Biosignal visualization

Practical Session

Signal visualization in time domain

Today's agenda

- Signals in time domain
  - Exercise 1 - RR & Sleep
  - Exercise 2.1 - P300 Evoked Potentials
- Coffee break ☕
- Aliasing & Resampling
  - Exercise 2.2 - P300 Evoked Potentials

Data Science in Healthcare

Data Science in Healthcare

How is it possible to determine the presence of atrial fibrillation?

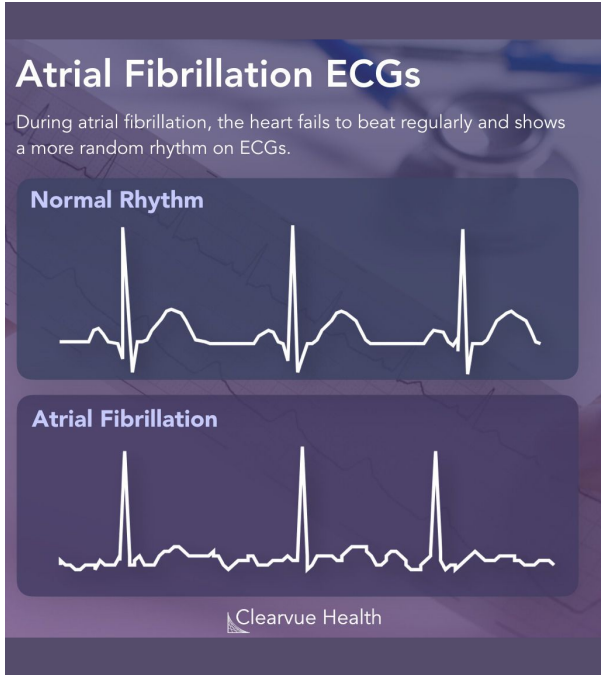
Data Science in Healthcare

Atrial Fibrillation — ♥ 118 BPM Average

This ECG shows signs of AFib.

If this is an unexpected result, you should talk to your doctor.

Data Science in Healthcare



Data Science in Healthcare

By processing the measured ECG signal, extracting features, and applying machine/deep learning algorithms to it, we can detect the presence of atrial fibrillation.

What is a signal?

Your wooclap poll will be displayed here

Install the **Chrome** or
Firefox extension

Make sure you are in
presentation mode

wooclap

How to participate?

1 Go to wooclap.com

2 Enter the event code in the top banner

Event code
MEZIAP

Short recap on signals

A signal is a varying physical quantity, that can carry information.

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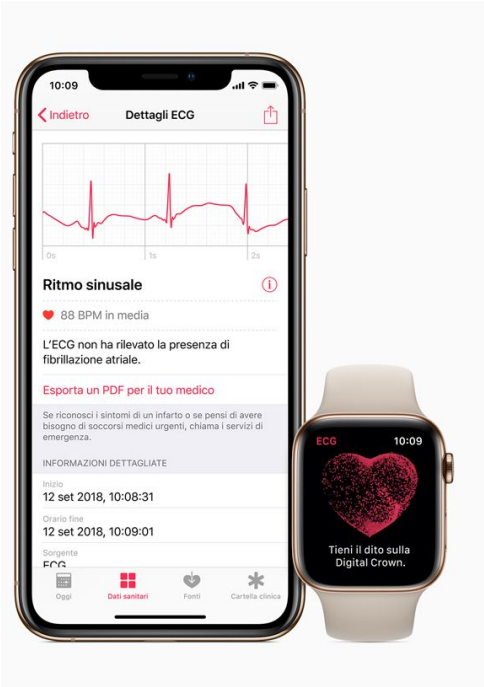
When we consider biological signals, the information that they carry is related to the system, structure, organ, and process that generate them.

Short recap on signals



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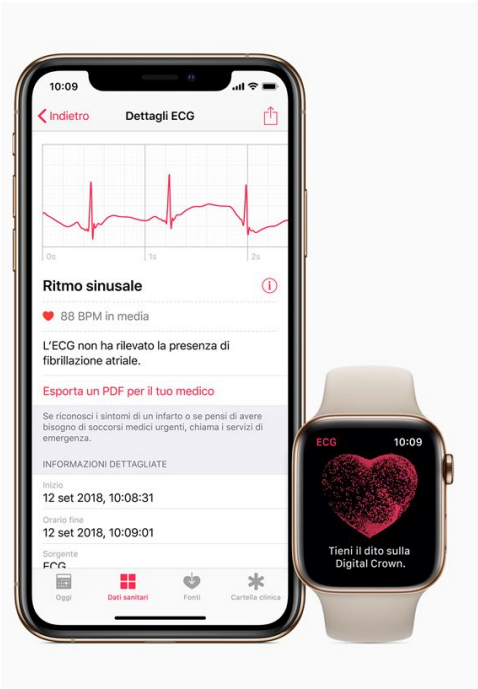

