Majid. In his office.

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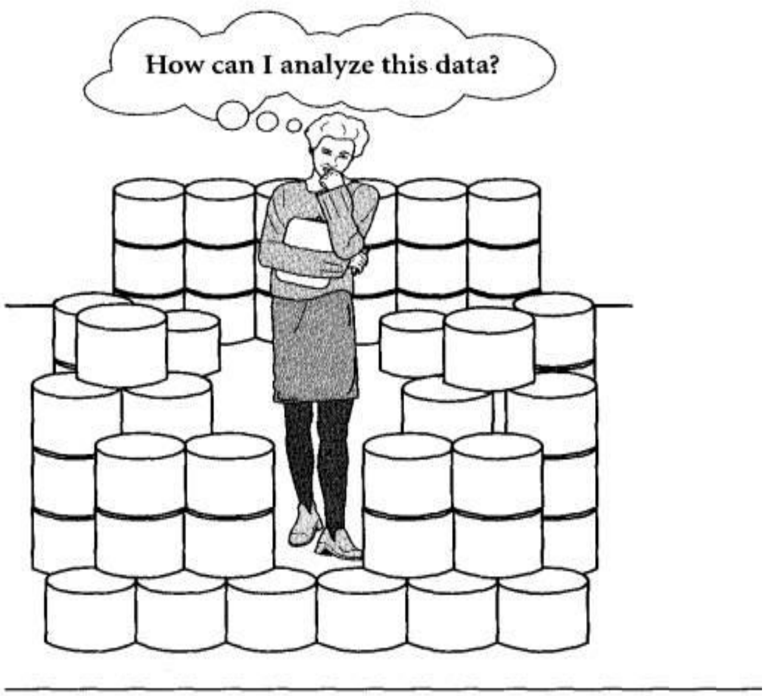
Drop in or email to
arrange an appointment.

SPS: The Story So Far

The sorts of ways we wish to manipulate and analyze data:

- Data Properties
- Data Modelling
- Classification and recognition
- Clustering and segmentation
- Estimation and detection



SPS: *The Next Frontier!*

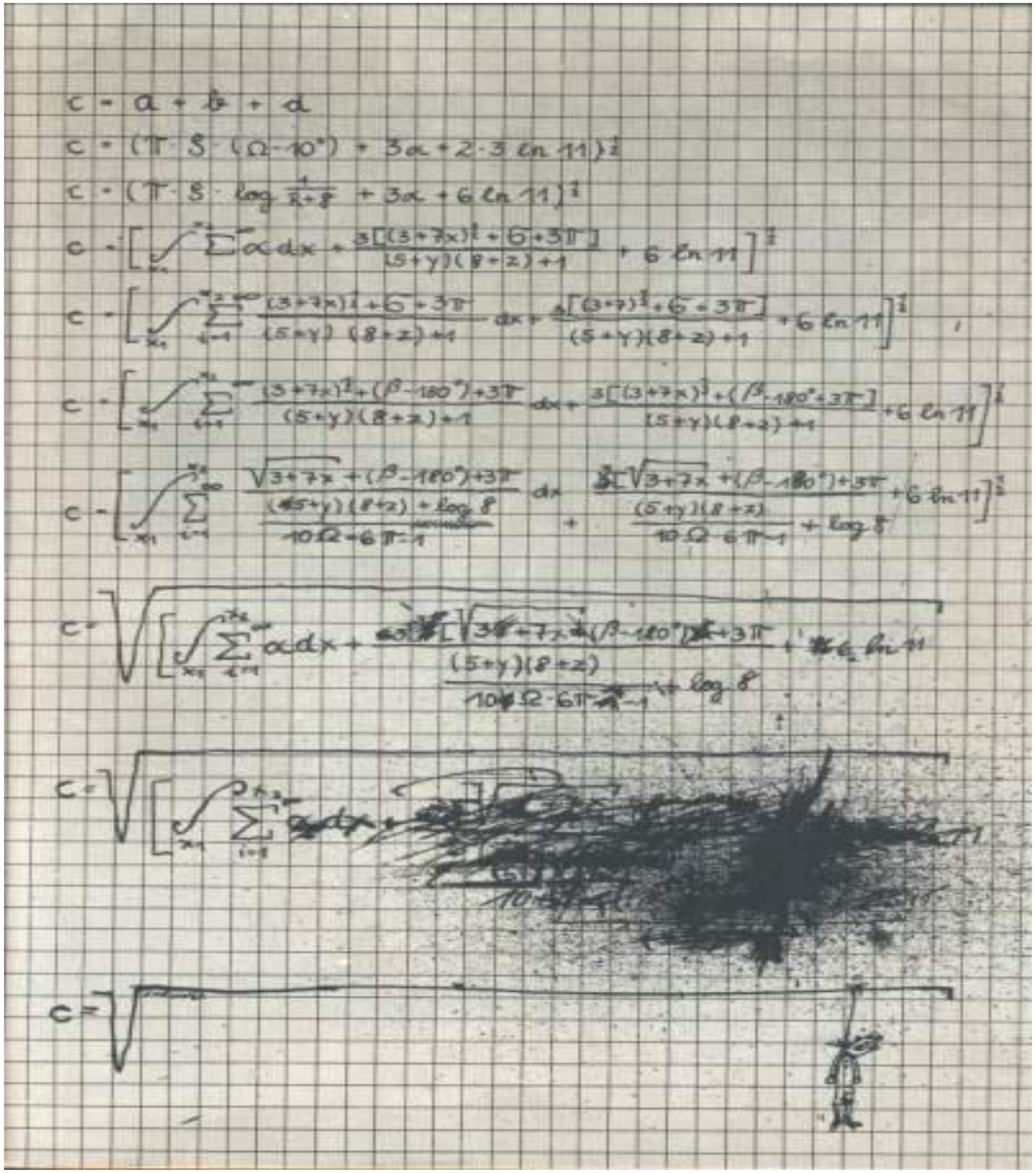
- Data Representations
- Data Transformations
- Feature extraction

