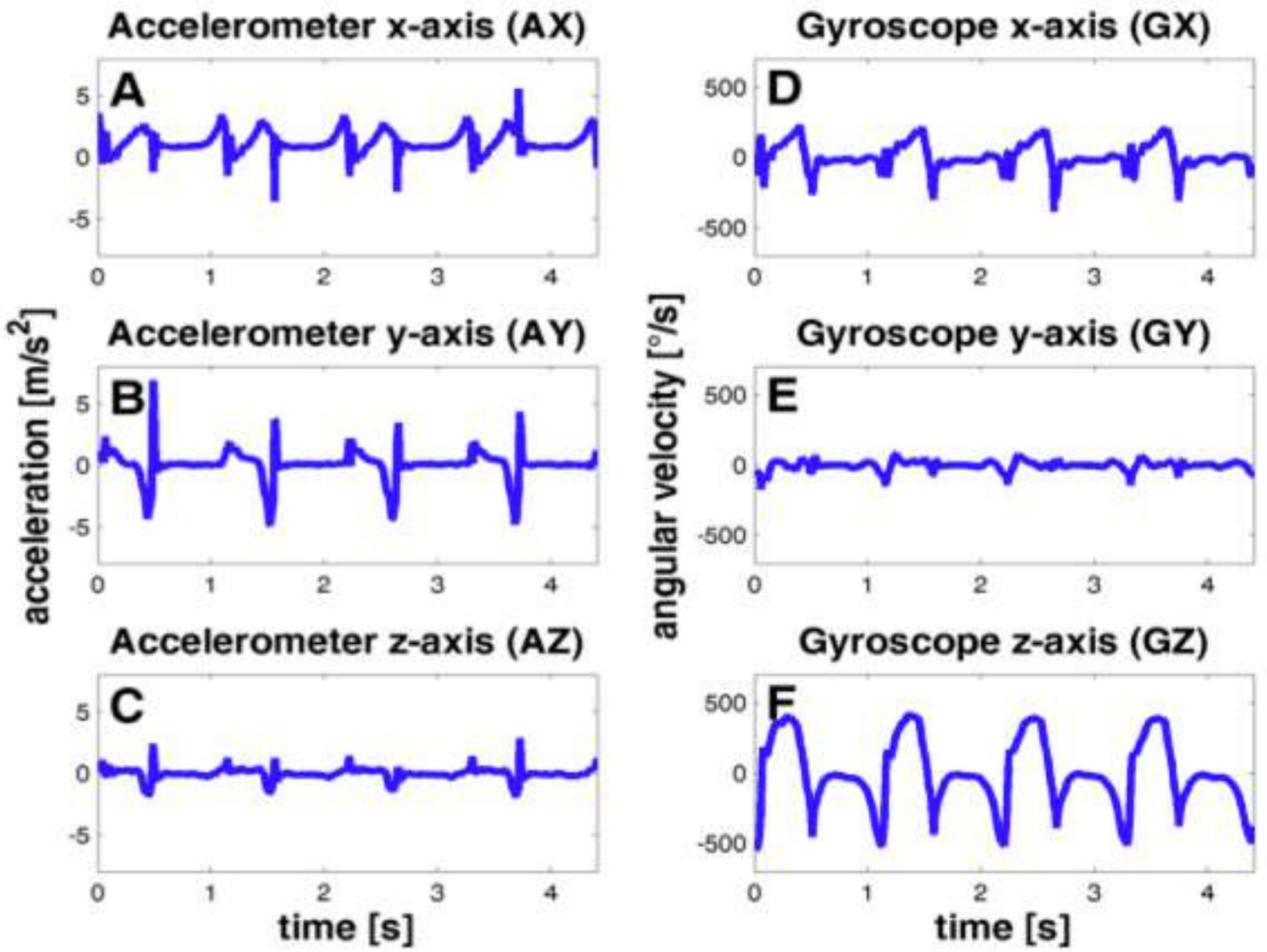
Source: https://www.nucleics.com/peaktrace/peaktrace-box-overview.html

