ECG signal conditioning by morphological filtering

Biomedical Signal Processing – Unimi

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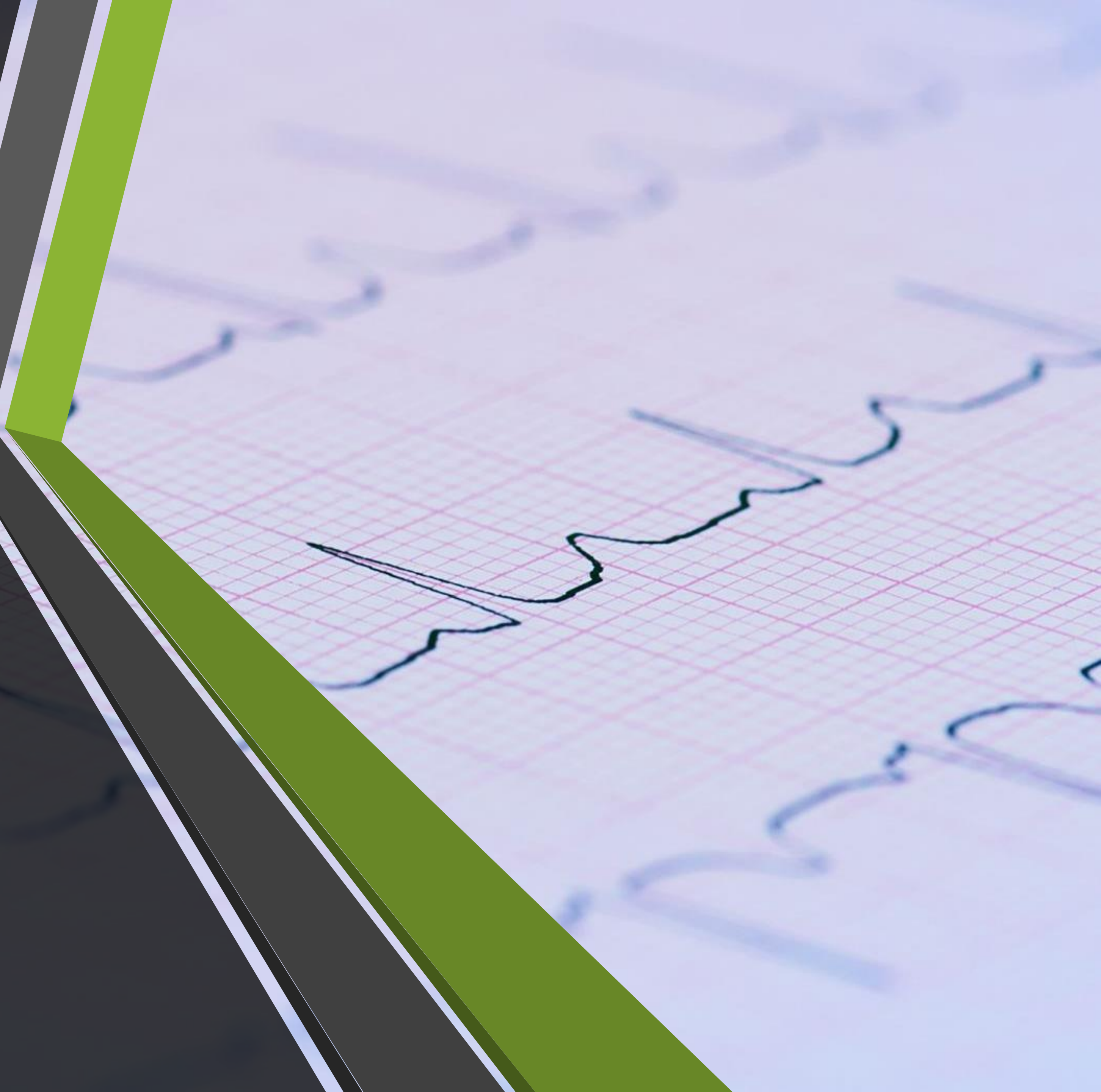


