Biomedical Signal Analysis

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Biomedical Signal Analysis

- Signals in Medicine
  - **1D:** EEG,EMG,EOG, ECG, etc.,
  - **2D:** X-ray films, USG, MRI, CT, Nuclear Medicine, etc
  - **3D:** MRI, CT, video, etc.

Signal

– **Analog Signal:** It is a signal that has a continuous nature rather than a pulsed or discrete one.

– **Digital Signal:** only takes discrete values

- **Analog** and **digital signals** are used to transmit information, usually through electric signals.
- In both these technologies, the information, such as any audio or video, is transformed into electric signals.

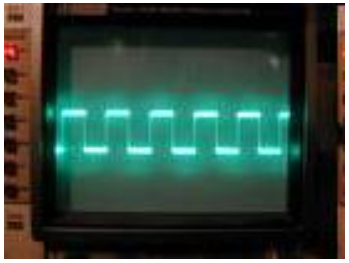
- The **difference between analog and digital** technologies is that in analog technology, information is translated into electric pulses of varying amplitude. In digital technology, translation of information is into binary format (zero or one) where each bit is representative of two distinct amplitudes.

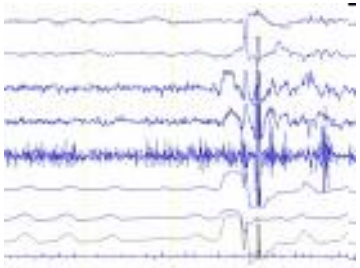
Analog Signal

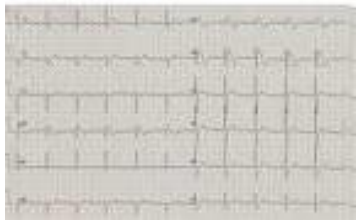
Analog Signal varies in a continuous manner.

Because of a continuous function It consists of infinite number of values.

Examples: signals on oscilloscope/CRT-screen (TV signals on CRT-screen, Rx films, EEG, EMG, ECG signals & anjiography images on CRT-screen/paper) etc.



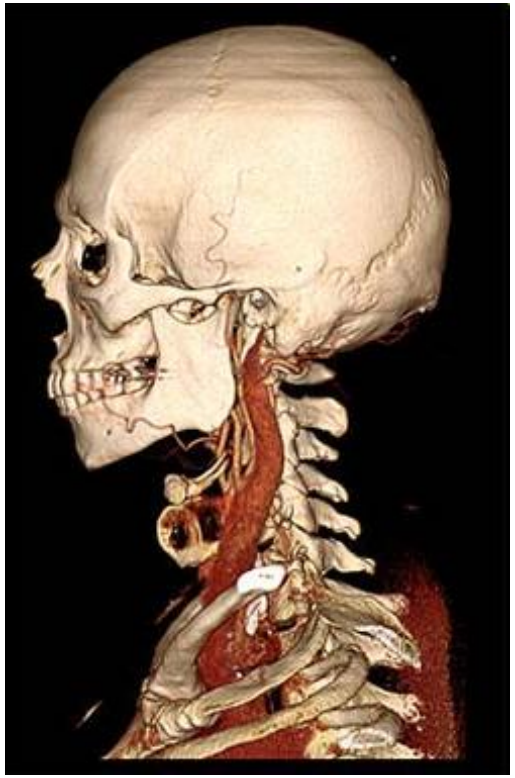




Digital Signal

Digital Signal takes only discrete & computer-storable values.

Examples: ECG / EEG/ EMG, ultrasonography/ echocardiography signals etc.