Signals

Example: 4 walking strides from an elderly



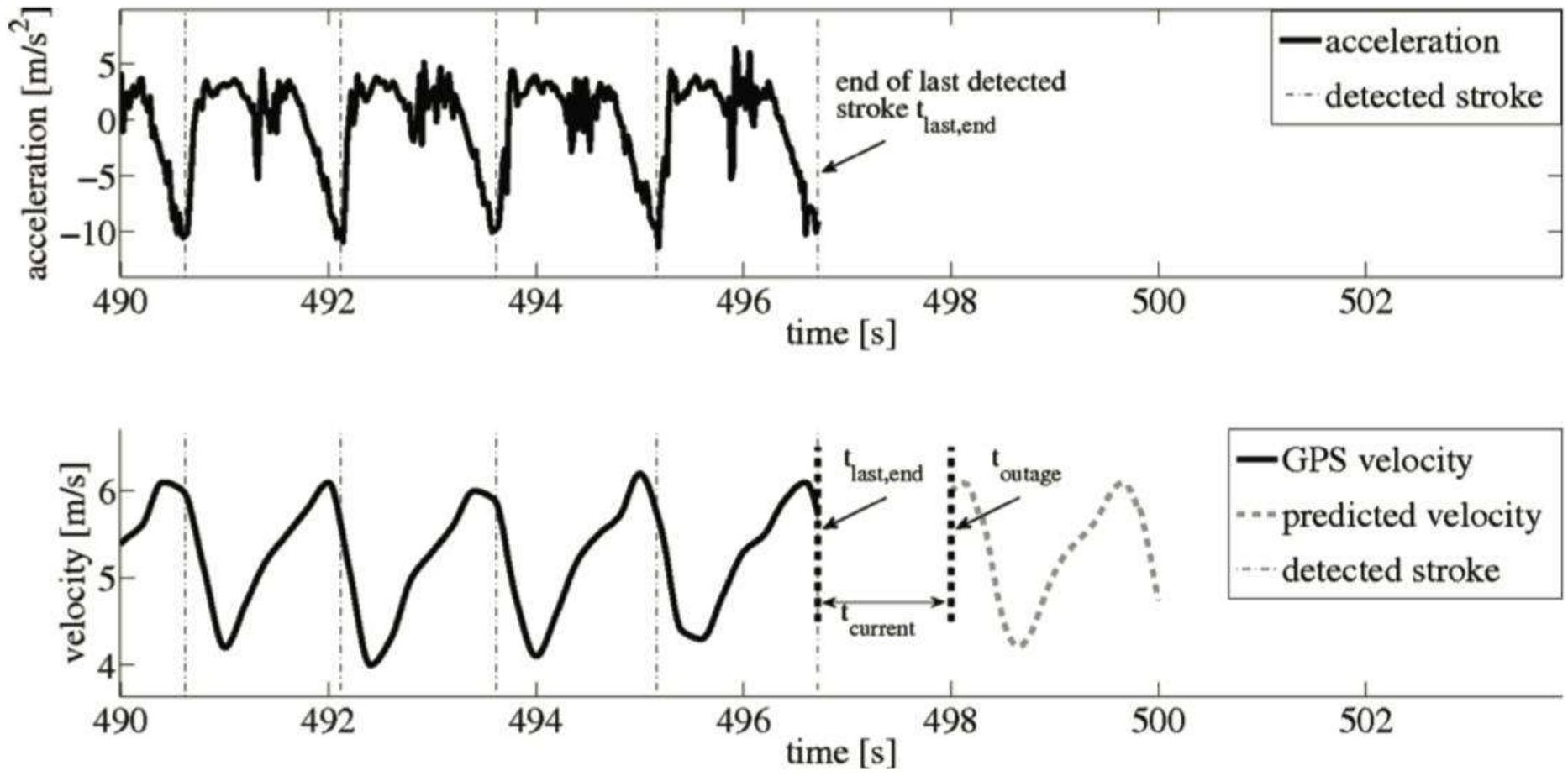




Source: doi:10.3390/s150306419

Signals

Example: Acceleration and velocity in rowing



Source: DOI: 10.1109/ISSNIP.2014.6827684

Signals

Example: Ultrasound image

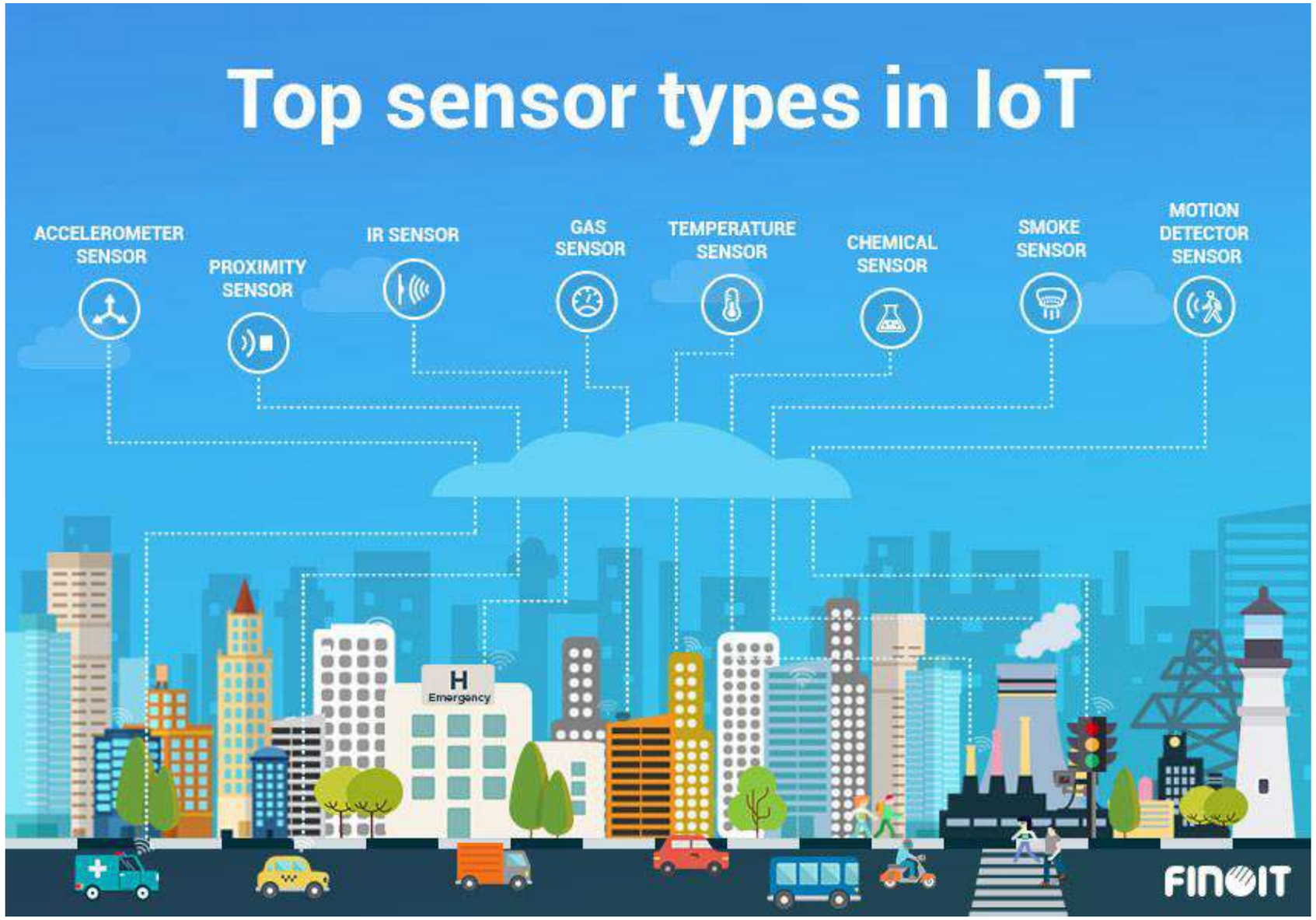
Source: https://www.cliniciansbrief.com/article/liver-ultrasound-guided-fine-needle-aspiration

Sensors that produce signals

Signals

Sensors are getting more and more important to make the world ‘smart’

