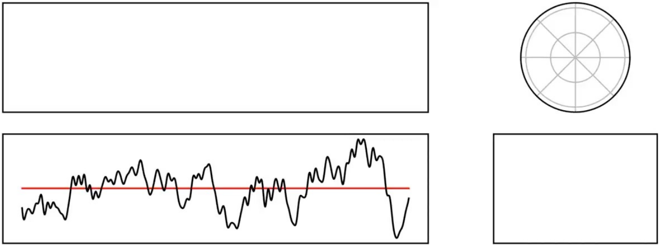
COMS20011 – Data-Driven Computer Science

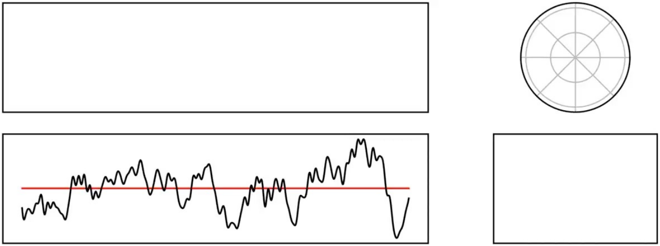


Lecture Video MM06 – Signals & Frequencies

March 2022

Majid Mirmehdi

Next in DDCS



Feature Selection and Extraction

- Signal basics and Fourier Series
- 1D and 2D Fourier Transform
- Another look at features
- Convolutions

Typical Data Analysis Problem

Steps:

1. Pre-processing [Unit - Part 1] → Majid Mirmehdi (~10%)
2. Feature Selection [Unit - Part 3] → Majid Mirmehdi (~40%)
3. Modelling & Classification [Unit - Part 2] → Laurence Aitchison **[UD]** (~50%)

Summary: Typical Data Analysis Problem (Reminder from Video #MM02)