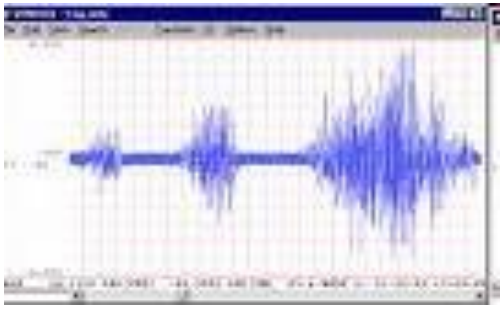


Digital signals = vector or matrix of finite numbers

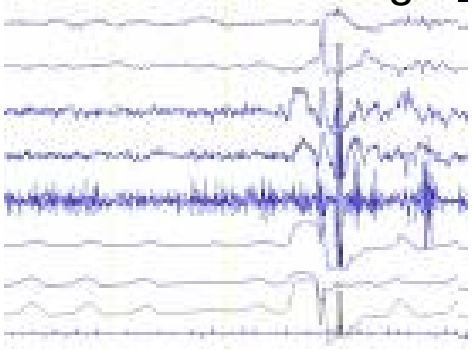
Types of Signals-1D

1D: amplitude vs. time signals (EEG/ EOG/ ECG/ EMG) etc.

1D signal

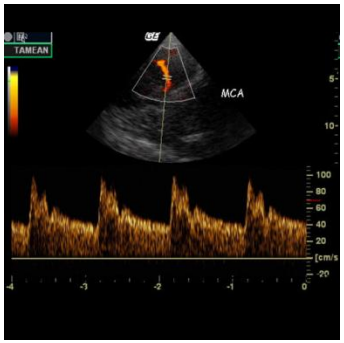


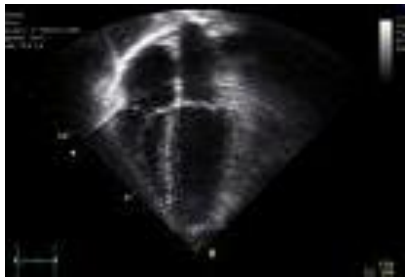
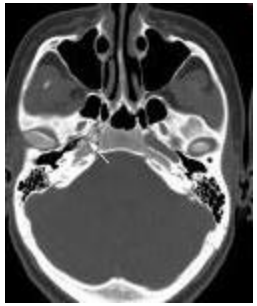
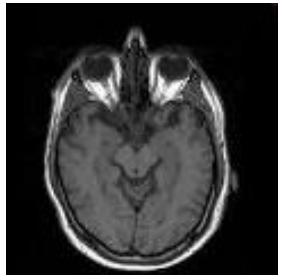
multichannel 1D signal



Types of Signals-2D

~images (Rx, one slice of USG, Doppler, CT, MR signals etc.) etc.