"One way to think of IoT is second phase of internet", by The Economist



Source: https://www.finoit.com/blog/top-15-sensor-types-used-iot/

Sensors

Temperature sensors

Source: https://icon-library.net/icon/temperature-sensor-icon-19.html

- Function: measure amount of heat energy that allows to detect a physical change in temperature from a particular source
- In early days mostly used in Aircon, refrigerators
- Now, Manufacturing: as some machines require specific environment temperature, need monitoring
- Now, agriculture: soil temperature is crucial for crop growth; helps with plants production, maximizing output

Source: https://www.finoit.com/blog/top-15-sensor-types-used-iot/

Sensors

Proximity sensors

- Function: detects the presence or absence of a nearby object, or properties of that object without getting in contact with them.
- Used in vehicles a lot, also for parking availability
- In retail industry, detect motion and the correlation between customer and the product they are interested in
- Some sensors specifically detect metallic objects

Source: https://icon-library.net/icon/proximity-icon-6.html

Source: https://www.finoit.com/blog/top-15-sensor-types-used-iot/

Sensors

Pressure sensors

- Function: sense pressure and converts it into electric signal
- Often used to check if pressure deviates from standard range
- Useful in manufacturing
- Useful in maintenance / monitoring of whole water systems and healting systems, as it is easy to detect any fluctuation or drops in pressure

Source: https://www.123rf.com/profile_vectori1

Source: https://www.finoit.com/blog/top-15-sensor-types-used-iot/

Sensors

Water quality sensors

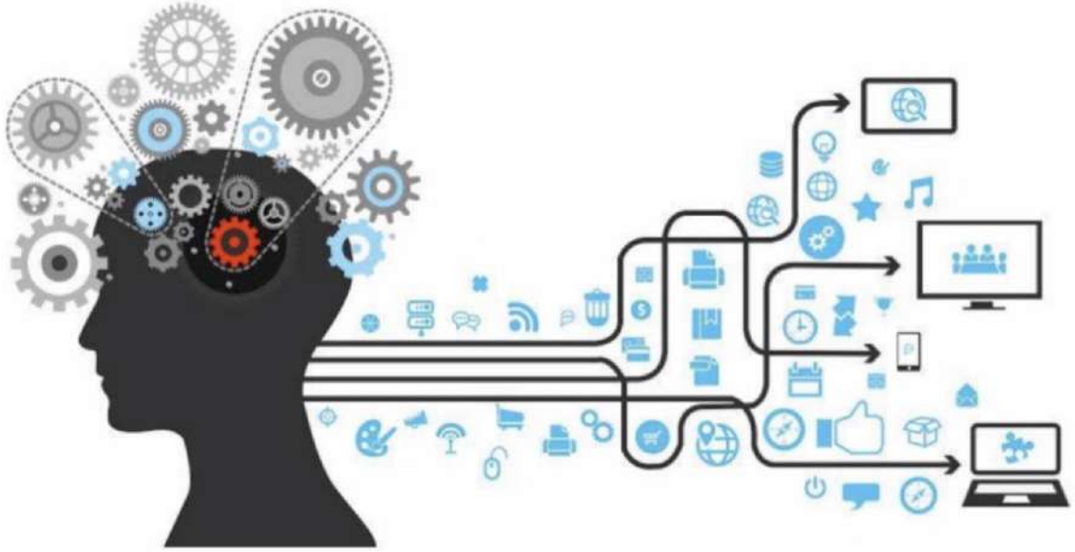
- Function: monitor water quality and ion
- Chlorine residual sensor: measure chlorine residual
- Total organic carbon sensor: measure organic element in water
- Turbidity sensor: measure suspended solids in water, typically used in river
- pH sensor: measure pH level in water