❖ Fourier Space Analysis
❖ Convolutions
❖ Principal Component Analysis
❖ Coordinate Transformations

This Lecture:

- Overview
- Intro to Signals

Maths: *nothing scary!*



Representing Data

To manipulate data properly we may have to represent it in a different way. ***Why?***

- Sometimes we need to look at data in a different way.
- Sometimes we need to alter it to prepare it for the next stage of processing or data analysis. Because:
  - It is noisy (errors or outliers),
  - It is missing values,
  - It contains redundancies,
  - It contains inconsistencies
  - It reveals its substance or begins to make sense

Representing Data

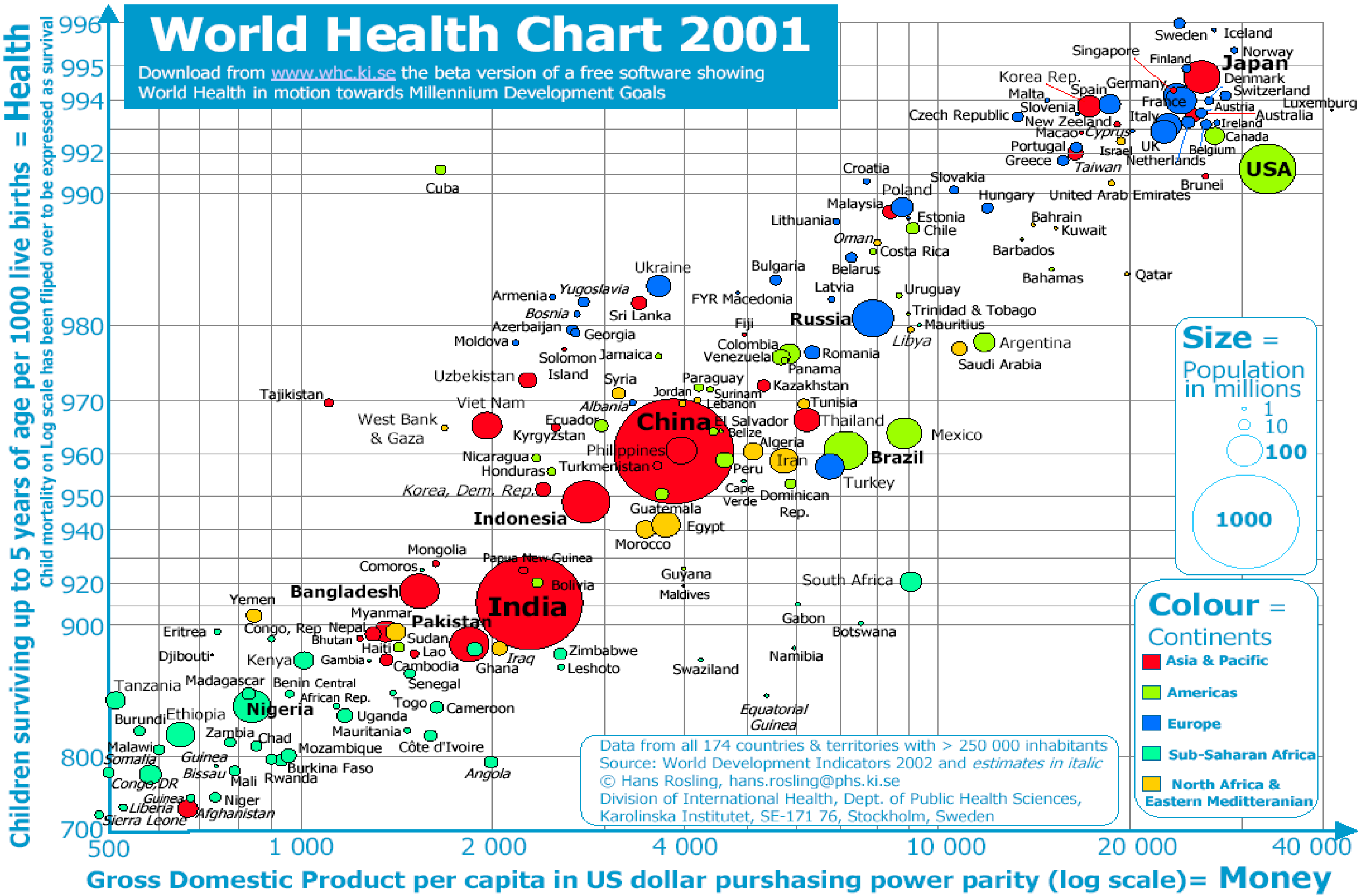
To manipulate data properly we may first **pre-process** it:

- **Data cleaning**: a process that removes or transforms noise and inconsistent data
- **Data integration**: where multiple data sources may be combined (also known as Data Fusion)
- **Data selection**: where data relevant to the analysis task are retrieved, filtered, extracted

Then we are ready for data representation:

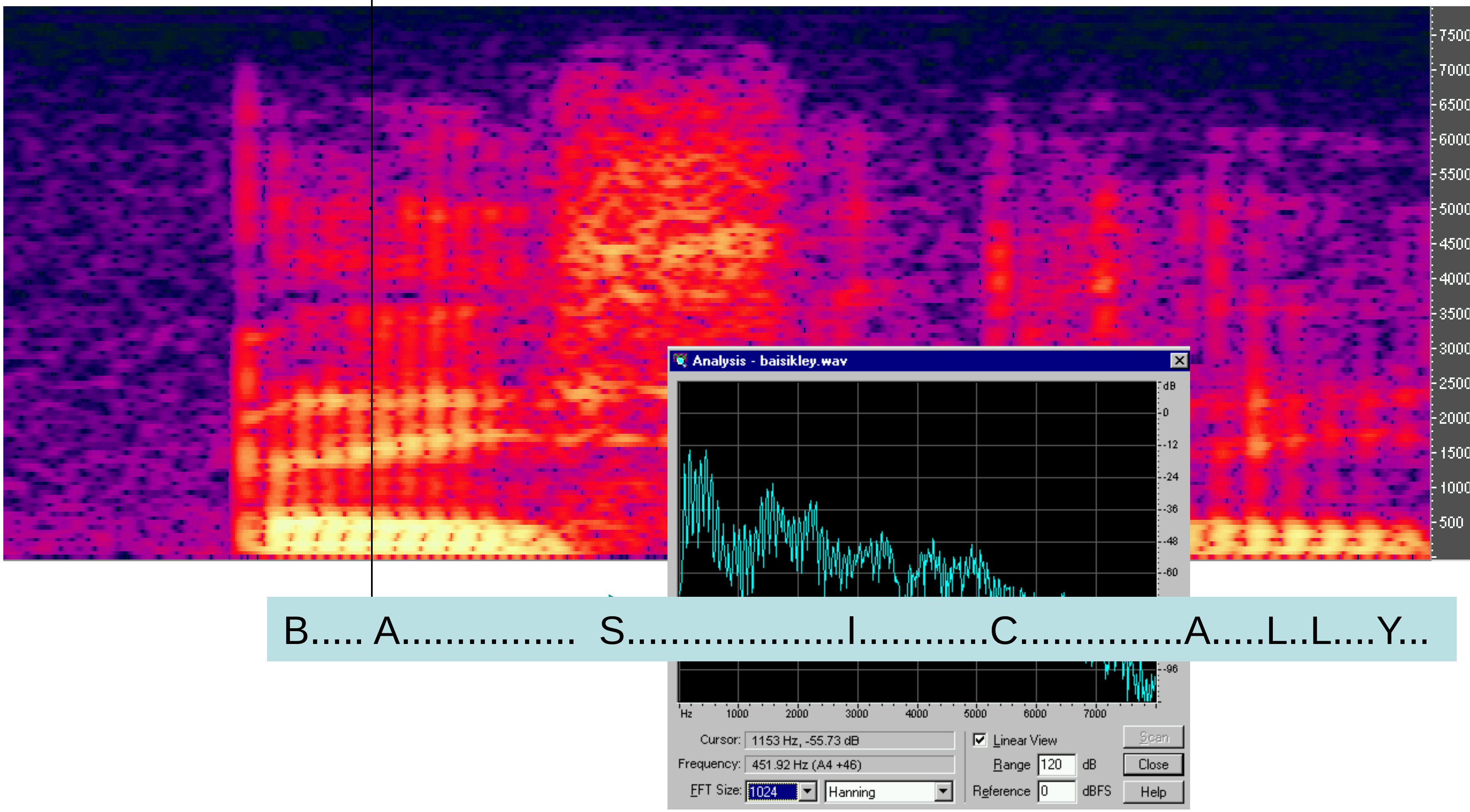
- **Data transformation**: where data are transformed, reduced or consolidated into forms appropriate for alternative representation and/or further analysis.

Visualizing Data



Frequency Domain Data Analysis

Spectrogram: Representation of time, frequency and amplitude



B..... A............... S...................I...........C..............A.....L..L....Y...

Spatial Domain Data Analysis: Cleaning/Clearing up Data

Sometimes we may manipulate data just so we (humans) can *see* the data better.

Noisy Gene Sequence:

GGATACAWCTTTAGAG

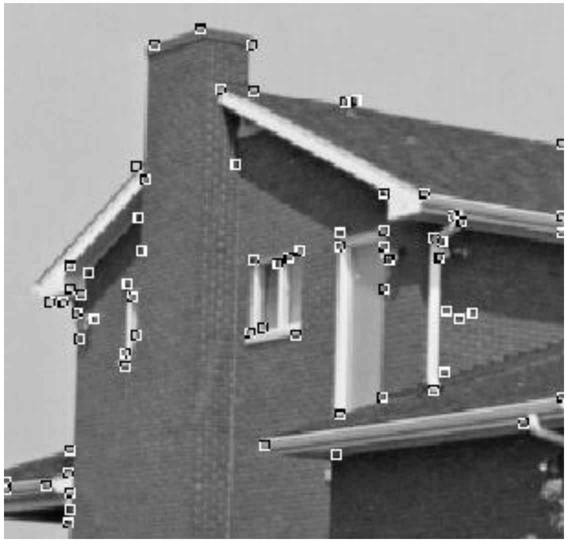
Cleaned Gene Sequence:

GGATACAACTTTAGAG

Spatial Domain Data Analysis: Feature Detection

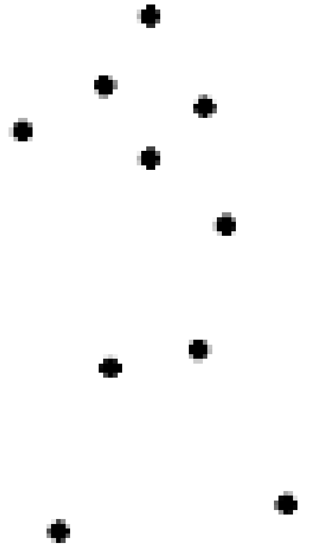
Edge Detection

Corner Detection



Features help simplify the problems

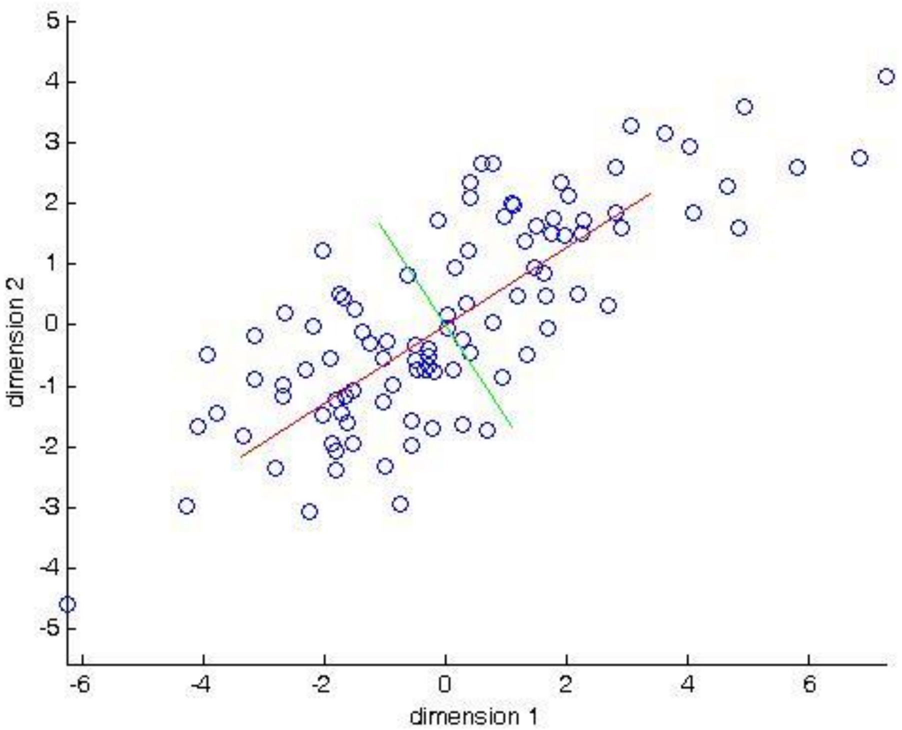
- Even “impoverished” motion data can evoke a strong percept



- Some tracking examples

Principal Component Analysis

The two principal eigenvectors demonstrate the orthogonal directions of maximum variation in the data.



Before :

$$\mathbf{C} = \begin{pmatrix} 0.258 & 0.314 \\ 0.314 & 0.403 \end{pmatrix}$$

After :

$$\mathbf{C} = \begin{pmatrix} 0.518 & 0 \\ 0 & 0.174 \end{pmatrix}$$

Coordinate Transformations

Transforming data from one coordinate system to another for representation

Orthographic Projection

Perspective Projection

Signals and Functions

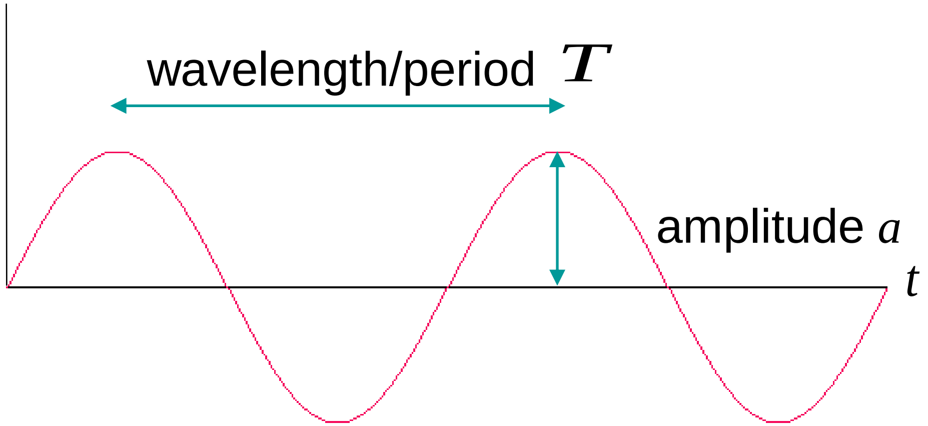
A signal is a physical quantity that is a function of one or more independent variable(s), such as space and/or time.

