Digital Signal Analysis and Processing

Report about blood pressure and ways to reduce noises from signals

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Blood pressure

What is blood pressure?

Blood is carried around the body in tubes called blood vessels.The pumping of the heart keeps blood moving through the blood vessels.

Blood pressure is the measurement of the pressure in the walls of bigger blood vessels called arteries.
High blood pressure is also called hypertension. It can be very dangerous if left untreated..

What is normal blood pressure?

Blood pressure varies from moment to moment. It is affected by many factors including breathing, body position, emotional state, exercise, sleep, medicines and alcohol .
Normal blood pressure is less than 130/85 mmHg.
You need more than one high reading to confirm you have high blood pressure.

What causes high blood pressure?

- Family history
- Being overweight
- Poor diet
- Too much salt
- Drinking too much alcohol
- Not exercising
- Cigarette smoking
- Kidney problems

This table shows the stages of blood pressure

BLOOD PRESSURE CATEGORY	SYSTOLIC mm Hg (upper number)		DIASTOLIC mm Hg (lower number)
NORMAL	**LESS THAN 120**	**and**	**LESS THAN 80**
ELEVATED	**120 – 129**	**and**	**LESS THAN 80**
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 1	**130 – 139**	**or**	**80 – 89**
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 2	**140 OR HIGHER**	**or**	**90 OR HIGHER**
HYPERTENSIVE CRISIS (consult your doctor immediately)	**HIGHER THAN 180**	**and/or**	**HIGHER THAN 12**

Talking about physiology!

During each heartbeat, blood pressure varies between a maximum (systolic) and a minimum (diastolic) pressure. The blood pressure in the circulation is principally due to the pumping action of the heart. Differences in mean blood pressure are responsible for blood flow from one location to another in the circulation. The rate of mean blood flow depends on both blood pressure and the resistance to flow presented by the blood vessels. Mean blood pressure decreases as the circulating blood moves away from the heart through arteries and capillaries due to viscous losses of energy. Mean blood pressure drops over the whole circulation, although most of the fall occurs along the small arteries and arterioles Gravity affects blood pressure via hydrostatic forces (e.g., during standing), and valves in veins, breathing, and pumping from contraction of skeletal muscles also influence blood pressure in veins.