Source: https://stock.adobe.com/sg/contributor/207708434/anton-shaparenko

Source: https://www.finoit.com/blog/top-15-sensor-types-used-iot/

More than data

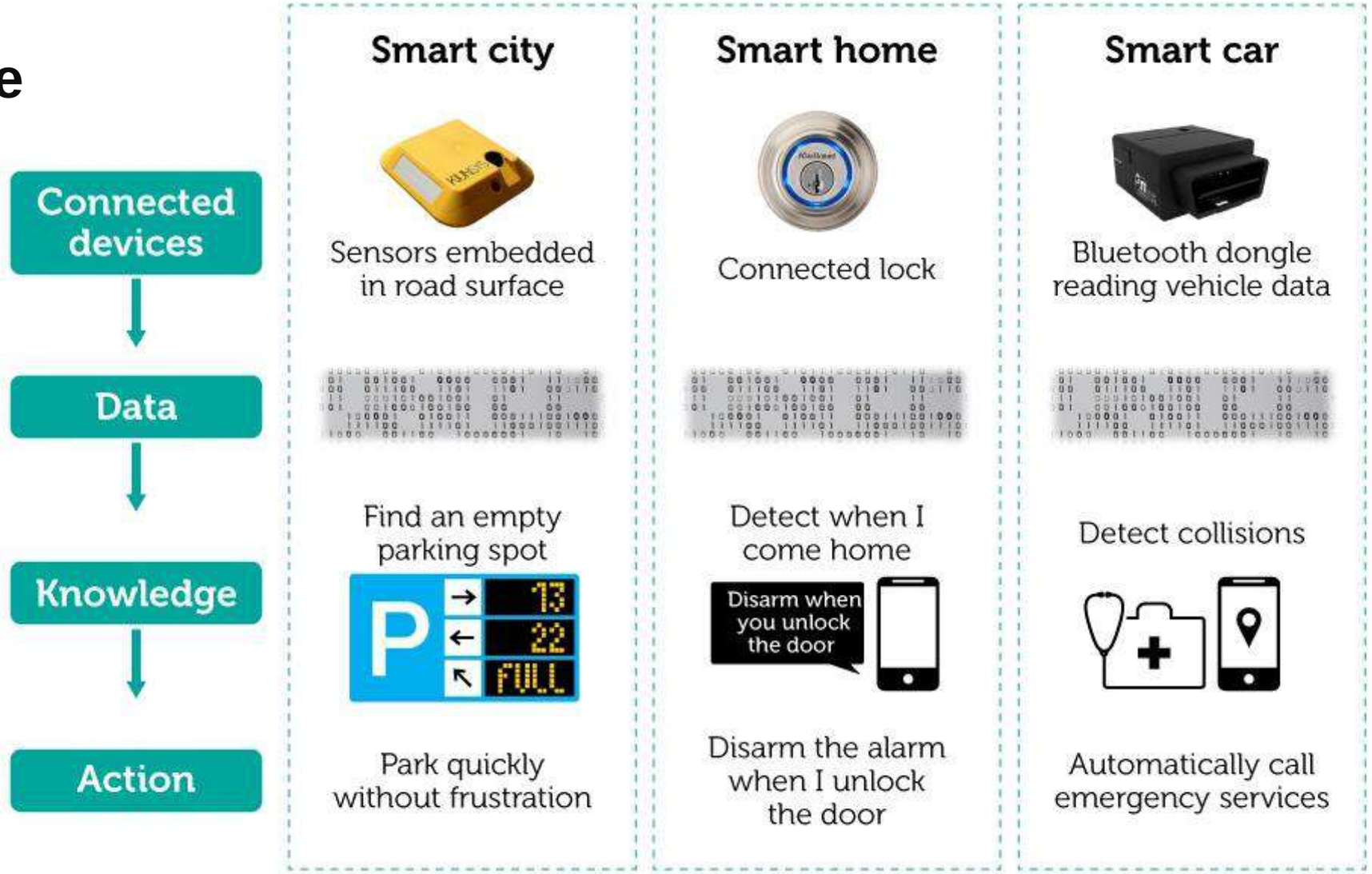
Intelligent sense making



- Signals are just ….. numbers
- Need to extract useful information from signal - making sense out of the signal
- Understand the underlying events that produce the signals, then make prediction, or take action, or suggest possible actions
- Create values for user and customer

Source: https://www.slideshare.net/muralidhar9s/data-analytics-for-iot

Value is created by making sense of data



Source: vmob.me/IoT

Group exercise

Suggest an example on intelligent sense making.

Avoid re-use any examples given in the lecture notes.

Refer to the given "use case exercise" template with some examples in it.

You are to describe clearly:

(a) how the sensor(s) is used/deployed and what is the acquired signal,

(b) what are the findings you are looking for from the signal

(c) what are the possible actions after the finding

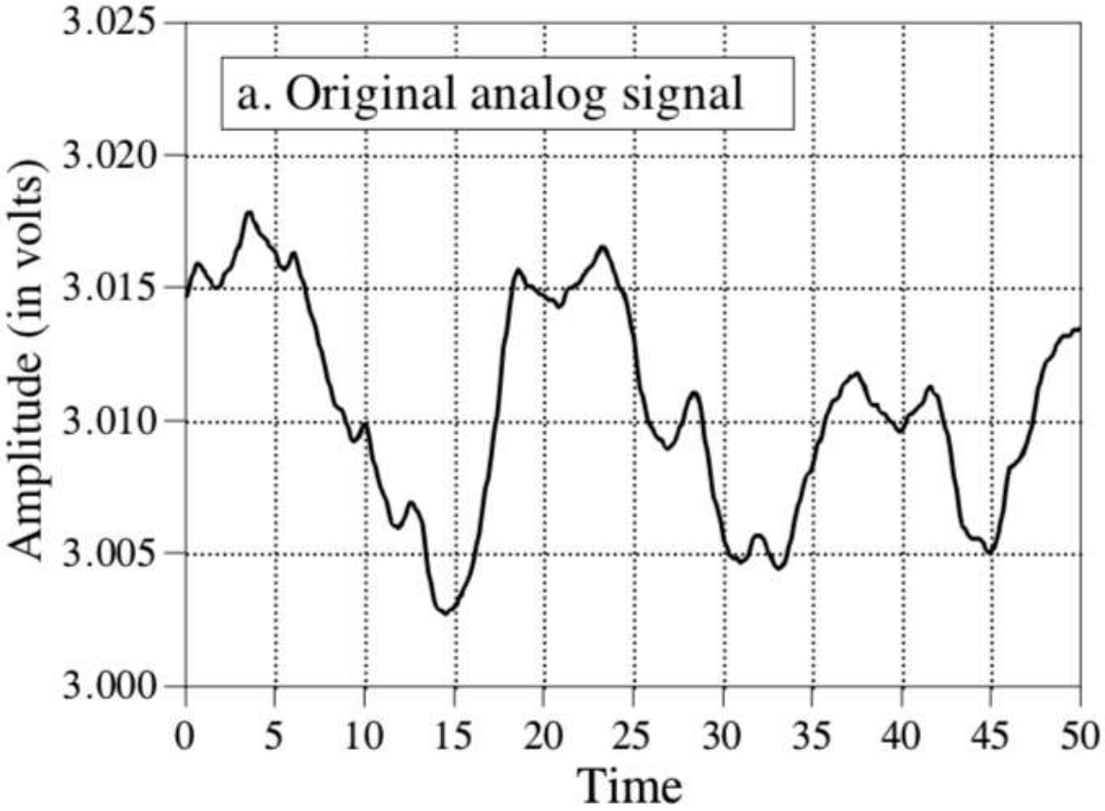
Fundamentals of signals

Signal as function

Real - Real

- Continuous function of real indepedent variables
- 1 dimensional: $z = f(x)$
- 2 dimensional: $z = f(x, y)$