Introduction

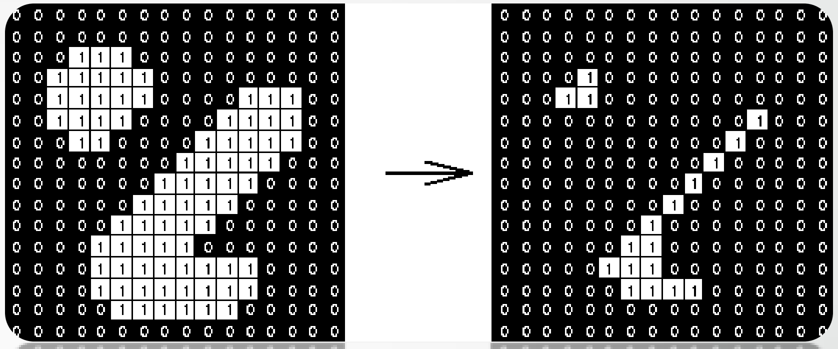
- Clinically obtained electrocardiographic (ECG) signals are often contaminated with different types of noise and baseline drifting commonly occurs.
- A modified morphological filtering (MMF) technique is used for signal conditioning in order to accomplish baseline correction and noise suppression with minimum signal distortion.

Mathematical Morphology

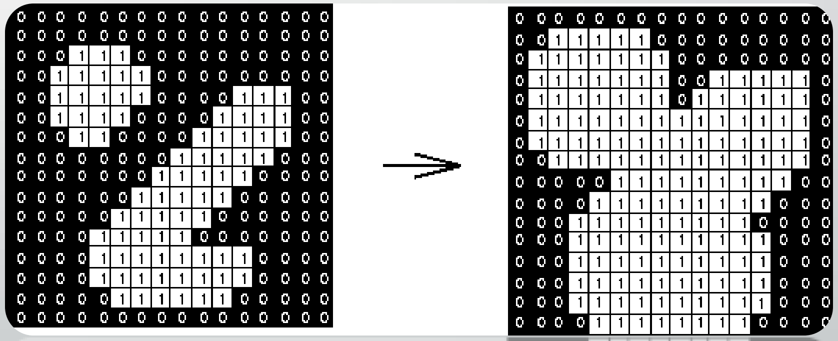
Mathematical morphology (MM) provides an approach to the development of non-linear signal processing methods.

The shape information of a signal can be extracted by using a structuring element to operate on the signal.

There are two basic morphological operators:



Erosion:
removes pixels on object boundaries.



Dilatation:
adds pixels on the object boundaries.

Proposed MMF algorithm for ECG signal conditioning

Corrupted ECG signal (input)

↓

Baseline corrected signal

↓

Noise suppression

↓

ECG signal after conditioning (output)

Algorithm testing using simulated data

- The performance of the algorithm could be evaluated by starting with a known signal, corrupting it by adding noise and baseline drift.

- Noise is modelled by a mixture of Gaussian noise.
- Baseline drift is simulated by adding a slanted line to a sinusoidal signal.

Data extraction

The ECG signals were extracted from MIT–BIH arrhythmia database (physionet.org)

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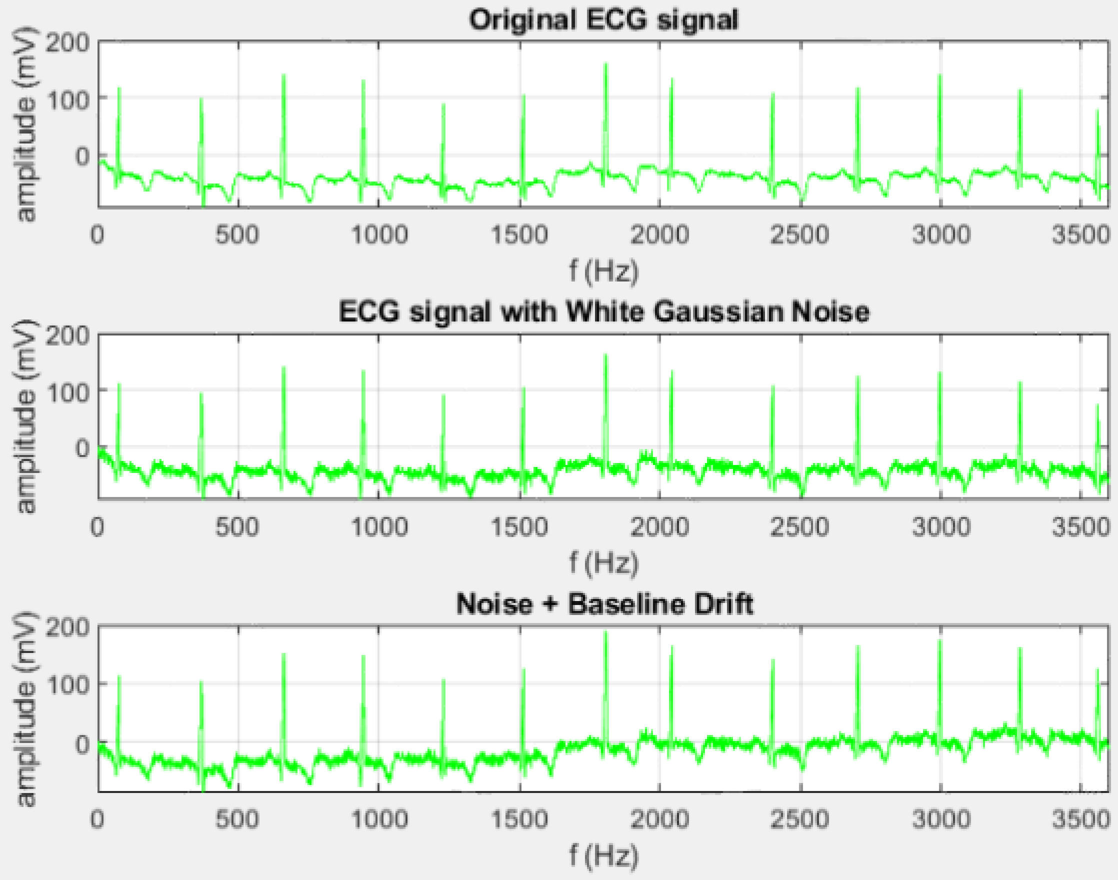
Signal corrupted by adding noise and baseline drift