Data from a Gene pool

Position of a car in a video sequence

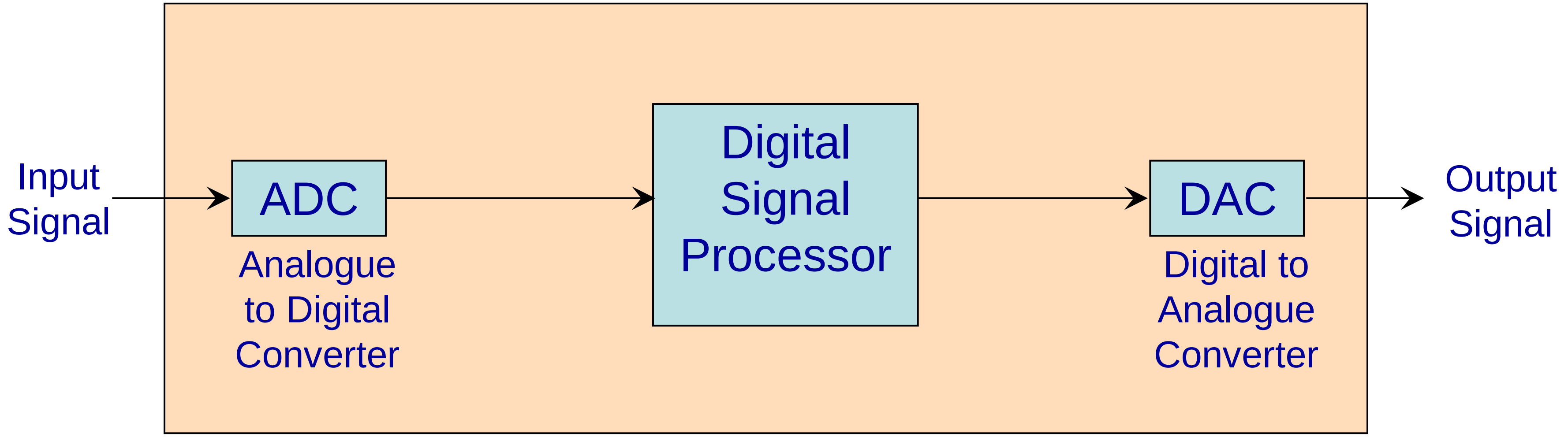
Example signals:

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



What is DSP?

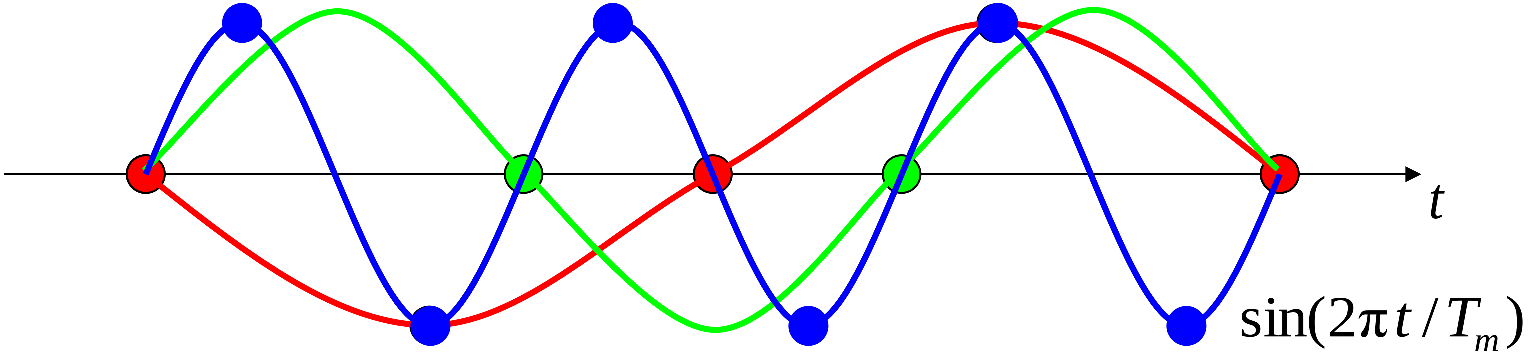
- **Digital Signal Processing** – the processing or manipulation of signals using digital techniques



Shannon’s Sampling Theorem

“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 criterion: sampling frequency should be at least twice the highest spatial frequency.

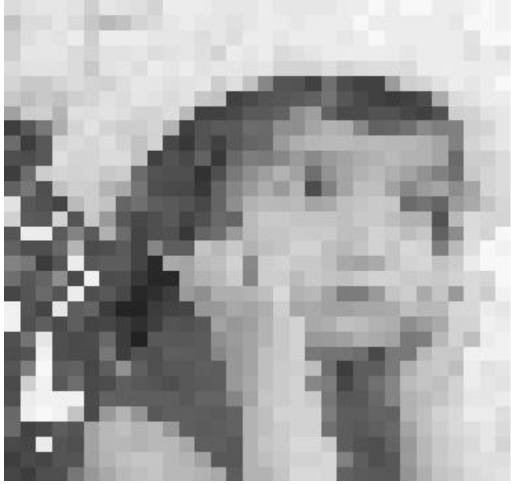


Sampling

The effect of sparser sampling…is ALIASING

256 x256

64x64



32x32

Anti-aliasing achieved by filtering to remove frequencies above Nyquist limit.