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



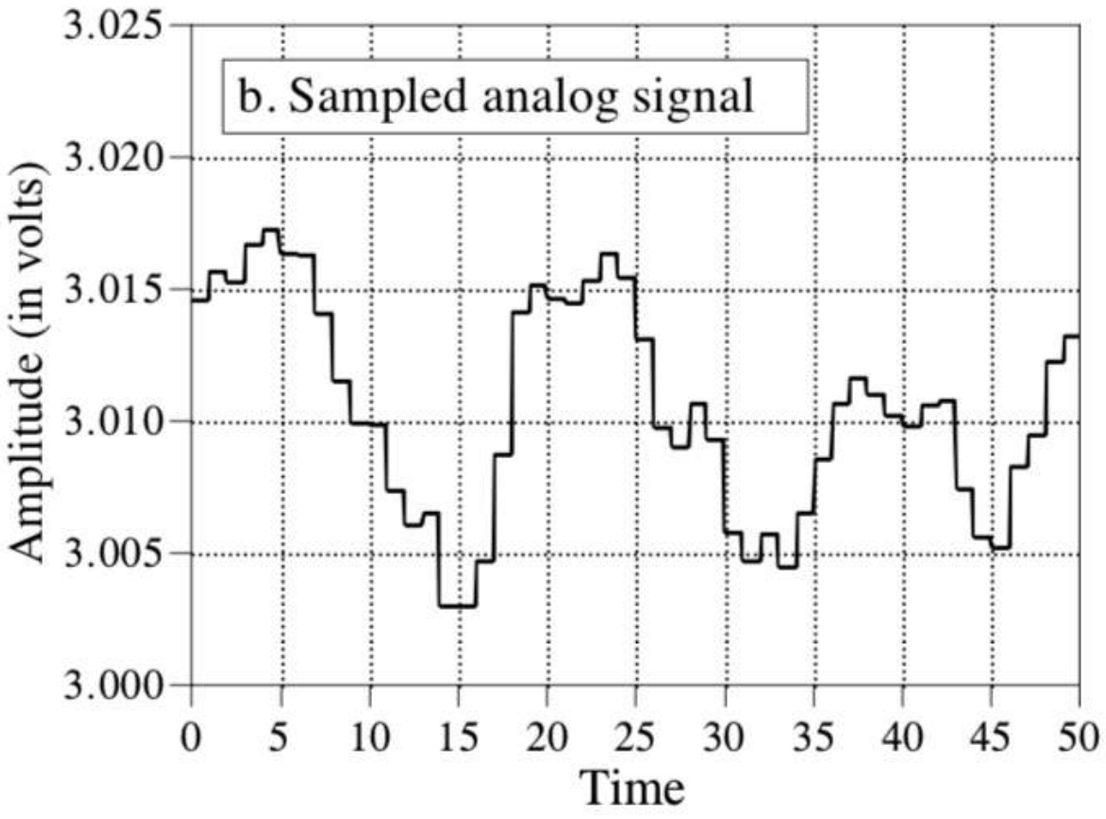
Source: "The scientist and engineer's guide to digital signal processing", by Steven W. Smith

Signal as function

Real - Discrete

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

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



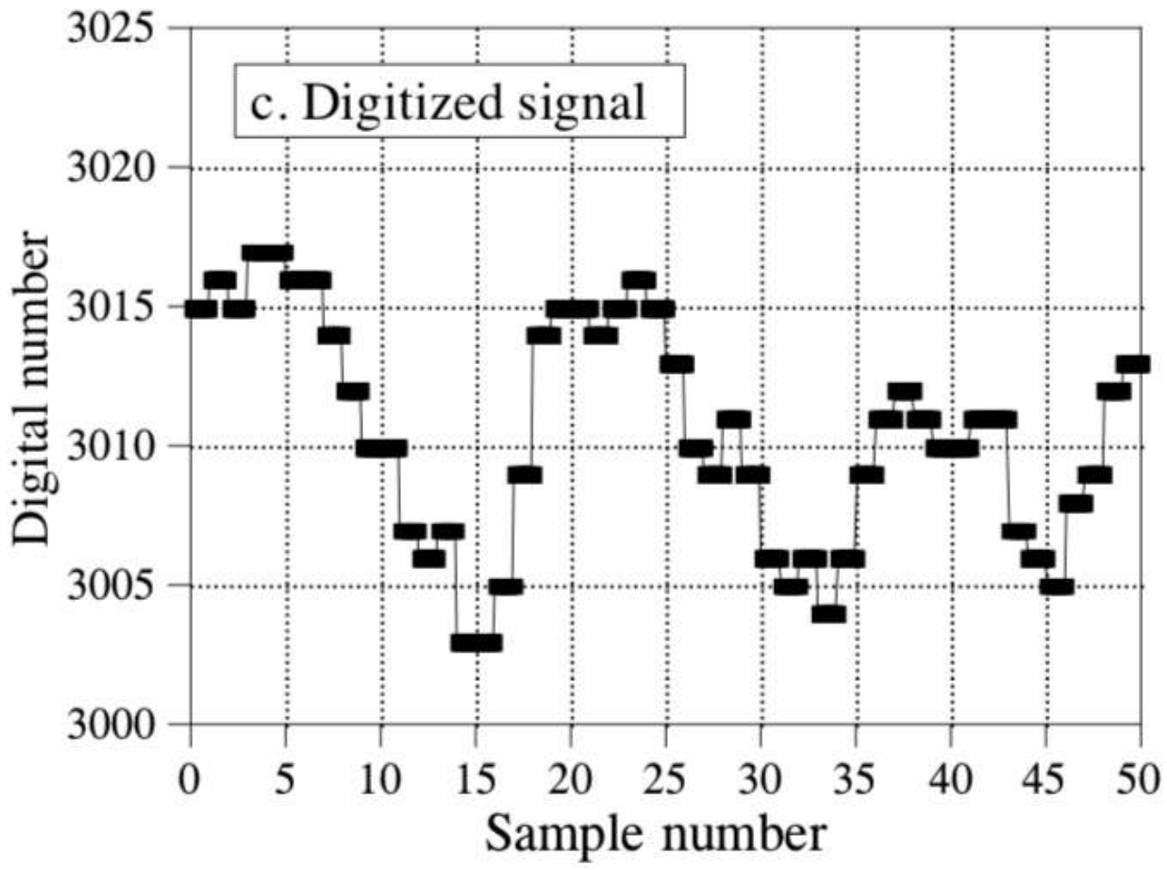
Source: "The scientist and engineer's guide to digital signal processing", by Steven W. Smith