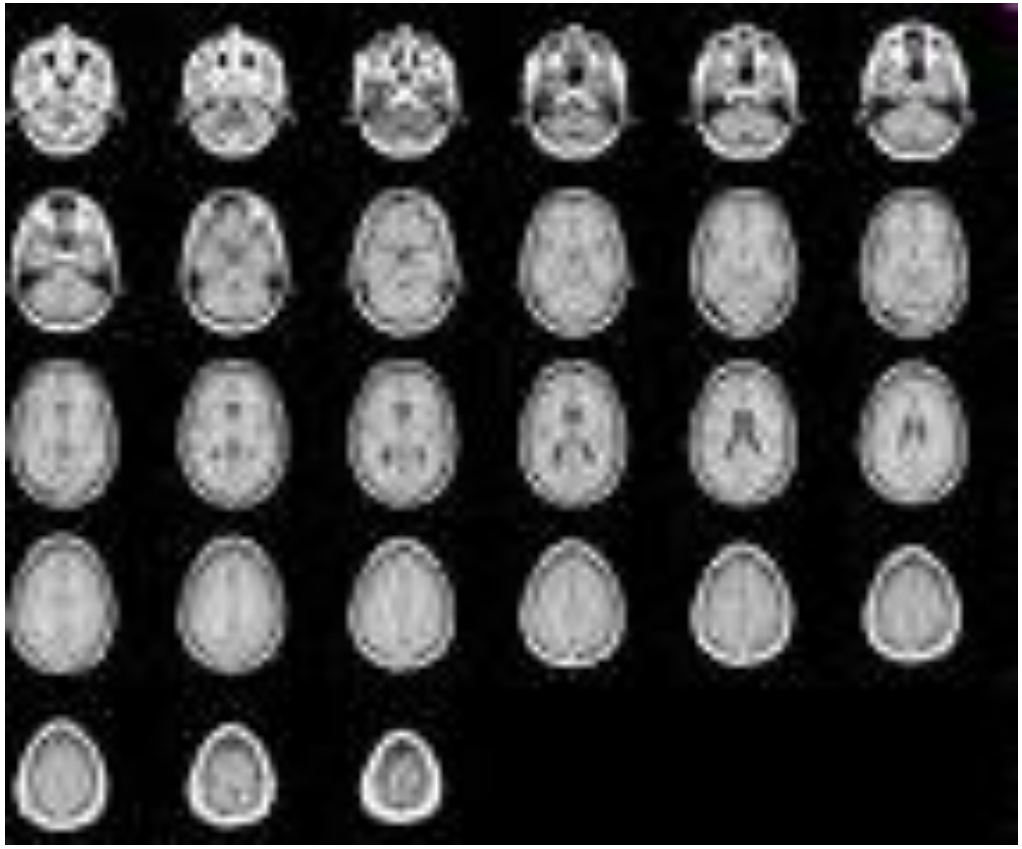



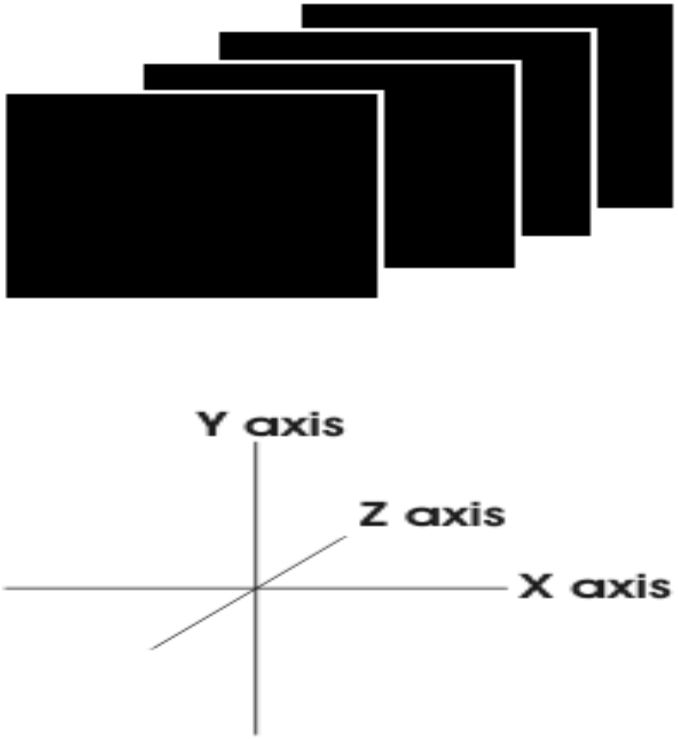







Types of Signals-3D

video (echocardiography,USG video signals etc.), **3D** MR, **3D** CT data

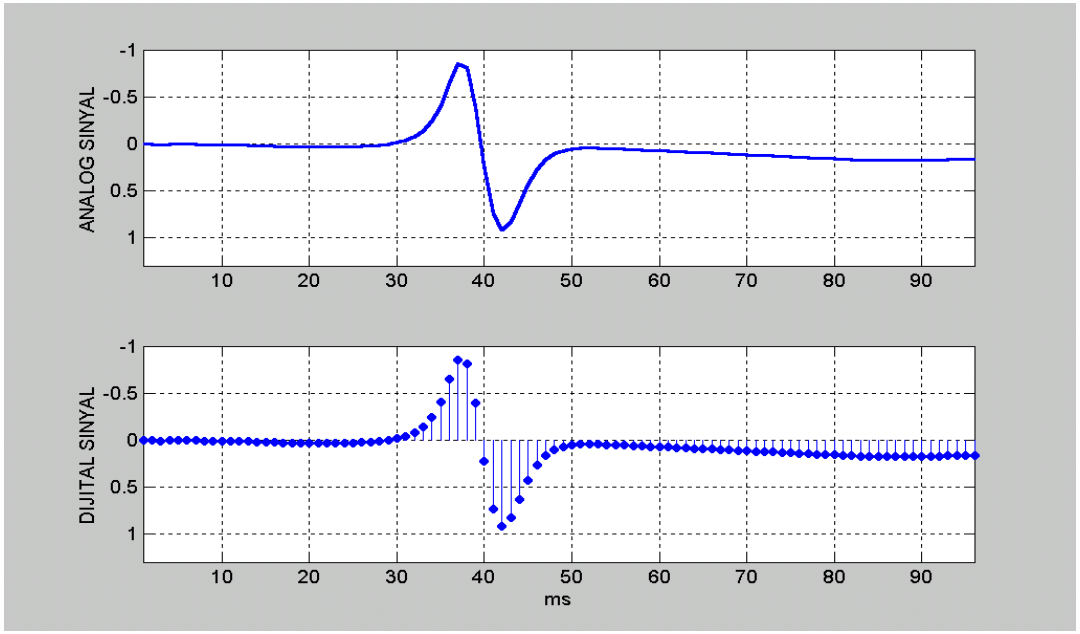




- We need to convert analog signals to digital numbers
- **OTHERWISE**
  - We cannot display them on digital screens.
  - We cannot store them on servers/computers
  - We cannot apply digital filters on them (to remove noise etc.)
  - We cannot make automatic calculations on them
  - WE CANNOT EVALUATE AND USE EASILY.