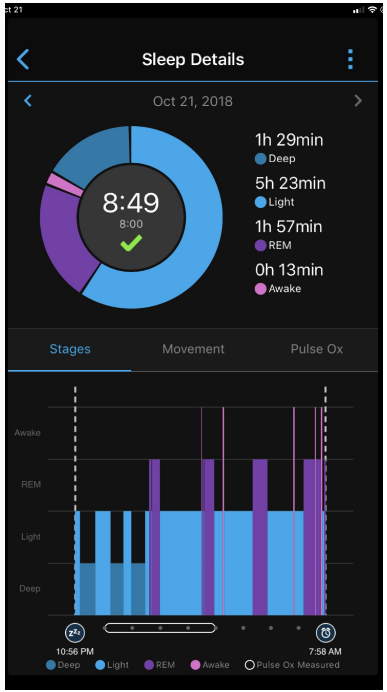

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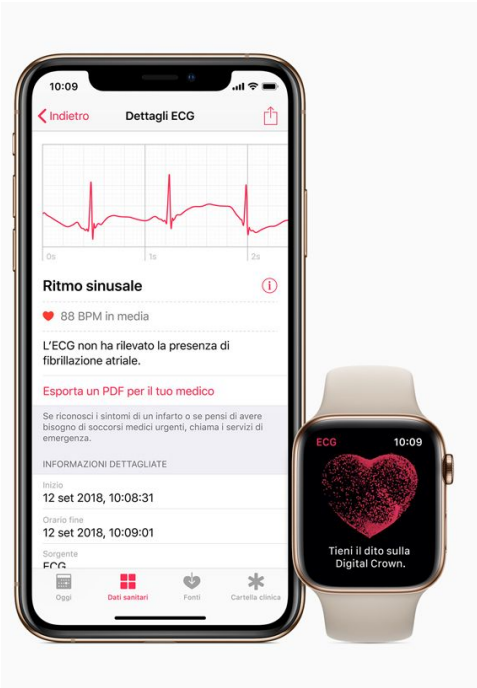
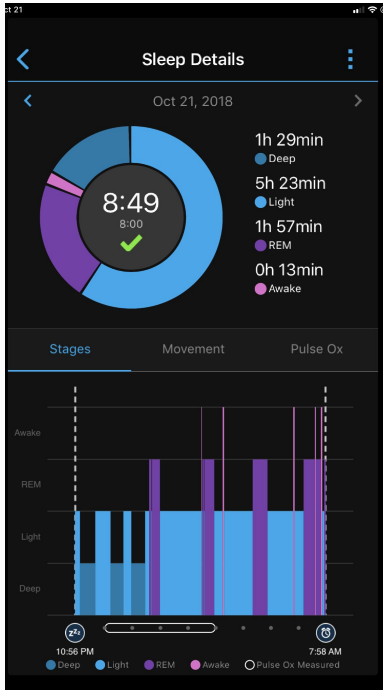
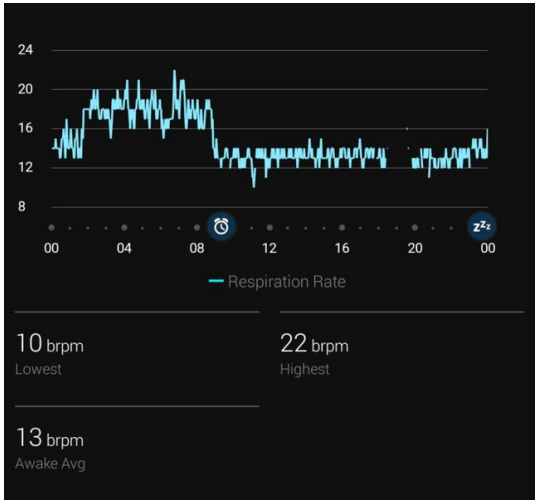




Respiratory Rate



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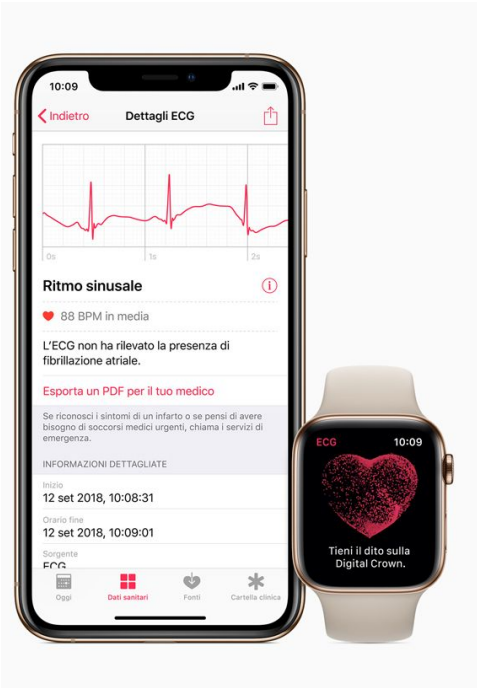

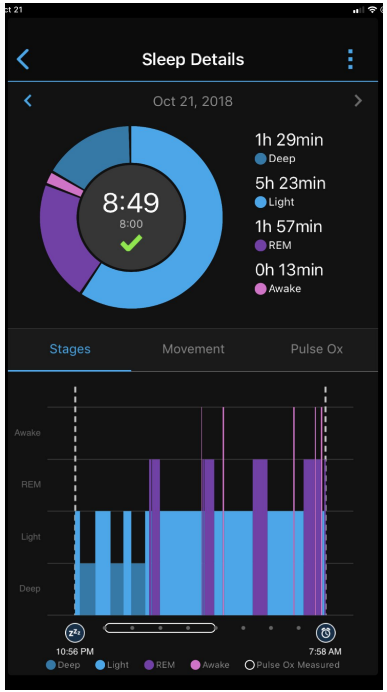

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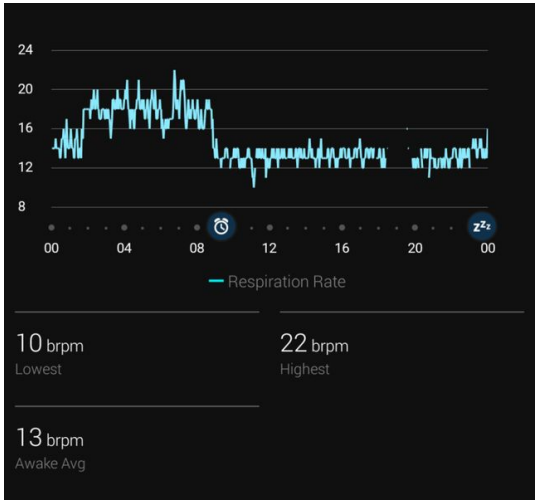
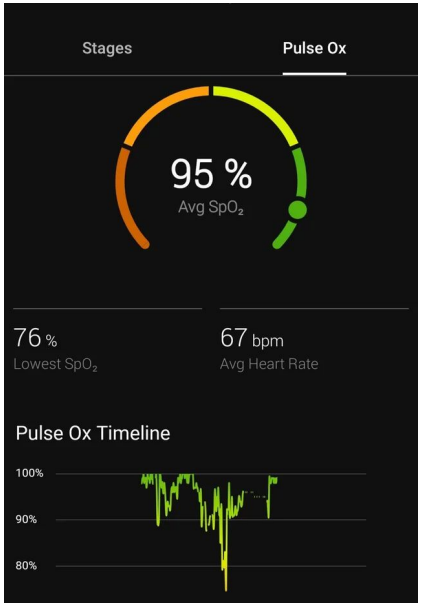


Oxygen Saturation



Goals of Biomedical Signal Analysis

- **Information Retrieval**: to better understand/interpret the behavior of a system