Quantization

This results from representing a continuously varying function *f(x)* with a discrete one using quantization levels

16 levels

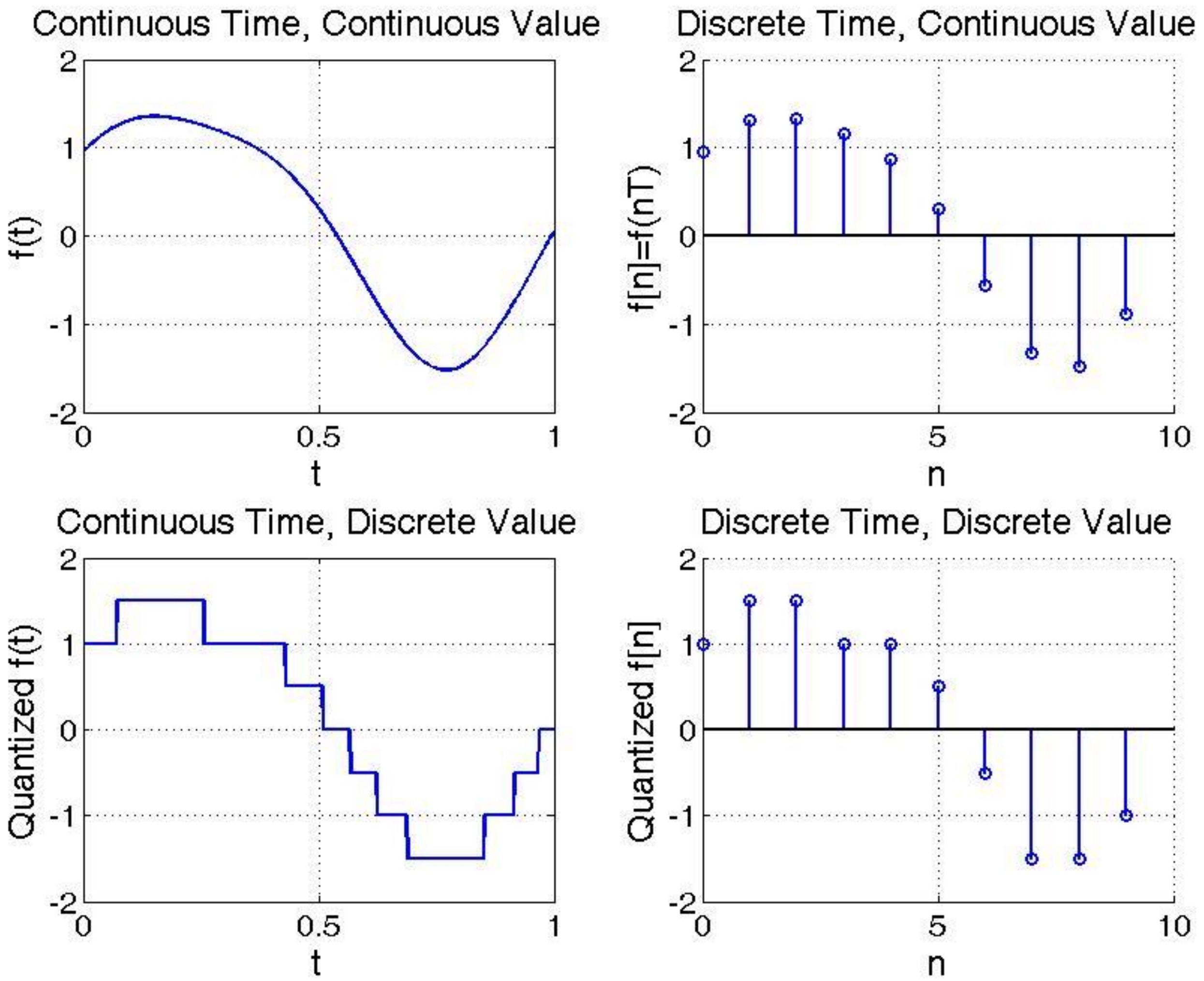
6 levels

2 levels

- Matlab code:

```
F = imread('romina.gif');
[X, map] = gray2ind(F, 16);   // 2, 6, or 16
imview(X, map);
```

Signal Processing



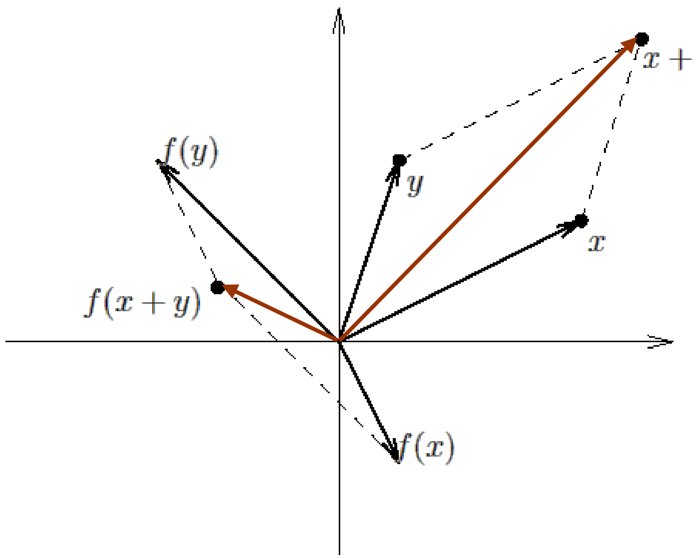
Linear Systems

- 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.



Linearity allows us to decompose our input into smaller, elementary objects. Output is the sum of the system's response to these basic objects.