  - etc.

SAMPLING OF 1D SIGNALS

Sampling Period (T): the time between 2 consecutive samples.
Sampling rate/frequency (f_s=1/T): acquired samples in one seconds.



ALIASING

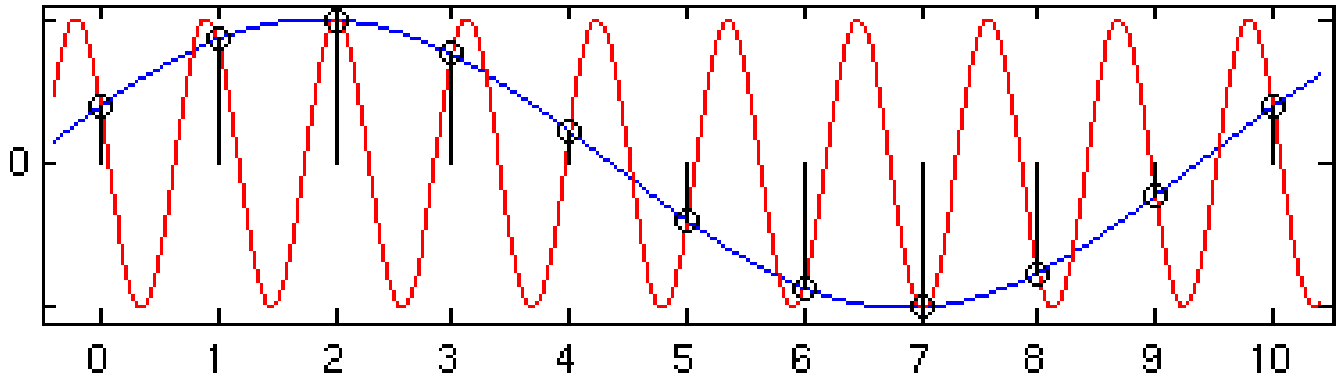
A type of distortion that occurs when digitally recording high frequencies with a low sample rate.

Circles: Sampled signal points

Red: Analog signal,

Blue: Reconstituted (from sampled points) analog signal

NOTE THAT aliasing occurs (Volt vs. second)



SAMPLING OF 2D SIGNALS

There are TWO sampling rates (or periods) for 2 dimensions.