Signal as function

Discrete - Discrete

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

$z \in Z$ $\quad$ $i, j \in Z^+$



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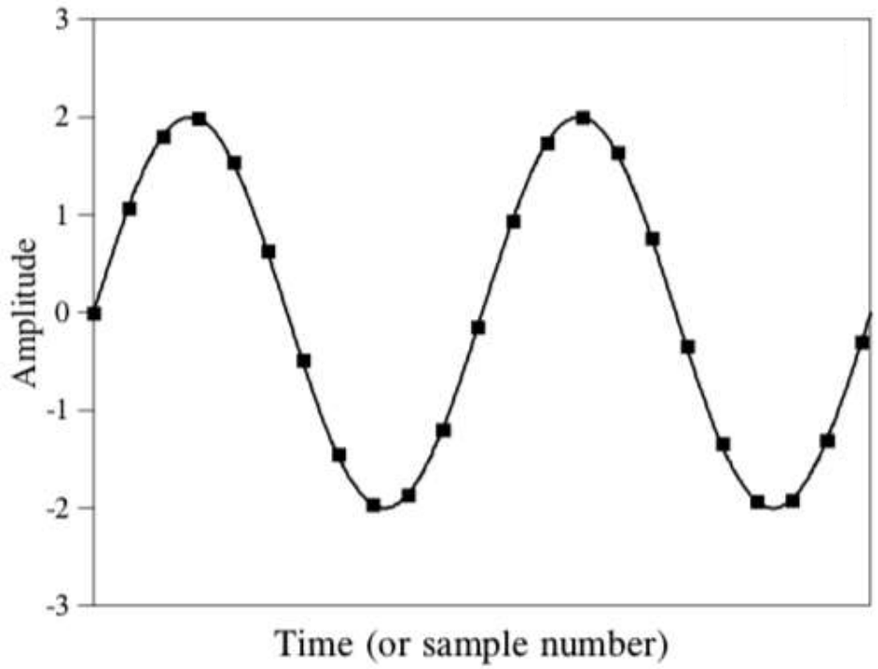
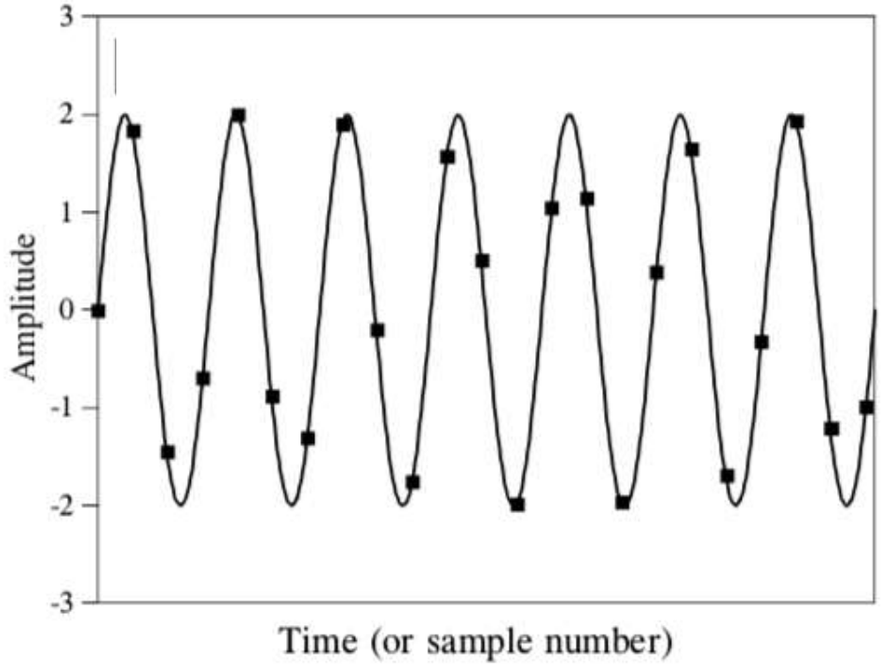
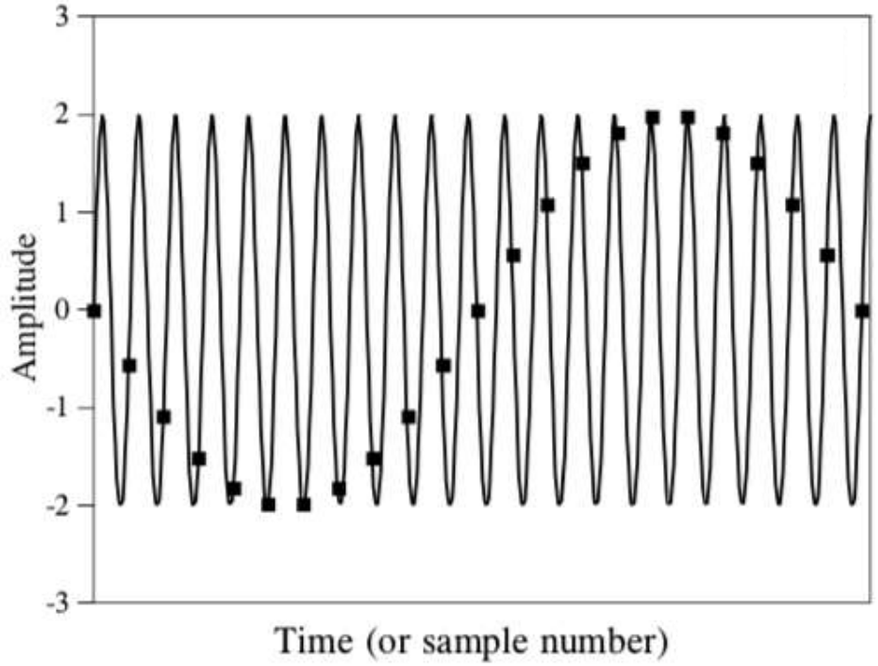
Sampling



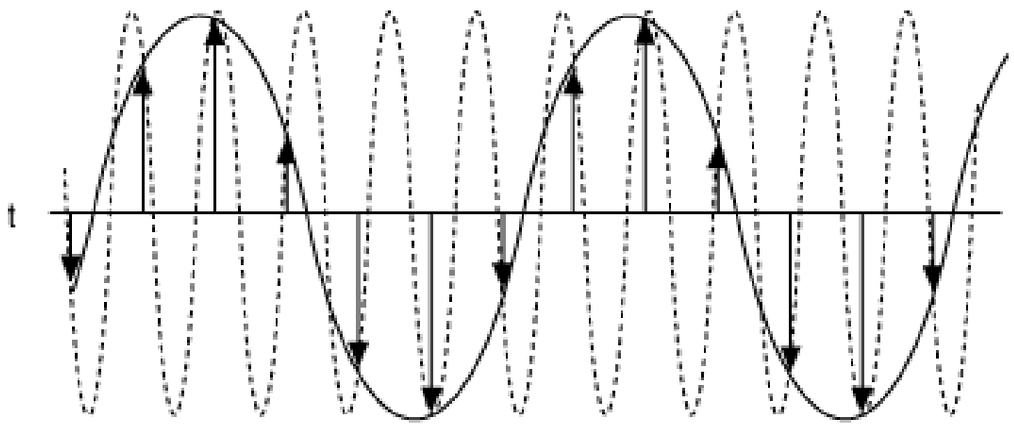




Source: "The scientist and engineer's guide to digital signal processing", by Steven W. Smith