1. Pre-processing
2. Feature Selection
3. Modelling & Classification

Supervised Training

Pre-processed data

Image Features

Training Labels

Classifier Training

Trained Classifier

Testing

Test Data

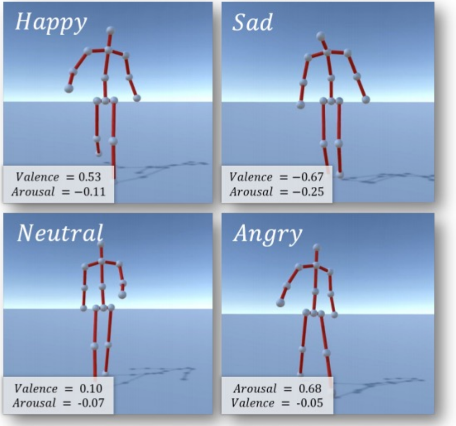
Image Features

Trained Classifier

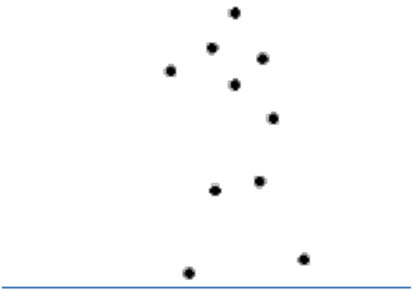
Prediction

Outdoor

Features help simplify the problem



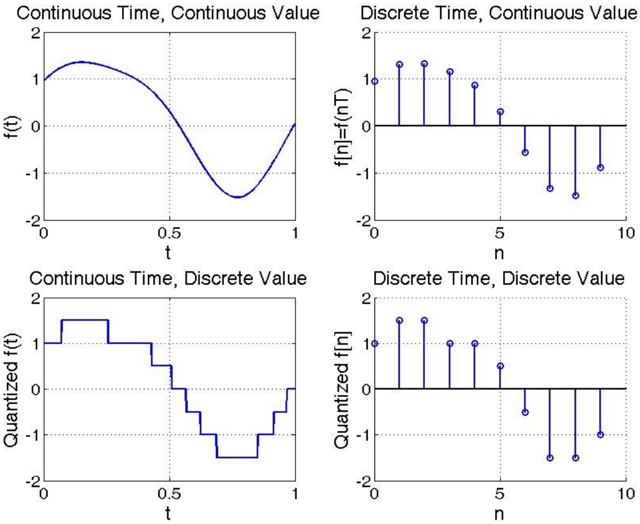
Patient with mild Parkinson's Disease



- Even "impoverished" motion data can evoke a strong perception

Image from https://medium.com/artificial-intelligence-network/

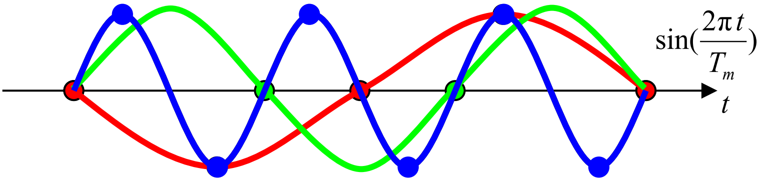
Sample and Quantise – Reminder



Nyquist-Shannon Sampling Theory - Reminder

"An analogue signal containing components up to some maximum frequency ***u*** *(Hz) may be completely reconstructed by regularly spread samples, provided the sampling rate is at least* ***2u*** *samples per second"*

Also referred to as the Nyquist-Shannon criterion: sampling rate s should be at least twice the highest spatial frequency u.



sampling period $T_m \leq \frac{1}{2u}$

equivalent to *sampling rate* $s \geq 2u$

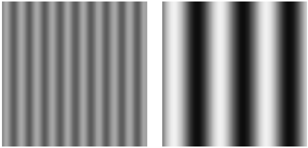
Basic Signals

AAAAATAAAAA

0000001000000

$$\delta[n] = \begin{cases} 0, n \neq 0 \\ 1, n = 0 \end{cases}$$

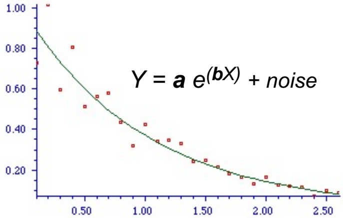
*x = sin(t) = sin(t+2**π**)*



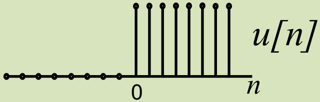
Some basic signals:

- **Unit impulse signal**
- **Unit step signal**
- **Exponential signal**
- **Periodic signal**

All signals can be represented by these basic signals!



$Y = \boldsymbol{a}\, e^{(\boldsymbol{b}X)} + noise$

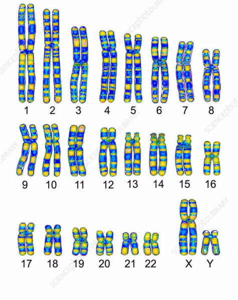


$$u[n] = \begin{cases} 0, n < 0 \\ 1, n \geq 0 \end{cases}$$

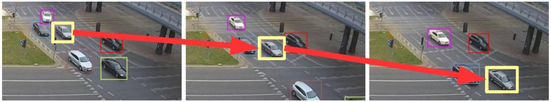
Signals as Functions

A signal is a physical quantity that is a function of one or more independent variable(s), such as space and/or time.

Data from a Gene pool



Position of a car in a video sequence



Example signals:

1D signal: $f(t)$
2D signal: $f(x,y)$
3D signal: $f(x,y,t)$ etc.

Signals as Functions – *self-study slide!*

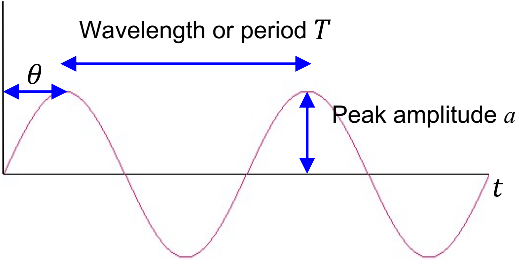
period is the time T it takes to finish one oscillation.

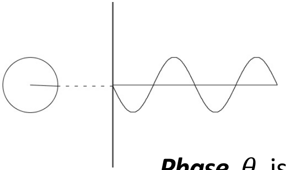
frequency $u = \dfrac{1}{T}$ is the number of periods per second, measured in Hz.

amplitude a is a measure of how much it changes over a single period.

Example: sine function

$$f(t) = a\,\sin 2\pi u t$$





Phase θ is where the signal is in the oscillation (or the angular position).