X-Ray film

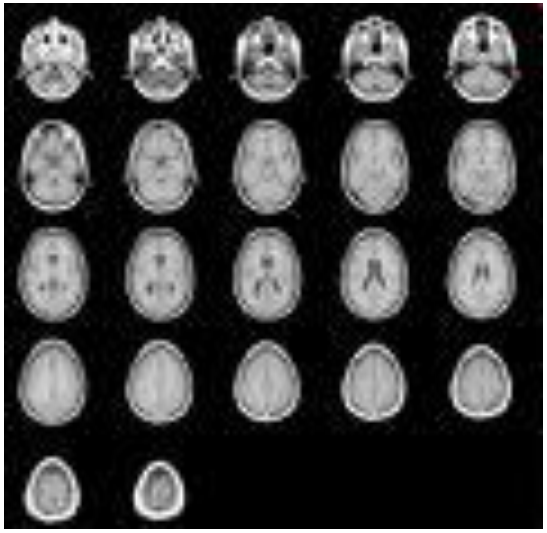
=>

2D matrix of numbers

...	...	...	...	...
...	256	127	46	...
...	256	121	46	...
...	128	110	45	...
	...	...	...	...

SAMPLING OF 3D SIGNALS

There are THREE sampling rates/periods for 3 dimensions.



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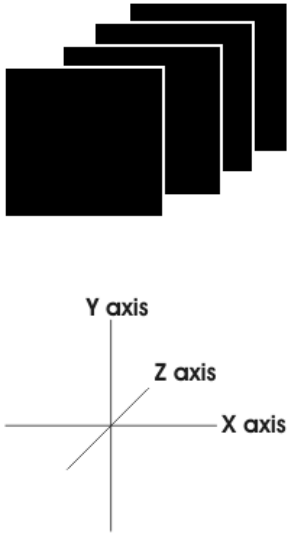
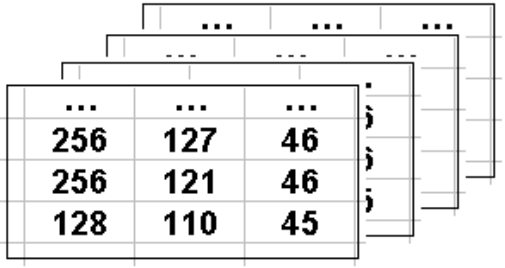