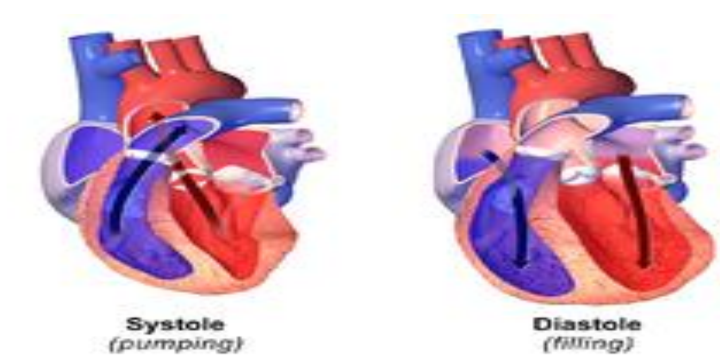

Figure 1

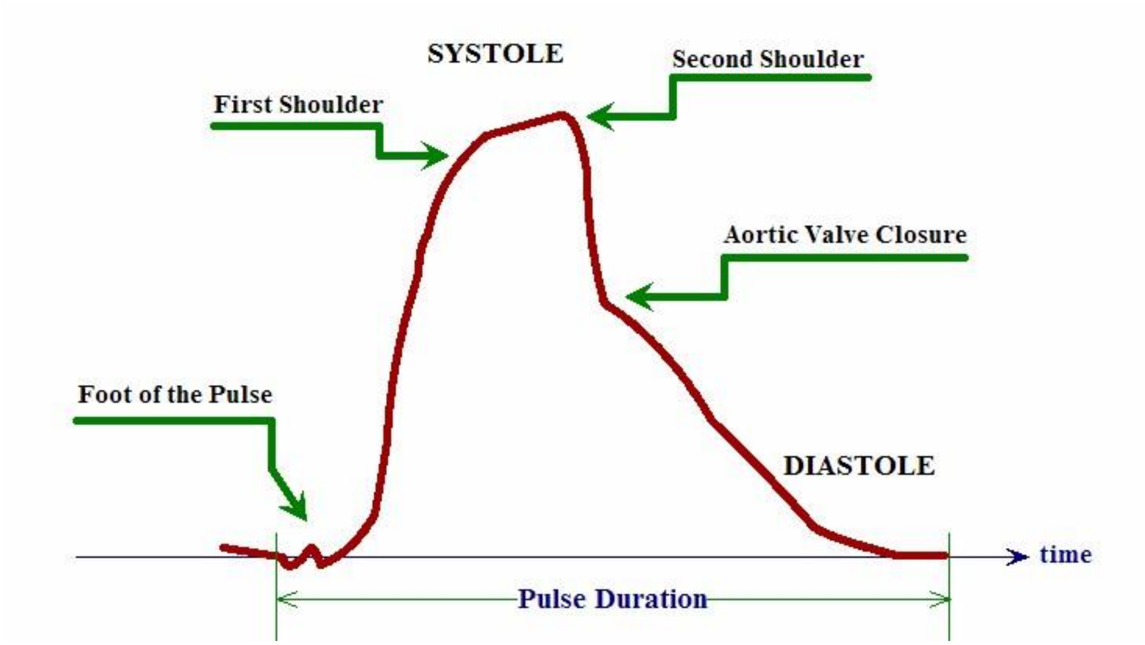

Figure 2

At the beginning of the pumping cycle, the Left Atrium has already received fresh oxygenated blood from the lungs by virtue of the Pulmonary Veins of the Pulmonary Circulation System (see Figure 2). From the Left Atrium, the blood enters the Left Ventricle through the Mitral Valve

The contraction of the heart at this point of time leads to pumping of the blood from the Left Ventricle into the Aorta, which is a major human artery. The heart begins to eject blood through the arteries after the foot of the pulse. This leads to an increase in blood flow through the arteries of the body leading to an increase in the Blood Pressure. The pressure wave rises to an initial peak where the First Shoulder is marked. The pressure then proceeds to a Second Shoulder, typically the peak pressure value in elderly people. The First Shoulder marks the timing of peak flow, whereas the Second Shoulder relates to reflected waves. The end of blood ejection from the heart is associated with the closure of the aortic valve, which is often seen as a distinct notch on the aortic pressure pulse. After this phase, there is a gradual decline in the pressure during the Diastole, due to the absence of blood flow from the ventricle. The deoxygenated blood from all the capillaries flows through the major veins: the superior and the inferior vena-cavae, back to the Right Atrium through the Tricuspid Valve. From here, the blood flows into the Right Ventricle.

Filtering out the noise..

Most of the time when we measure signals we always end up with some kind of noises.

These noises make the signal hard to read or even effect the processing we are trying to make!

The following plot exemplifies an observed signal (in blue) with noise and the underlying signal without noise (in red).