Linear Systems

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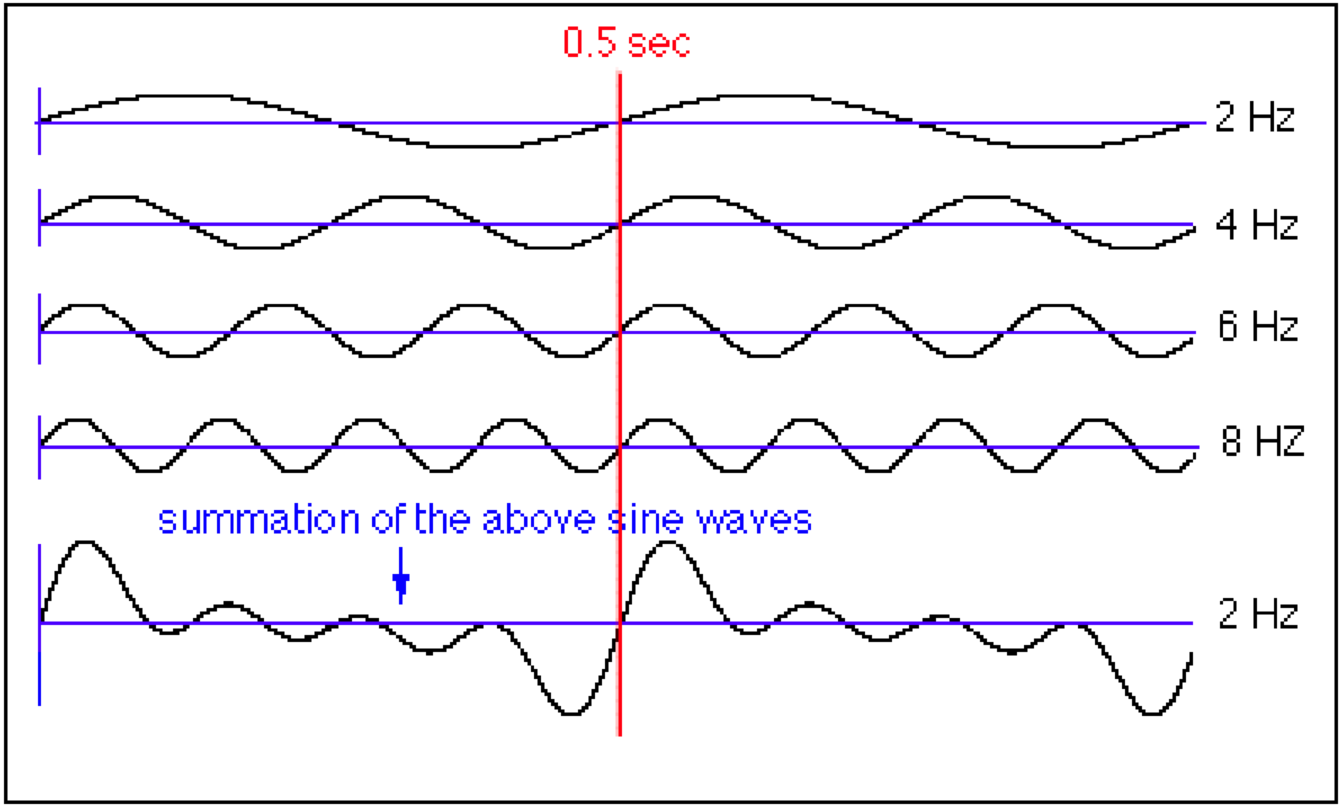