=>

3D matrix of numbers

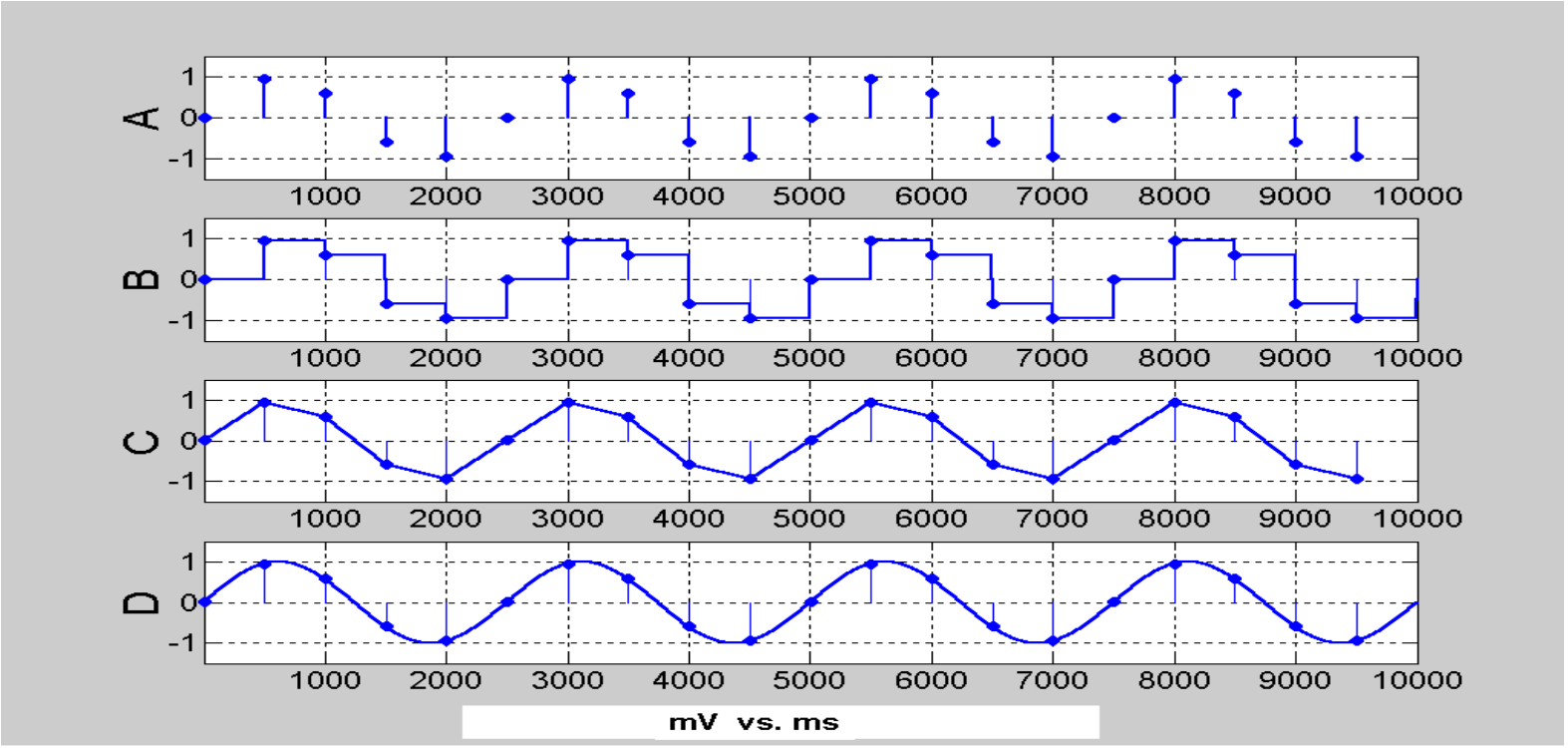


Interpolation, Decimation and Downsampling of Digitial Signals

- **Interpolation** is a method of constructing new data points within the range of a discrete set of known data points.
- **Downsampling** (or "subsampling") is the process of reducing the sampling rate of a signal.
- **Decimation** is a technique for reducing the number of samples in a digital signal. It is a two-step process:
  - 1. Low-pass anti-aliasing filter, then
  - 2. Downsampling

Interpolation in 1D- 1

- There are many methods for interpolation
- In the following figure, empty parts of the signal in **A**, were filled with different (**B**, **C**, **D**) interpolation methods

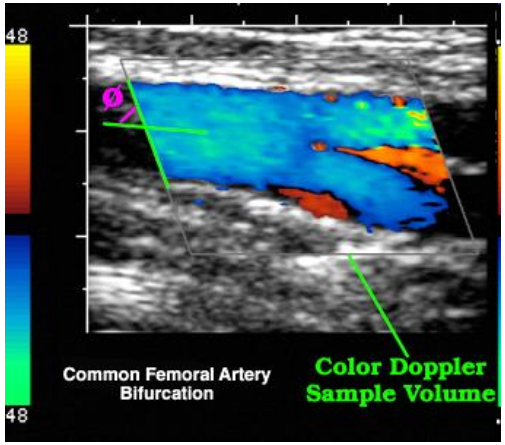


Interpolation in 1D- 2

- Interpolation increases size of signal vector/matrix
- X:original signal
- Y: interpolated signal
- Length of Y > Length of X

Interpolation in 2D- 1

- There are many methods for interpolation in 2D also
- Example: In color doppler imaging (CDI), every color corresponds to a velocity
  - Many pixel are INTERPOLATED on the image.
  - Question marks are filled w.r.t. their neighbours
  - Sometimes, errors can be seen due to interpolation