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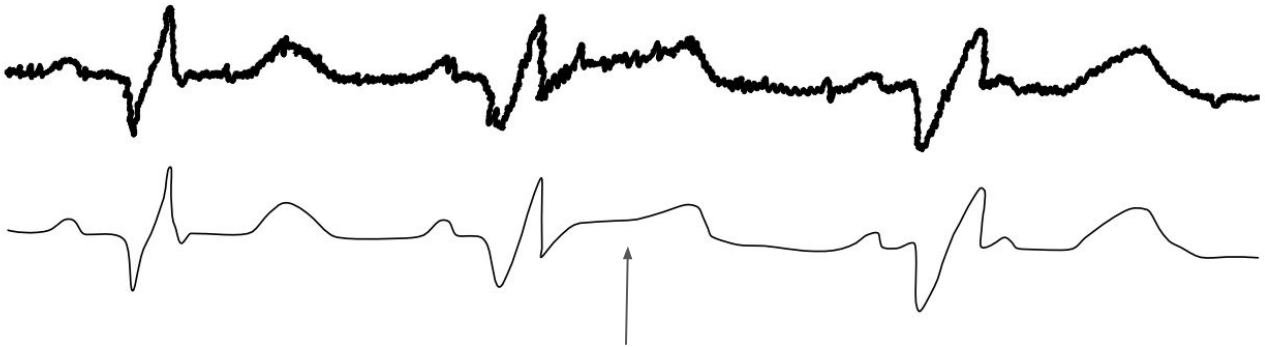
- **Therapy & Control**: Changes in the behavior of a system on the basis of therapy with the aim of ensuring a given result
- **Assessment**: Objective analysis to determine the ability to achieve defined functional performances

Goals of Biomedical Signal Processing

1. **Improve** the extraction of **information** already available in the signal

An example with an electrocardiogram (ECG)

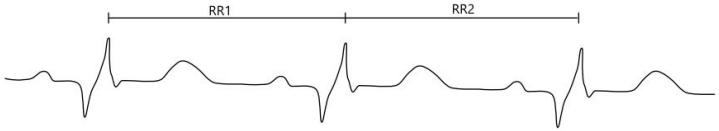


ST-segment elevation: index of ischemia

Goals of Biomedical Signal Processing

2. Extraction of **new information**

An example with RR intervals



Goals of Biomedical Signal Processing

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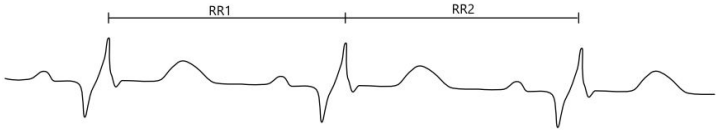
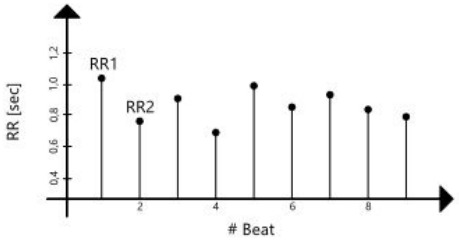


Tachogram



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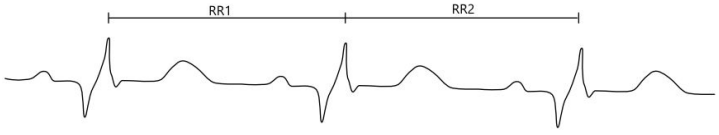

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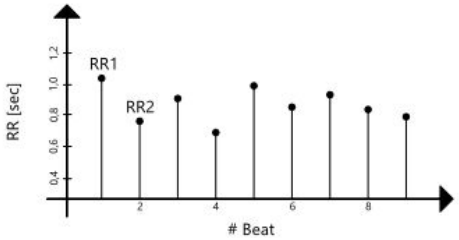

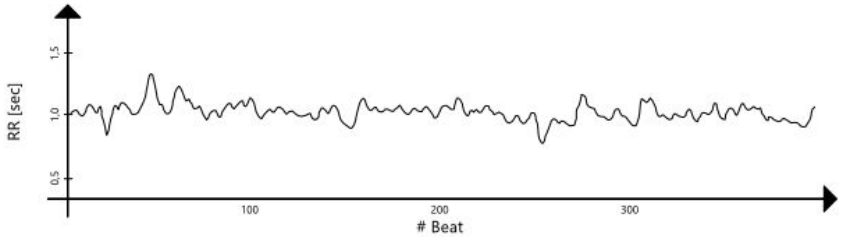

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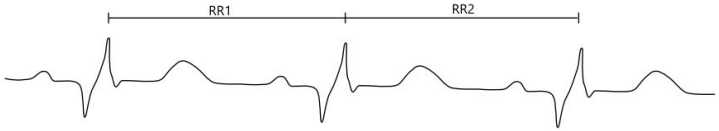

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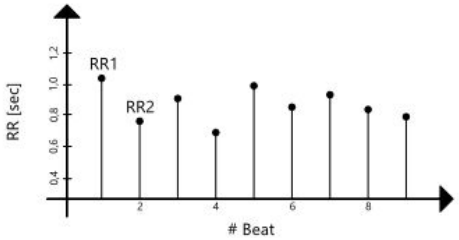

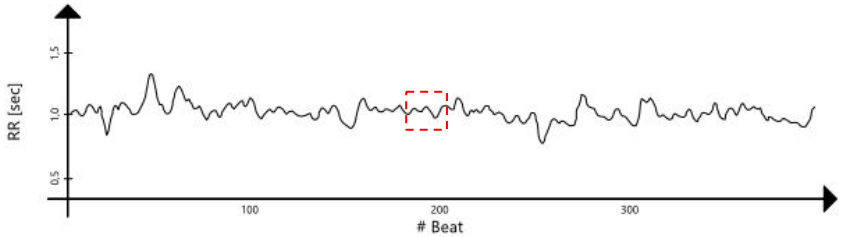

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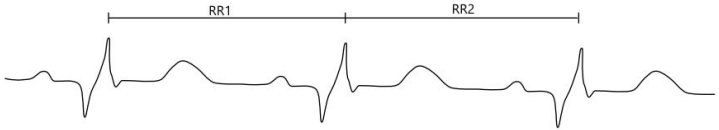
An example with RR intervals



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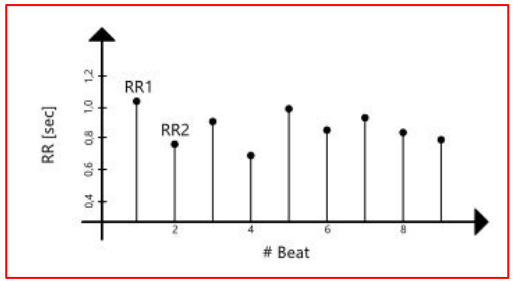