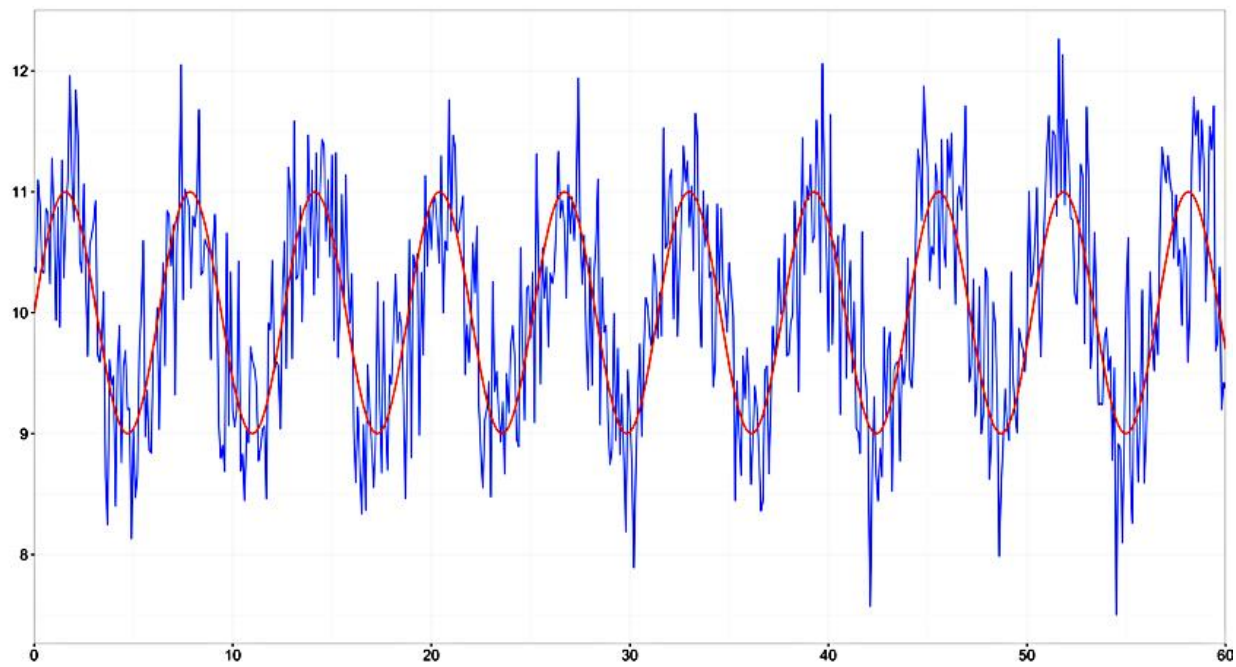

Figure 3

How to remove noise?

Over multiple decades, a large amount of work has been done is many different fields – such as, but not limited to, signal processing, statistics, information theory – to improve the *signal-to-noise ratio (SNR)*. Noise reduction plays a key role is large set of applications beyond operations, e.g., image/audio/video processing.

A wide variety of filters have been proposed to address noise reduction. Broadly speaking, filters can be classified into two categories:

1-Low pass filter: It passes signals with a frequency lower than a certain cut-off frequency and attenuates signals with frequencies higher than the cut-off frequency. In the context of a time series.

A simple moving average (MA) exemplifies a low pass filter.

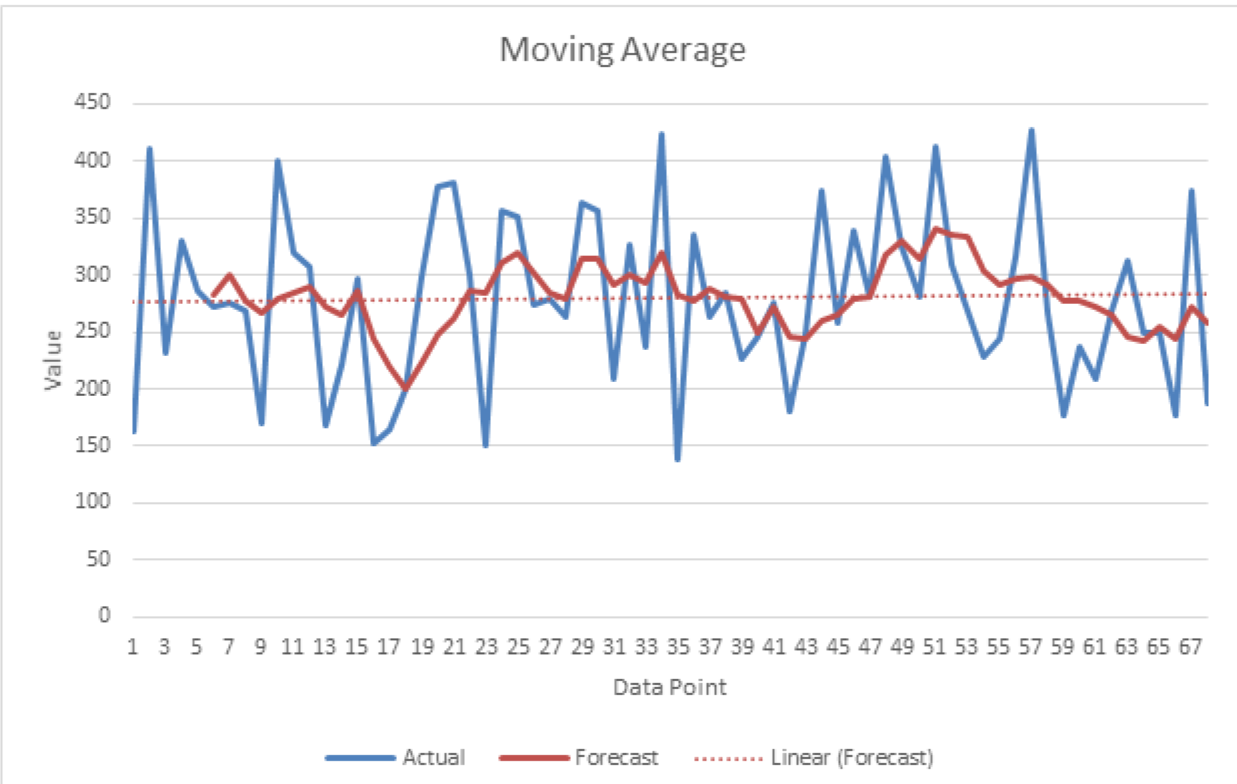

Figure 4

Basically..