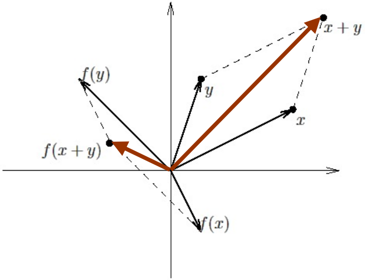
Linear Systems

For a linear system: output of the linear combination of many input signals is the same linear combination of the outputs → ***superposition***

A function f is linear if

- $f(x + y) = f(x) + f(y)$
- $f(\alpha x) = \alpha f(x)$

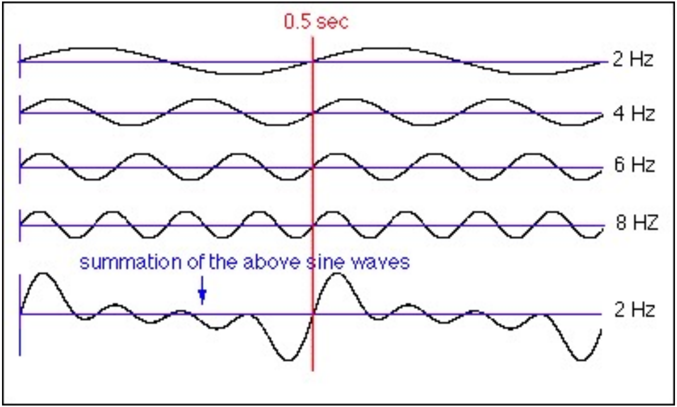
i.e., superposition holds.



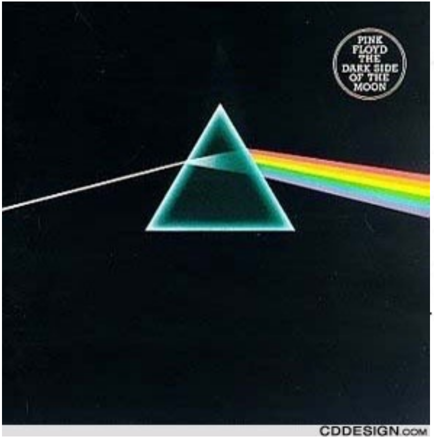
Output is the sum of the system's response to these basic objects.

Example I: a simple signal

For a linear system: output of the linear combination of many input signals is the same linear combination of the outputs → ***superposition***

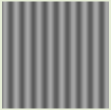


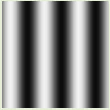
Example II: white light

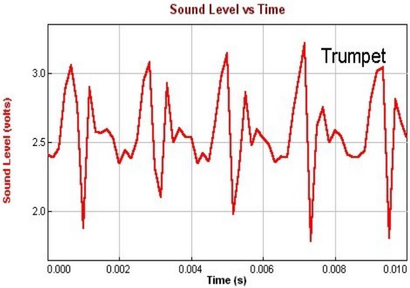


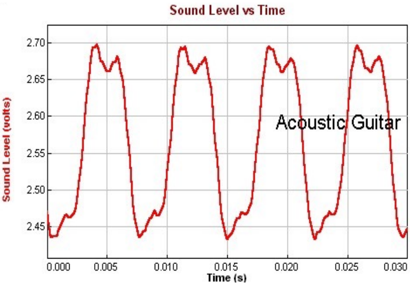
How should we interpret these musical instrument signals?

Characteristics of sound in audio signals:
High pitch - rapidly varying signal
Low pitch - slowly varying signal

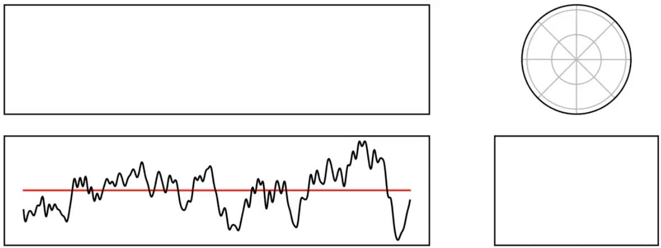








Next in DDCS



Feature Selection and Extraction

- Signal basics and **Fourier Series**
- 1D and 2D Fourier Transform
- Another look at features
- Convolutions