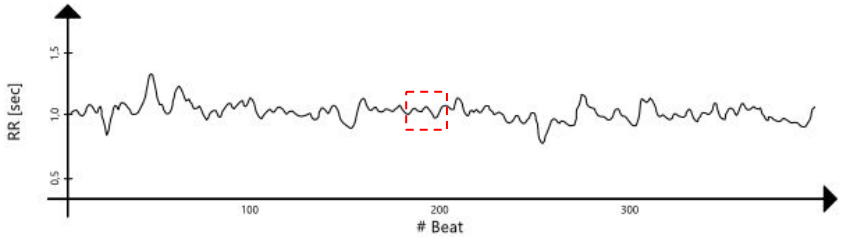

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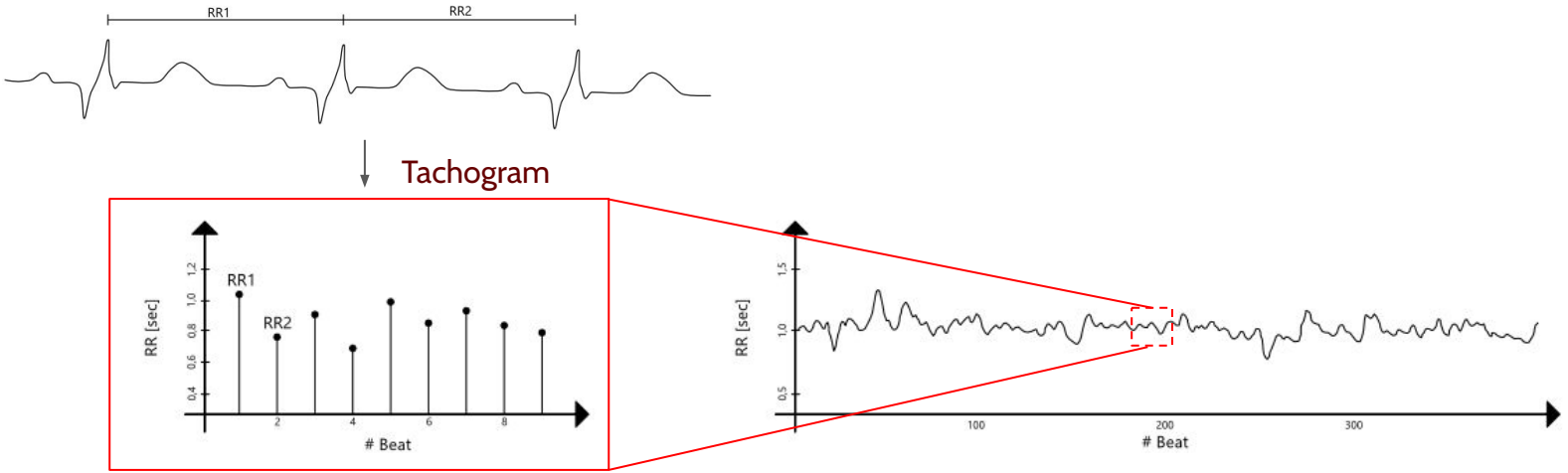


Information about the autonomic nervous system that controls the heart rate

Your wooclap poll will be displayed here

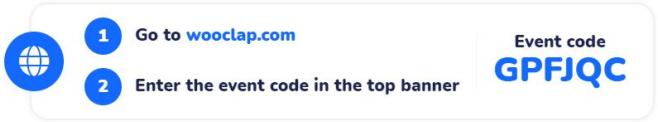
Install the **Chrome** or
Firefox extension

Make sure you are in
presentation mode

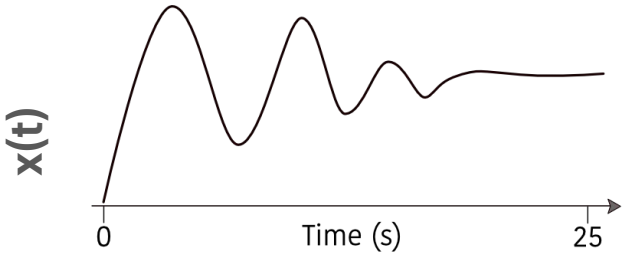
wooclap

What is the difference between an analog and a digital signal?

How to participate?

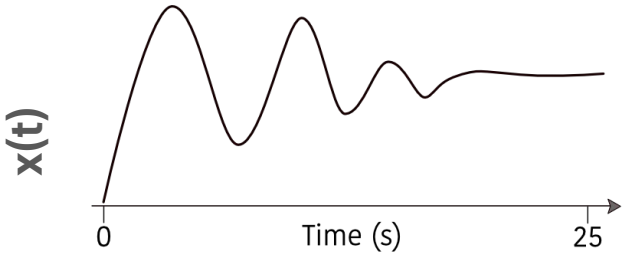


Signals: some definitions



A **continuous-time** (analog) signal *x(t)* is a signal which is defined at every time instant.

Signals: some definitions



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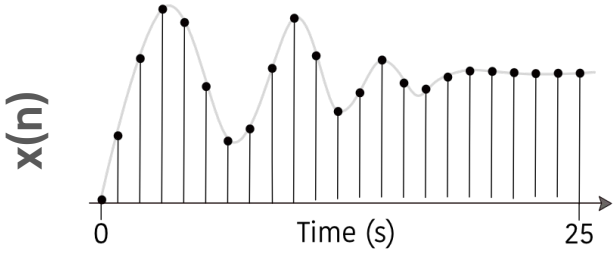
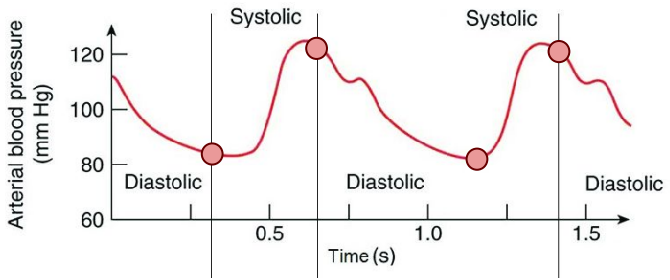


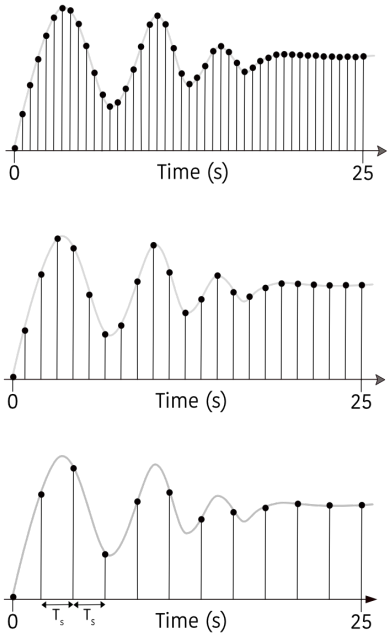
A **discrete-time** signal *x(n)* is a signal obtained by sampling y(t), i.e. considering only a subset of values of x(t), uniformly spaced in the time domain. In this case, we considered five samples per second.