Baseline correction

- The correction of baseline is performed by removing the drift in background from the original ECG signal.
- It follows Chu's method

The signal is first opened by a structuring element *Bo* for removing peaks in the signal.

Than the resultant waveforms with pits are removed by a closing operation using the other structuring element *Bc*.

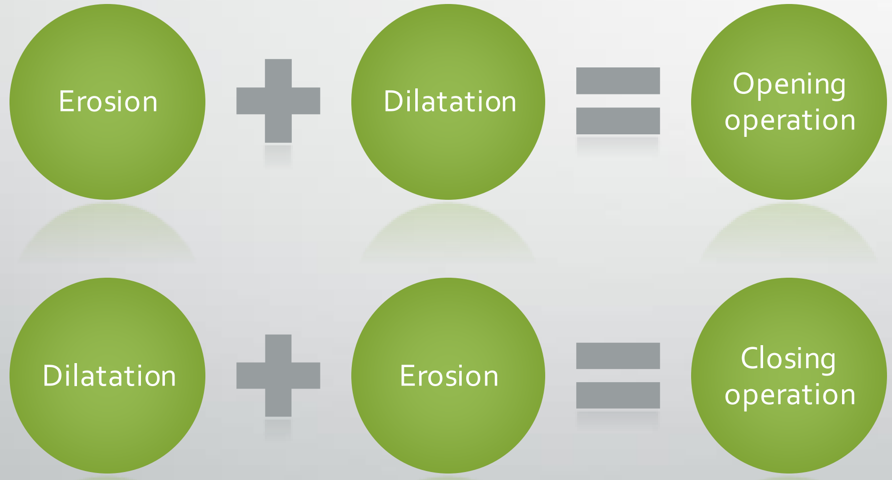
The final result is then an estimate of the baseline drift *f*.

The correction of the baseline is then done by subtracting *f* from the original signal.

Bo and Bc are selected as two horizontal line segments of zero amplitude, but with different lengths