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

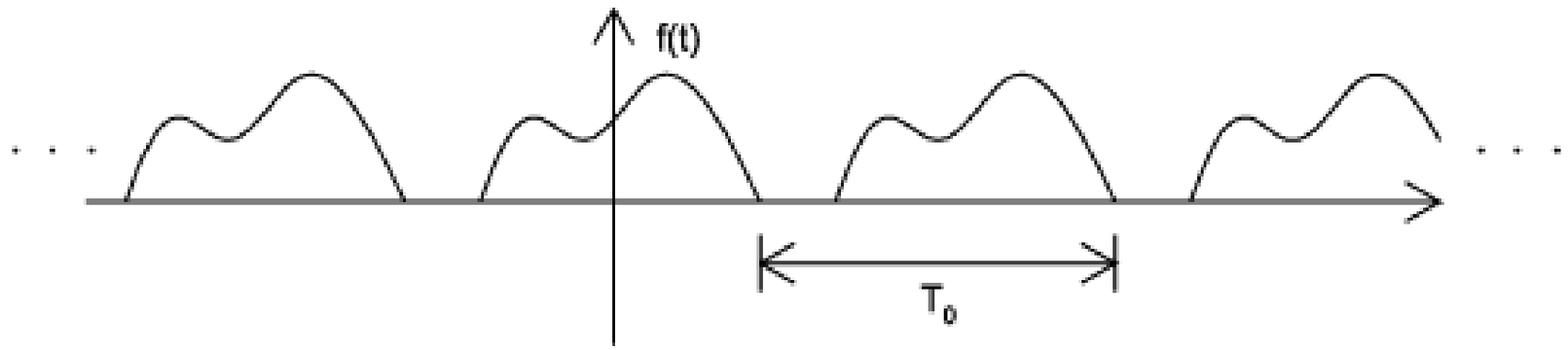
- A complex signal has a bandwidth of 200 kHz.
- What is the minimum sampling rate for this signal?

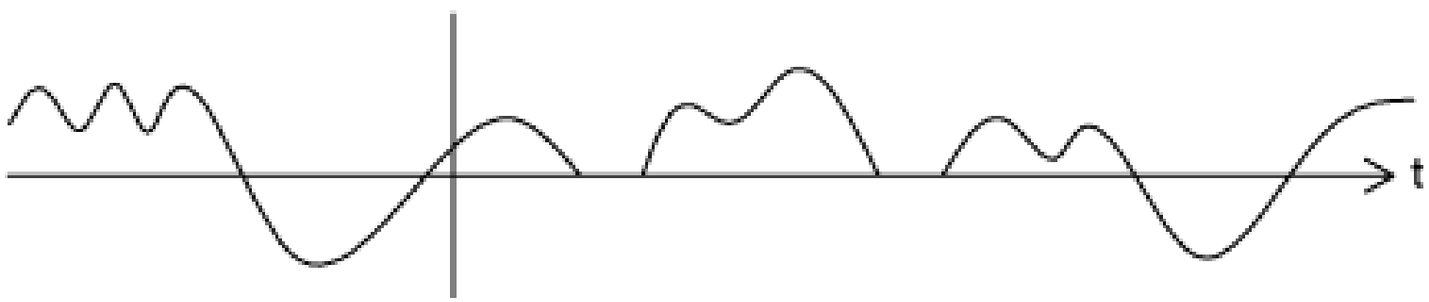
Signal types

Periodic | Aperiodic

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

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





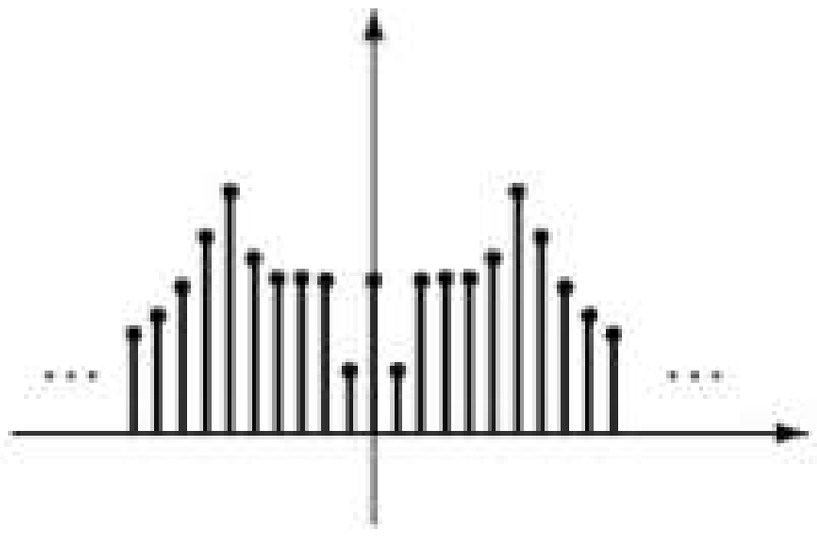
Source: http://pilot.cnxproject.org/content/collection/col10064/latest/module/m10057/latest