Signals: some definitions



If we measure our blood pressure (systolic and diastolic values) every 5 minutes, we have a discrete-time blood pressure signal. Of course, the underlying system (i.e., our heart) is continuously working.

Signals: some definitions

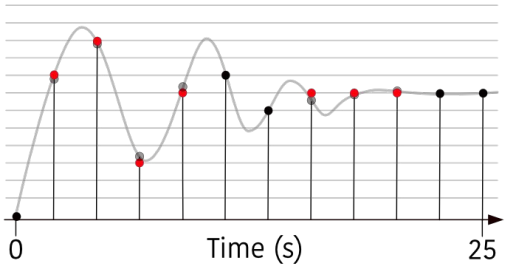


For **discrete-time** signals *x(n)*, we can determine how many samples to consider (typically, in a timeframe of 1 second). The time distance between two consecutive samples is called *sampling period* t_s.

Signals: some definitions

- When we decide to do 30 minutes of activity, we could measure our heart rate (HR) **before** and **after** this activity. In this case we would have only two *samples* with a sampling rate of 30 minutes
- Or we could measure our HR every **5 minutes**. In this case, we would end up with 7 *samples* with a sampling rate of 5 minutes

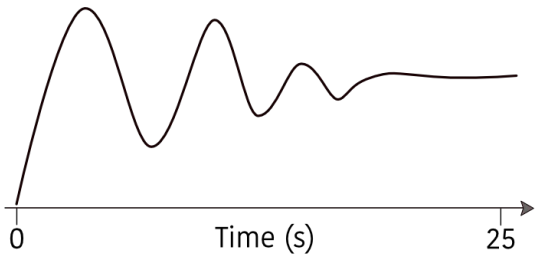
Signals: some definitions



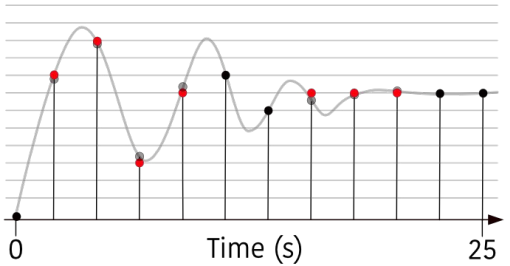
A **digital-signal** is a discrete signal that can take amplitude values only from a limited list of quantized levels.

Signals: some definitions

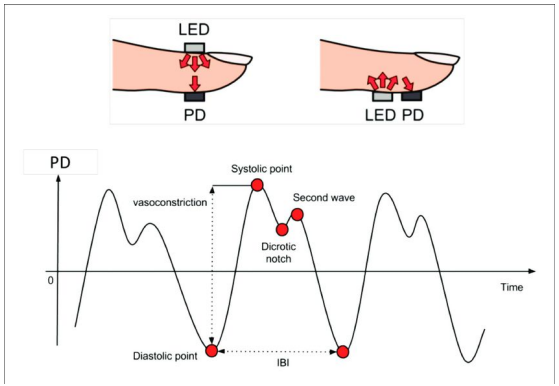
Analog signal



Digital Signal

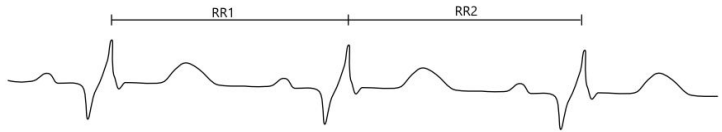


Exercise 1: RR Peaks and Sleep Data

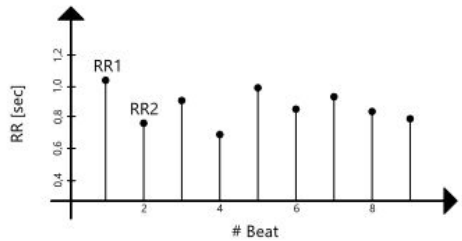


The systolic point results from the direct pressure wave travelling from the left ventricle to the body's periphery. The diastolic point (or inflection) results from reflections of the pressure wave by arteries of the lower body. A dicrotic notch is usually seen in the catacrotic phase of subjects with healthy compliant arteries, and an IBI is an inter-beat interval.

What are RR Peaks?



Tachogram



Exercise 1: RR Peaks and Sleep Data

Aim: Visualize a tachogram, compute heart rate based on RR intervals and qualitatively analyze the relation of heart rate with sleep

BBI & HR & HRV

	Beat-to-Beat Interval	Heart Rate (HR)	Heart Rate Variability (HRV)
Definition	Time between two heartbeats	Average beats per minute	Fluctuations in beat-to-beat intervals
Measured in	Milliseconds (ms)	Beats per minute (bpm)	Milliseconds (ms), often analyzed statistically
Indicates	Instantaneous beat timing	General cardiovascular activity	Autonomic nervous system balance and adaptability
Higher Value Means	Longer time between beats (slower HR)	Faster heartbeat	Greater adaptability and recovery ability

Exercise 1: RR Peaks and Sleep Data

Aim: Visualize a tachogram, compute heart rate based on RR intervals and qualitatively analyze the relation of heart rate with sleep

Lesson 1.2 - Biosignal Visualization #1 - Starter.ipynb

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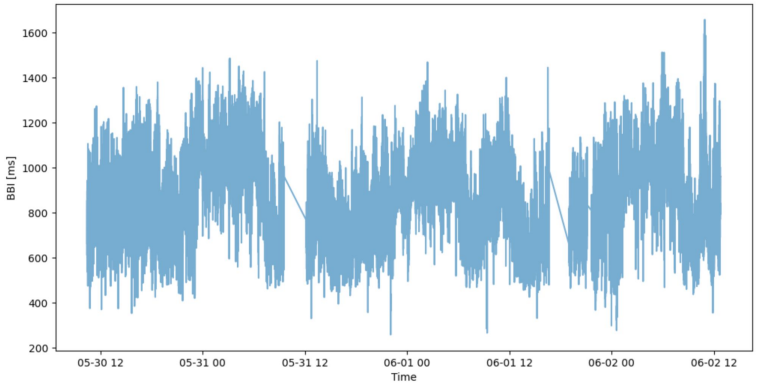
Lesson 1.2 - Biosignal Visualization #1 - Starter.ipynb