As the filter length increases (the parameter M) the smoothness of the output increases, whereas the sharp transitions in the data are made increasingly blunt. This implies that this filter has excellent time domain response but a poor frequency response.

The MA filter perform three important functions:

1) It takes M input points, computes the average of those M-points and produces a single output point
2) Due to the computation/calculations involved , the filter introduces a definite amount of delay
3) The filter acts as a Low Pass Filter (with poor frequency domain response)

2-High pass filter: It passes signals with a frequency higher than a certain cut-off frequency and attenuates signals with frequencies lower than the cut-off frequency.

There are many examples of high pass filter Depending on the requirement, either linear filters (such as SMA) or non-linear filters (such as median filter) can be used. Some common filters used are Kalman filter, Recursive Least Square (RLS), Least Mean Square Error (LMS), Wiener-Kolmogorov Filters.

For example Median filter is the nonlinear filter more used to remove the impulsive noise from an image, so it is a more robust method than the traditional linear filtering, because it preserves the sharp edges.

Median filter is a spatial filtering operation, so it uses a 2-D mask that is applied to each pixel in the input image. To apply the mask means to center it in a pixel, evaluating the covered pixel brightness's and determining which brightness value is the median value. Figure presents the concept of spatial filtering based on a 3x3 mask, where I is the input image and O is the output image.

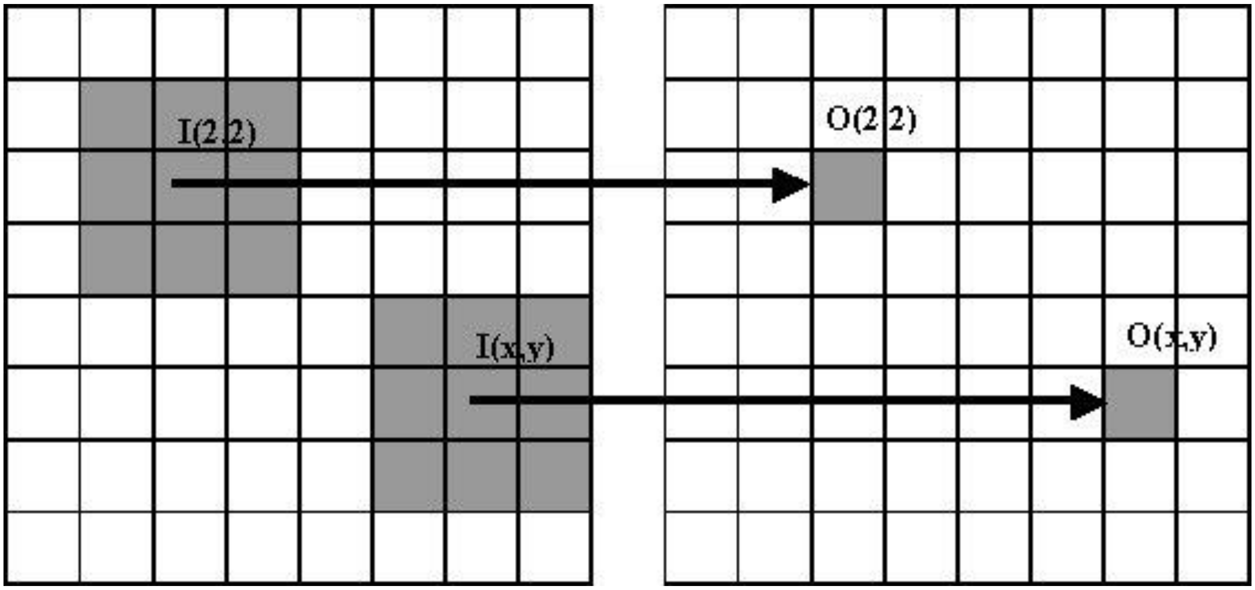

Figure 5

Here is a beautiful example of how the Median filter reduce the noise of an image