Linear Systems

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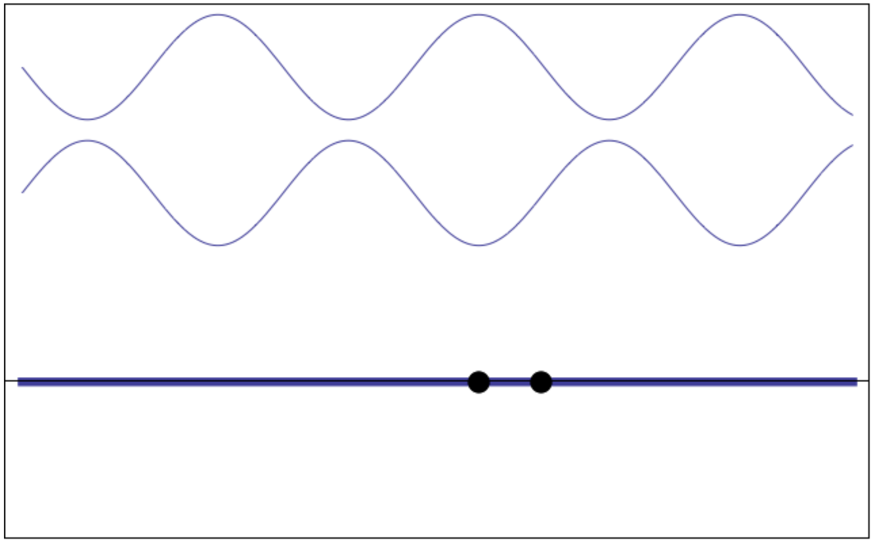
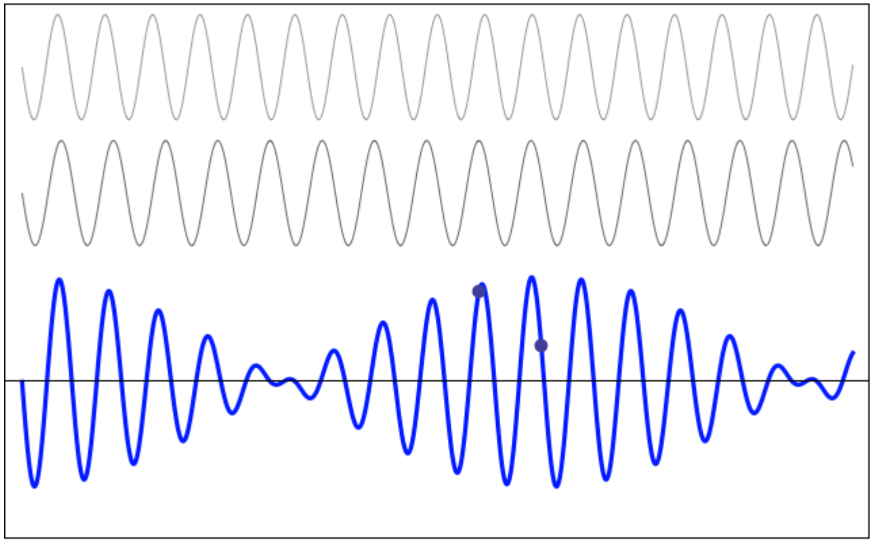
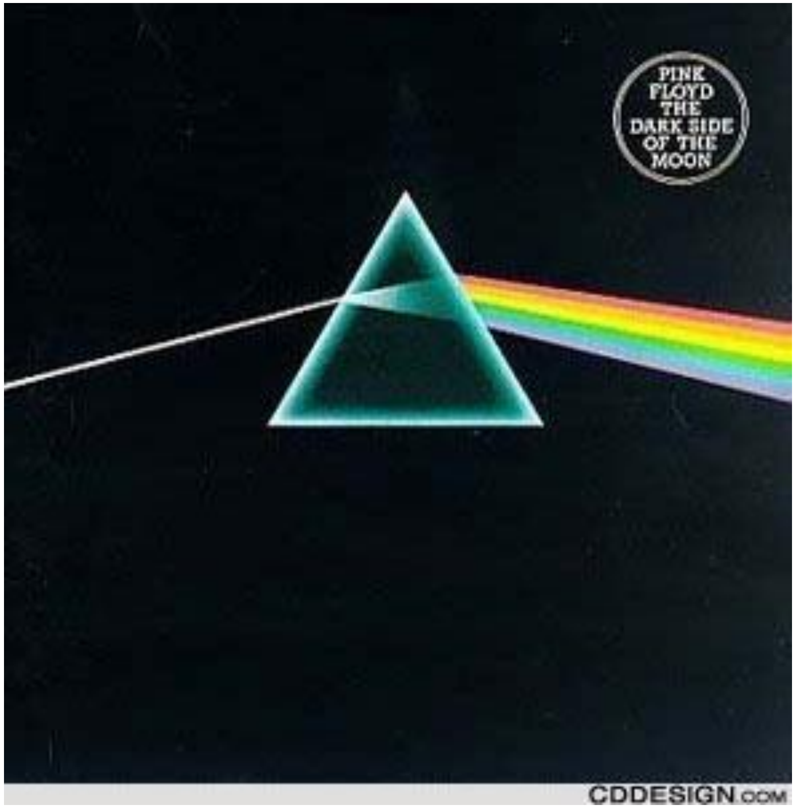




Animations courtesy of Dr. Dan Russell, Grad. Prog. Acoustics, Penn State

Example: White Light?

White light is made up of variable wavelengths of each component color.



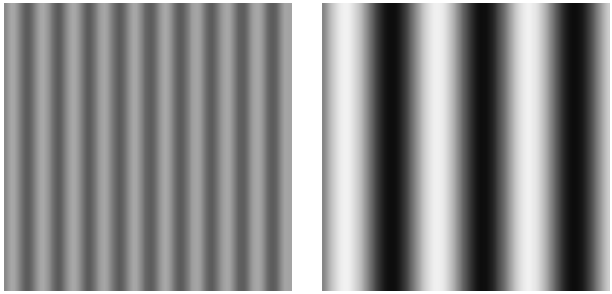
AAAAATAAAAA

0000001000000

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

Basic signals…

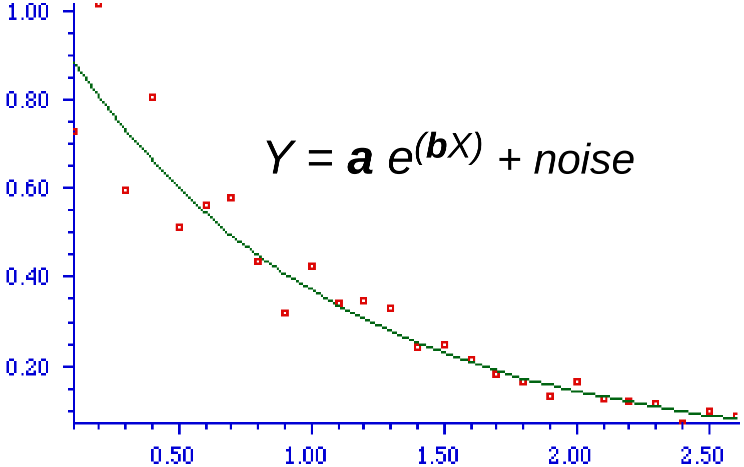
*x = sin(t) = sin(t+2****π****)*

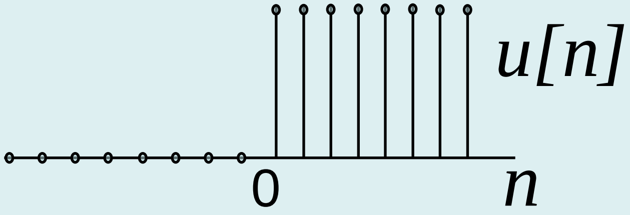


Some basic signals:

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

All signals can be represented by these basic signals!





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

Overview of next few lectures

- Fourier Series
- 1D and 2D Fourier Transform
- Convolution
- Feature Selection and Extraction
- PCA
- Coordinate transformations