Interpolation in 2D- 1

- There are many methods for interpolation in 2D also
- Example: In color doppler imaging (CDI), every color corresponds to a velocity
  - Many pixel are INTERPOLATED on the image.
  - Question marks are filled w.r.t. their neighbours
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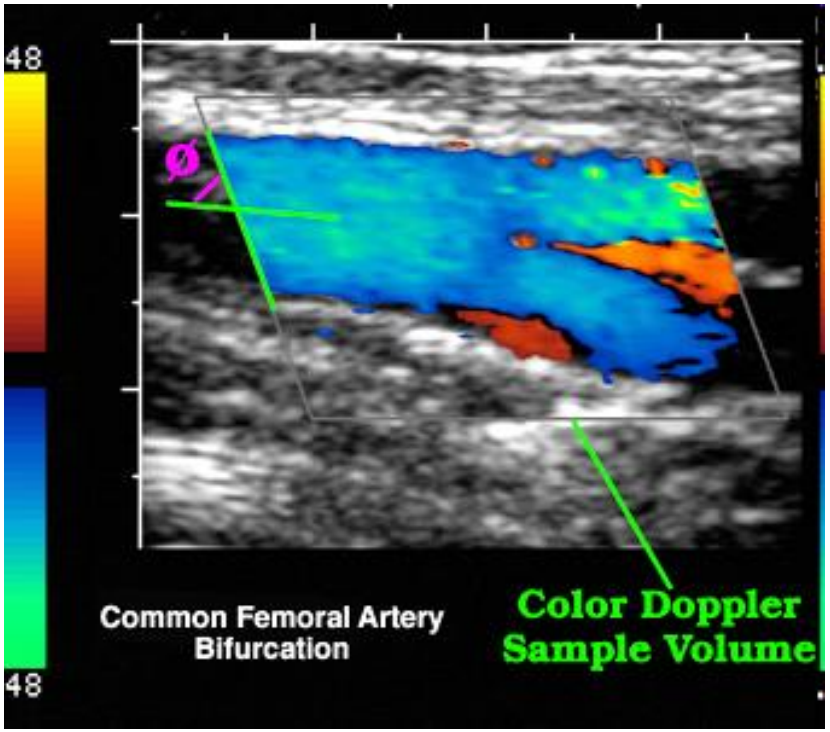
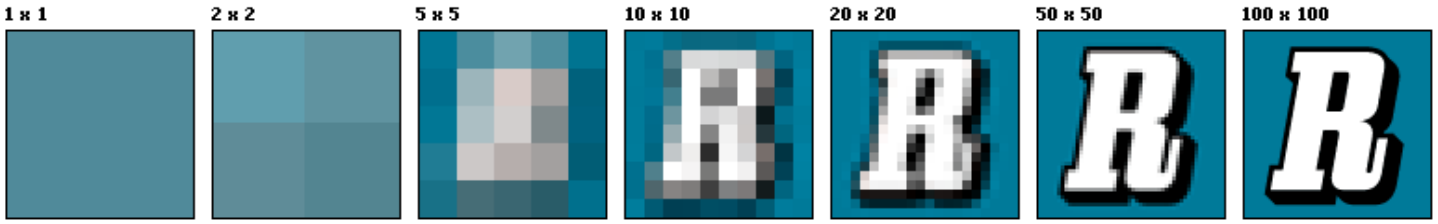


Downsampling & Decimation

- Downsampling/decimation decreases size of signal vector/matrix
- X:original signal
- Y: downsampled signal
- Length of Y < Length of X

More Definitions

- **Amplitude:** greatness of magnitude
- **Resolution:** capability of making distinguishable the neighbour parts of an object.
- There are many definitions w.r.t. topic (CT, MRI, USG videos, images etc.).
  - The term *resolution* is often used as a pixel count in digital imaging etc.