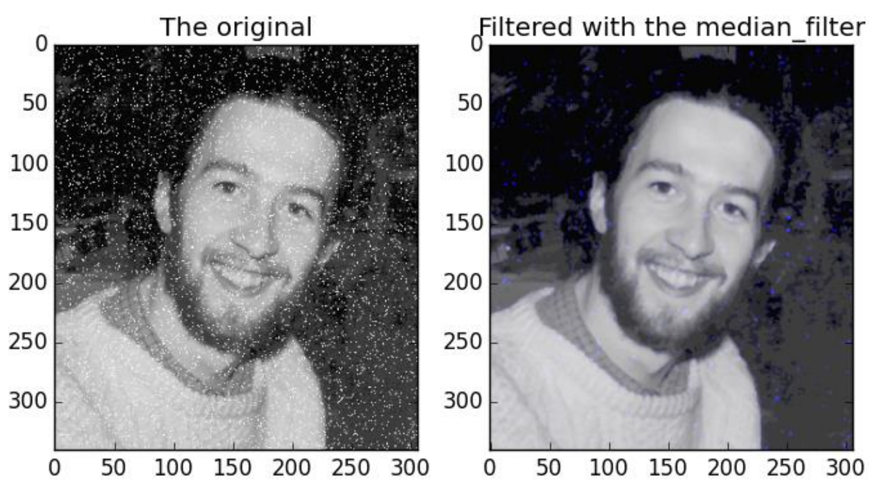

Figure 6

Furthermore, Low-pass and high-pass filter are implemented in the common electrophysiology software packages. Attenuating high-frequency components with a low-pass filter smoothens the filter output. Attenuating DC (“direct current”) offset and low-frequency components with a high-pass filter forces the filter signal to return to zero amplitude1. The choice of the cutoff frequency defines how fast the filtered signal converges to zero following signal deflections: the higher the cutoff frequency, the faster the filtered signal converges to zero due to the attenuation of low frequencies. Note that zero-phase filters introduce a symmetric change in the signal around a step, i.e., before and after the step.

These types of filter distortions can easily be observed in the step response. The evaluation of the step response intuitively helps one to understand that both low-pass and high-pass filters smear the signal in the time domain. In most electrophysiology software implementations, the roll off characteristics (or transition bandwidth) of the high-pass and low-pass parts have to be identical (with the exception of, e.g., the MATLAB filter de-sign tool).

However, high-pass filters are frequently needed in applications such as event-related potentials/fields (ERP/Fs) to achieve the intended low cutoff frequencies, while on the other hand the low-pass transition could be designed significantly shallower. Shallower filters are widely recommended as they produce less signal distortions and spread them less in the time domain due to their shorter impulse response.

Back to blood pressure..

How to remove Noise from the Measurement of blood pressure?

There are many filters to use to filter out the noise from BP signals I have chosen a filter called Butterworth filter

The frequency response of the Butterworth filter is maximally flat (i.e. has no ripples) in the pass band and rolls off towards zero in the stop band. When viewed on a logarithmic Bode plot, the response slopes off linearly towards negative infinity. A first-order filter's response rolls off at −6 dB per octave (−20 dB per decade) (all first-order lowpass filters have the same normalized frequency response). A second-order filter decreases at −12 dB per octave, a third-order at −18 dB and so on. Butterworth filters have a monotonically changing magnitude function with ω, unlike other filter types that have non-monotonic ripple in the passband and/or the stop band.

Compared with a Chebyshev Type I/Type II filter or an elliptic filter, the Butterworth filter has a slower roll-off, and thus will require a higher order to implement a particular stopband specification, but Butterworth filters have a more linear phase response in the pass-band than Chebyshev Type I/Type II and elliptic filters can achieve.

You can get your high and low cutoff using the equation

W1=(Low_Cuttoff)/(Fs/2);% lower cutoff frequency

W2=(High_Cuttoff)/(Fs/2);% higher cutoff frequency

Basically if you have a low-pass filter with a cutoff of **20** Hz and a sampling frequency (Fs) of **2500** Hz, you would define:

Fs = 2500;

Fco = 20;

Fn = Fs/2;

W1 = Fco/Fn;

Matlab code of Butterworth filter!

```
%%this code is for general use to filter blood pressure signal
load('BP DATA') %my blood pressure signal
 x1=val(1,:);



W1=(Low_Cuttoff)/(Fs/2);% lower cutoff frequency
W2=(High_Cuttoff)/(Fs/2);% higher cutoff frequency

[b,a]=butter(2,[W1,W2]); % Bandpass digital filter design
h = fvtool(b,a); % Visualize filter
low_pass_data1 = filtfilt(b,a,x1); % applying filter to our data

subplot (2,1,1)
plot (x1)
axis auto;
xlabel('Time index n');
ylabel('Amplitude');
title('blood pressure signal with noise');
grid;
subplot (2,1,2)

plot (low_pass_data1)
axis auto;
xlabel('Time index n');
ylabel('Amplitude');
title('blood pressure signal after filtering');
grid;
```