Step 1 Load the *bbi.csv* file and plot the tachogram (!Convert isoDate from string to datetime)



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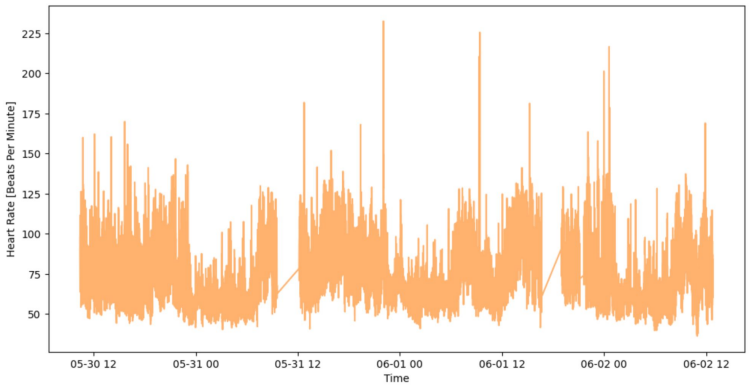
Aim: Visualize a tachogram, compute heart rate based on RR intervals and qualitatively analyze the relation of heart rate with sleep

Assignment:

Step1 Load the *bbi.csv* file and plot the tachogram
Step2 Compute heart rate starting from the tachogram

BBI → Beat-to-Beat Interval (one per every beat)
HR → Beats per Minute

What's the relation that links them?



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Step1 Load the *bbi.csv* file and plot the tachogram
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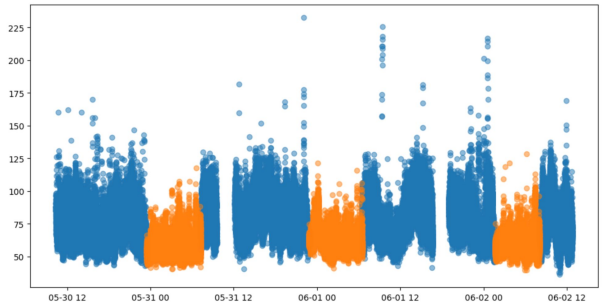
Step3 Load sleep information from *sleep.csv*
Step4 Plot the tachogram with information about sleep/awake cycles



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Step1 Load the *bbi.csv* file and plot the tachogram
Step2 Compute heart rate starting from the tachogram
Step3 Load sleep information from *sleep.csv*
Step4 Plot the tachogram with information about sleep/awake cycles
Step5 Compute daily average of heart rate in sleep and awake cycles

```
bbi.groupby(by=['calendarDate', 'sleep'])
```

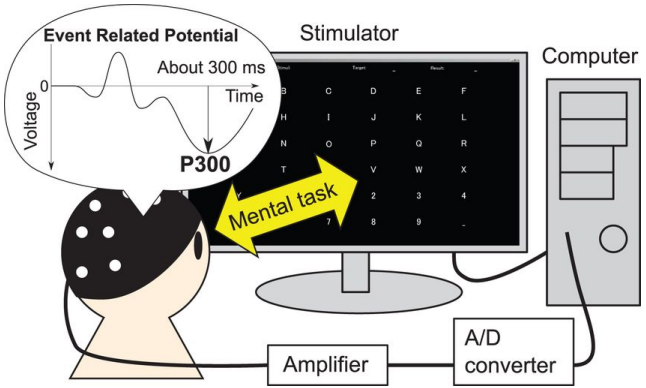
15-minutes coffee break

Exercise 2.1: P300

Aim: Visualize an EEG evoked potential, average it across epochs and show difference between target/non-target events

Exercise 2.1: P300

What is an evoked potential?



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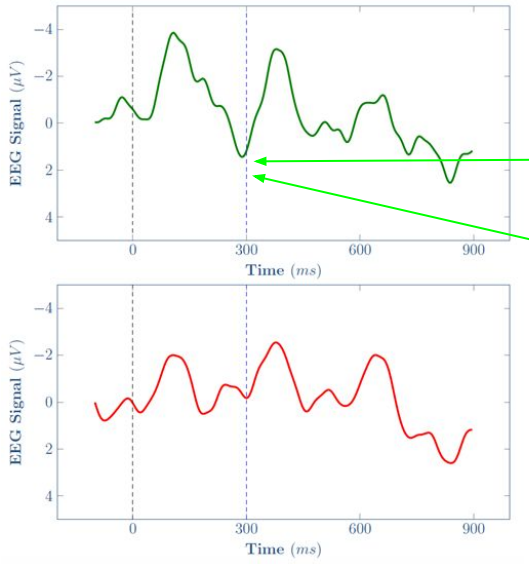

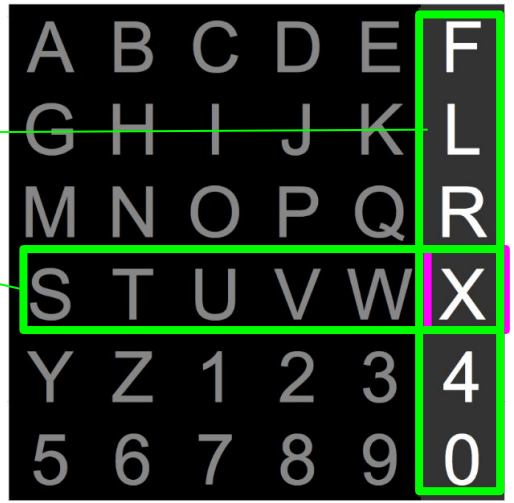

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Assignment:

1. Load the *epochs.csv* file and *stim_info.csv* file

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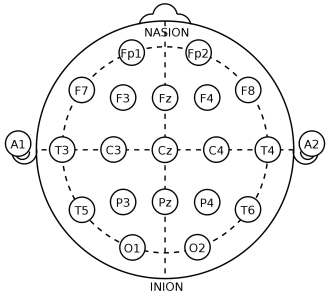
Assignment:

1. Load the *epochs.csv* file and *stim_info.csv* file



Channels

Samples (uV)

C3	C4	P3	P4	P7	P8	Pz	Oz	idx

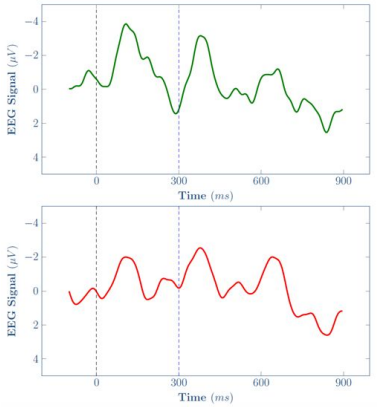
Exercise 2.1: P300

Aim: Visualize an EEG evoked potential and plot difference between target/non-target events