Signal types

Even | Odd

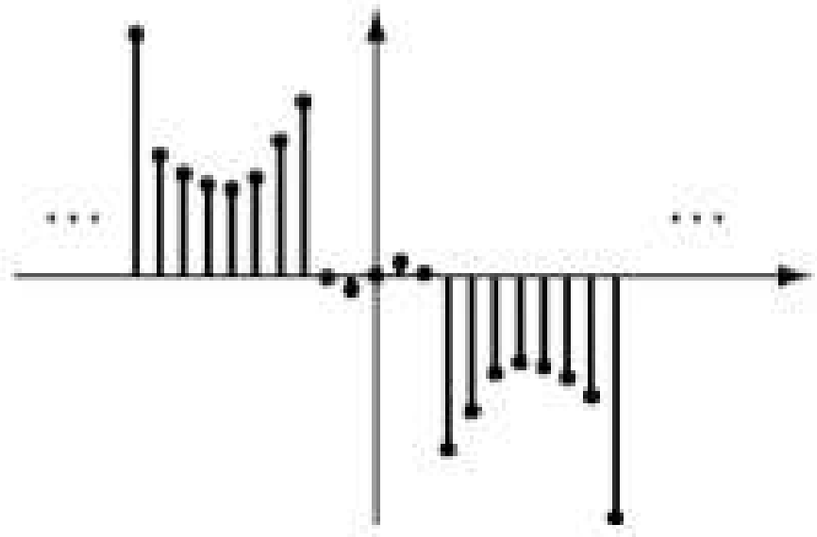
- Even signals can be easily spotted as they are symmetric around vertical axis

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



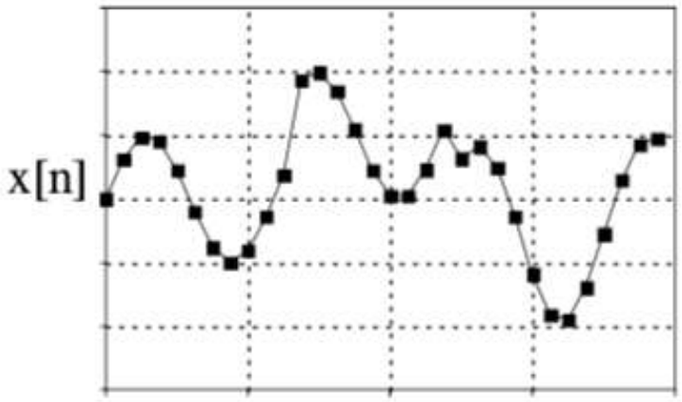
- An odd signal is a signal such that

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



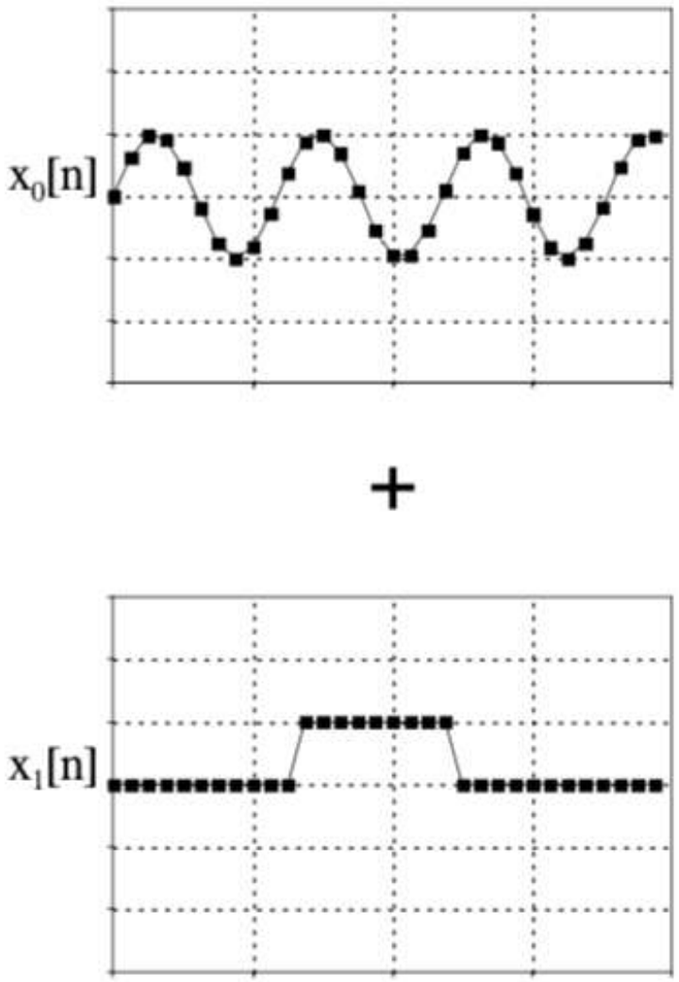
Source: https://www.slideshare.net/mihirkjain/ch1-46505880

Superposition, decomposition



decomposition

superposition



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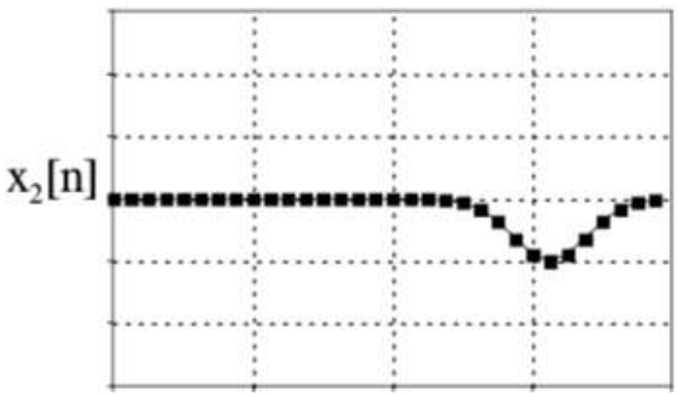
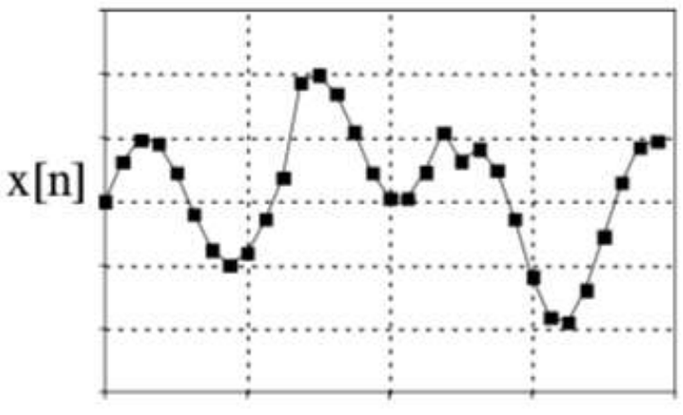


Source: "The scientist and engineer's guide to digital signal processing", by Steven W. Smith

Superposition, decomposition

- 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



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