DIGITAL SIGNAL COMPRESSION

- Definitions
  - 1 Byte=8-bit
  - 1 KByte=10^3 byte,
  - 1 MByte=10^6 byte,
  - 1 GByte=10^9 byte,
  - 1 TByte=10^{12} byte,

EXAMPLES

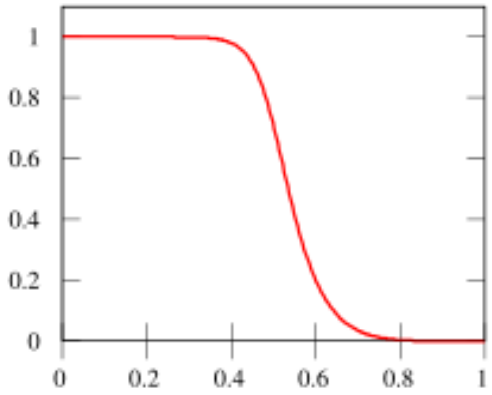
- An ECG signal: 16-bit x 1000 sample/sec
  - Bit-rate (Byte/s)=16,000 bit/s=2 KByte/s
  - Traditional ECG has 10 channels, so Bit-rate= 8x20 KByte/s
- a Rx image has 4000x4000 pixel and each pixel is represented with 16 bit gray value => 4000x4000x2 bytes =32 MBytes
- A medical video has 24 bits RGB pixels +1000x600 image frames + 30 fps video speed (3x1000x600@30 fps).
  - Bit-rate =8x3.1000.600.30 Byte/s=54.10^6 Byte/s ≈ 4.10^8 Bit/s
- Compressing medical signals for video and Rx is a requirement

Filters

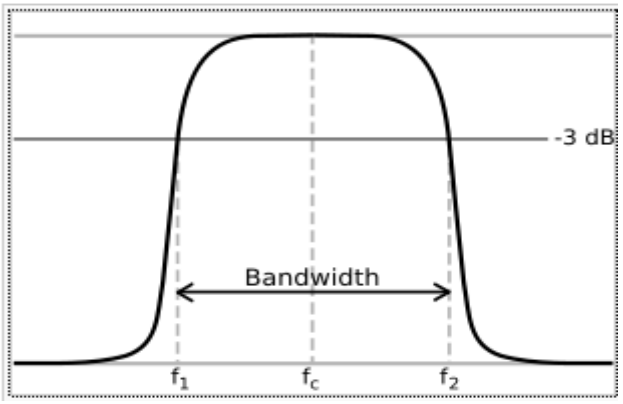
- Filters are devices/programs so that stop or pass some parts of frequency spectrum.
- **Low pass filter**: passes only low frequencies
- **High pass filter**: passes only high frequencies
- **Band pass filter**: passes only a band of spectrum
- **Band stop filter**: stops only a band of spectrum

Filter Types

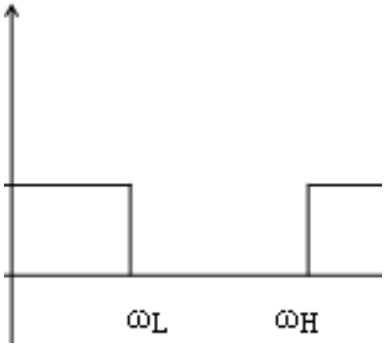
(Filter Amplitude vs. Frequency graphs of filters)



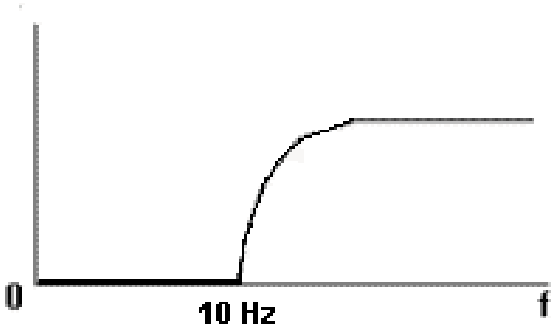
Low Pass (LP) filter, cut-off frequency is 0.5 Hz



Band Pass (BP) filter, cut-off frequencies are f_1 and f_2



Band Stop (BS) filter, cut-off frequencies are w_L and w_H



High Pass (HP) filter, cut-off frequency is 10 Hz