Assignment:

1. Load the *epochs.csv* file and *stim_info.csv* file
2. Average target (1)/non-target (0) epochs in *eeg* based on the *stimulusType* value

stimulusType
1
0

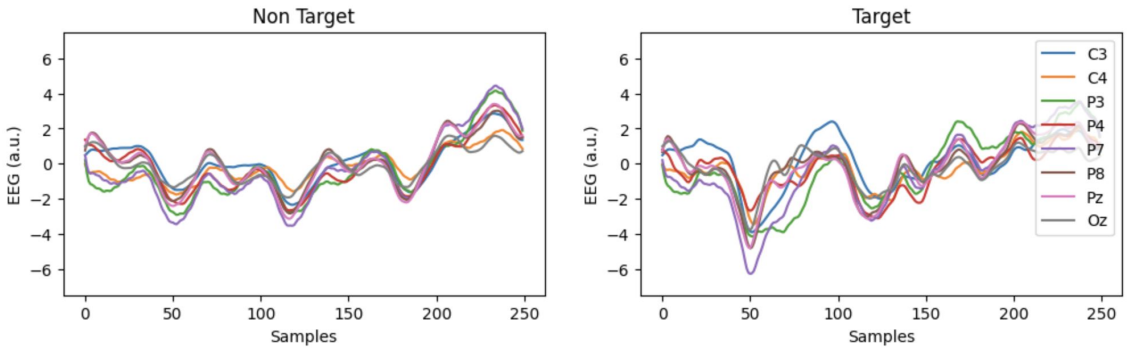


Exercise 2.1: P300

Aim: Visualize an EEG evoked potential and plot difference between target/non-target events

Assignment:

1. Load the *epochs.csv* file and *stim_info.csv* file
2. Average target/non-target epochs in *eeg* based on the *stimulusType* value
3. Plot average for each EEG channel

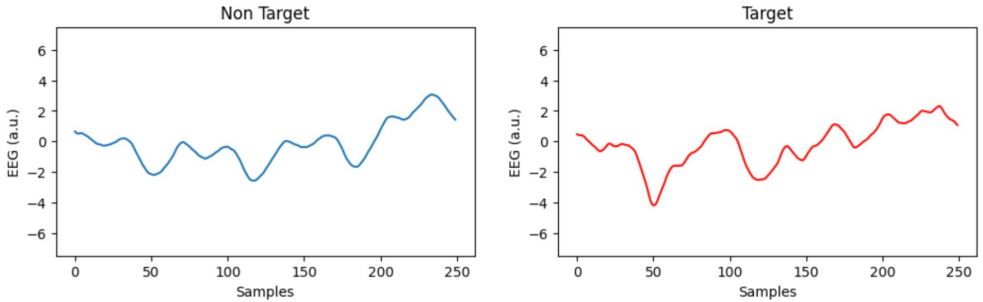


Exercise 2.1: P300

Aim: Visualize an EEG evoked potential and plot difference between target/non-target events

Assignment:

1. Load the *epochs.csv* file and *stim_info.csv* file
2. Average target/non-target epochs in *eeg* based on the *stimulusType* value
3. Plot average for each EEG channel
4. Plot average for all channels



15-minutes coffee break

Sampling

The time distance between two consecutive samples is called *sampling period* $\mathbf{T_s}$. The *sampling frequency* is defined as:

$$f_s = \frac{1}{T_s}$$

The unit of measurement of frequency is Hertz (Hz).

If we sample at 10Hz, then we will have 10 samples per second, and the sampling time will be 0.1 s

If we sample at 100Hz, then we will have 100 samples per second, and the sampling time will be 0.01 s

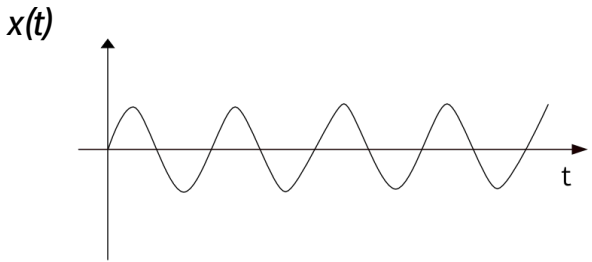
Can we choose any sampling frequency to sample our signals?

Sampling

When deciding which sampling frequency to use, care must be taken.

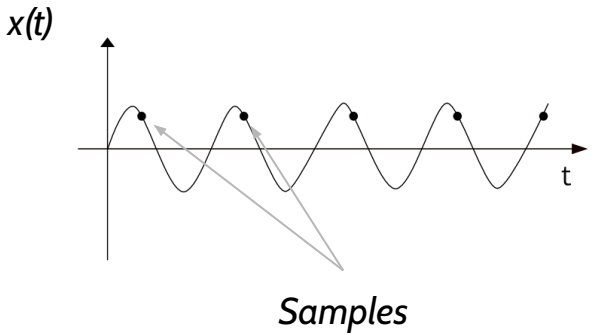
Sampling

When deciding which sampling frequency to use, care must be taken.



Sampling

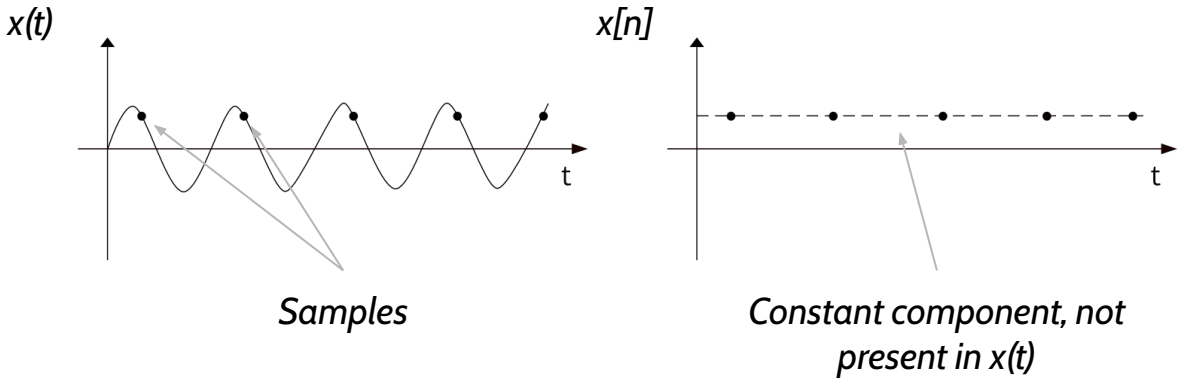
When deciding which sampling frequency to use, care must be taken.