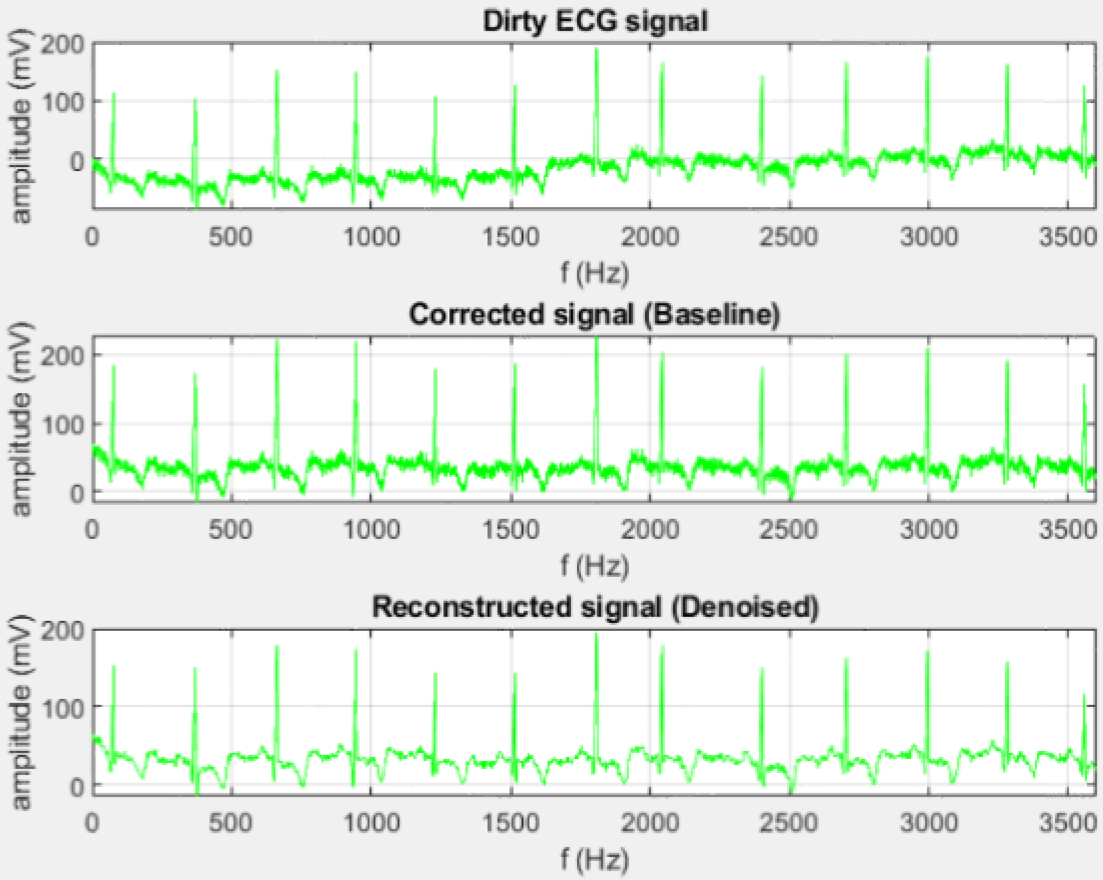
Noise suppression

- After baseline correction, noise suppression is performed by processing the data through an opening and a closing operation concurrently.
- Then the results are averaged.



The operations use a structuring element pair
Bpair = {B1, B2}
where B1 is different from B2

Application of MMF Algorithm



Performance evaluation of signal conditioning

- Three parameters are used for algorithm evaluation:
  - the baseline-correction ratio (BCR),
  - the noise-suppression ratio (NSR),
  - and the signal-distortion ratio (SDR)

$$\mathrm{BCR} = \frac{\sum_{t=1}^{T} \|b(t)\|}{\sum_{t=1}^{T} \|b_o(t)\|},$$

$$\mathrm{NSR} = \frac{\sum_{t=1}^{T} \|n(t)\|}{\sum_{t=1}^{T} \|n_o(t)\|},$$

$$\mathrm{SDR} = \frac{\sum_{t=1}^{T} \|d_o(t) - \mathrm{d}(t)\|}{\sum_{t=1}^{T} \|\mathrm{d}(t)\|},$$

BCR, NSR and SDR for performance evaluation of signal conditioning

1	BCR	NSR	SDR
2	0.672719474032845	0.601273263938964	2.51247298807406
3	0.628505883665629	0.5574965003223	2.63141526677257
4	0.5875052838061	0.513802460530557	2.74116906326739
5	0.647010200571428	0.575851878657107	2.55376896311286
6	1.1924025468865	1.11558527852688	1.74068269529465
7	1.30838903919637	1.23076176952861	1.67184048430231
8	1.06205965226227	0.966900483900009	1.75682566520662
9	1.09852970624177	1.00258396539871	1.73004543855241
10	2.68156421280311	2.59693834657369	1.3292165171567

A = 0.8 mV; N = 60; maxDrift = 50; snr = 20

1	BCR	NSR	SDR
2	0.654533222383351	0.606099883203987	2.5015181332581
3	0.642672658604488	0.593104855602282	2.53390459500258
4	0.46445977268502	0.414211060225932	3.13836429769081
5	0.484986008418492	0.434012884670594	3.05448212169981
6	1.17233641173569	1.11289155681579	1.74189165009792
7	1.15011694543517	1.09021492280772	1.75730775003982
8	0.95435917767504	0.881979386692336	1.82880728241712
9	0.987202886474887	0.913652167719131	1.80053783961125
10	2.60617606237037	2.53733142579218	1.3364290290373

A = 0.2 mV; N = 40; maxDrift = 40; snr = 30

Conclusions

The MMF algorithm can retain the significant characteristic waves and intervals in the ECG signal

which is more important for subsequent processing, such as the ECG characteristic wave or interval detection, or arrhythmia recognition.