Sampling

When deciding which sampling frequency to use, care must be taken.

What happens if we choose a sampling frequency which is **too low**?



Sampling

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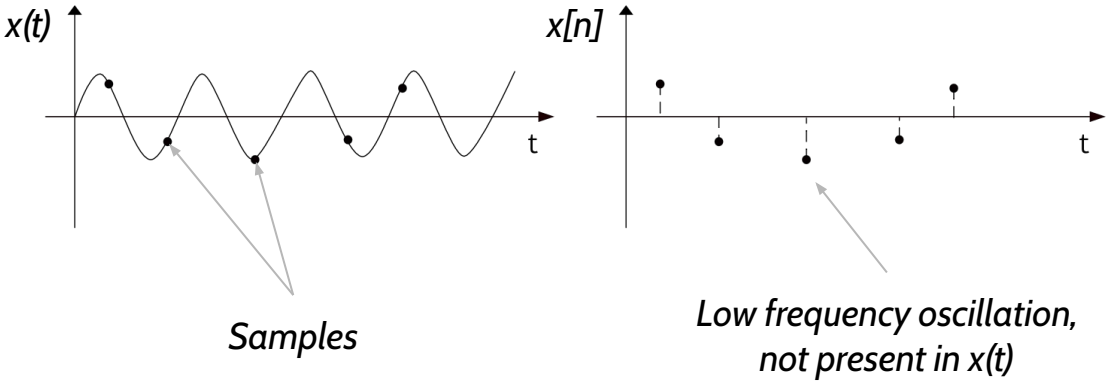
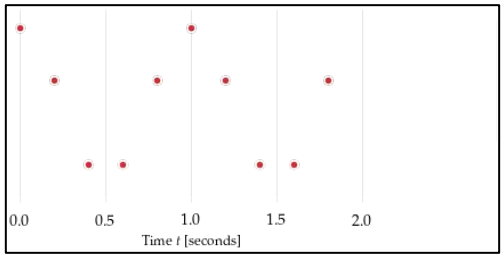


Sampling - Aliasing

Aliasing is the name we give to the phenomenon when two distinct continuous signals $x_1(t)$ and $x_2(t)$ produce the same sequence of sample values $x(n)$ when sampled at a fixed rate f_s.

Sampling - Aliasing



f=1Hz, f_s=5Hz

Sampling - Aliasing

Aliasing is the name we give to the phenomenon when two distinct continuous signals $x_1(t)$ and $x_2(t)$ produce the same sequence of sample values $x(n)$ when sampled at a fixed rate f_s.

Aliasing should be always taken into consideration when sampling a signal, as the consequence of this fact is that once you've sampled a signal, you may not be able to determine the frequency of the wave that produced the samples you've observed.

More than words :_)

https://www.youtube.com/watch?v=Jv5FU8oUWEY
(Stop at 4m 10s)

Applet

http://webapps.chem.uoa.gr/efs/applets/AppletNyquist/Appl_Nyquist2.html

Sampling - Nyquist Shannon Sampling Theorem

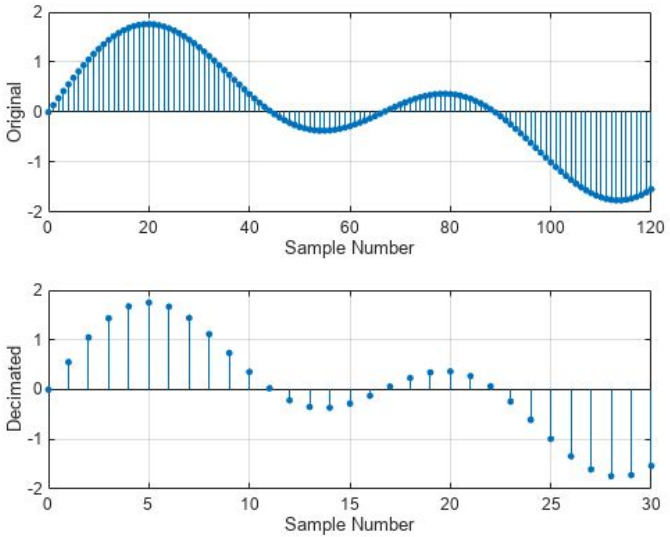
Nyquist-Shannon theorem:

$$fs \geq 2 \cdot f_{+}$$

Alternatively, for a fixed sampling rate f_s, the highest frequency that can be measured without aliasing artifacts is $f_s/2$, also known as the Nyquist frequency (for sampling rate f_s).

Downsampling

Resampling is the process of reducing the sampling rate of a signal.



Down-sampling

- Reduce the sampling rate at the output of one system, so that a system operating at a lower sampling rate can input the signal.
- Reduce the cost of processing (more related to the hardware side): the use of a lower sampling rate usually results in a cheaper implementation.
- ...

Resampling: when can I downsample a signal?

Suppose you have an ECG signal sampled at 500 Hz. The highest frequency component that you have in your signal is 100 Hz.

Can we downsample the signal (i.e., reduce the sampling frequency) to 150 Hz?

Resampling: when can I downsample a signal?

We can downsample a signal if it is *oversampled*, meaning that it was sampled at a frequency higher than the Nyquist frequency.

So.. The highest frequency component in the signal must be less than half the post-decimation sampling rate.

$$f_+ < f_d/2$$

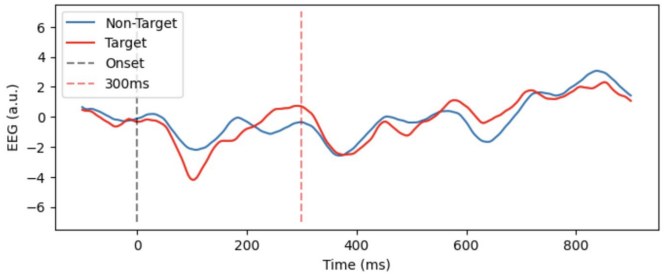
Exercise 2.2: P300

Aim: Visualize EEG evoked potentials using sampling frequency information

Assignment:

Using the data of exercise 2.1, plot the grand averages of target and non target P300 epochs with time information on the x-axis, considering that:

- EEG was sampled at 250 Hz
- Epochs were extracted in the time window of (-100, +900) ms around the stimulus onset



Questions?

See you next Week !