Detection of Heart Rate Variability From a Wearable Differential ECG Device

Mipro DC VIS

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Problem

- A wearable sensor constantly records the heart activity of an active subject for several days
- Limited resources $\implies$ low frequency (120 Hz)
- Precisely detect beat-to-beat times and their variability

Heartbeat sample

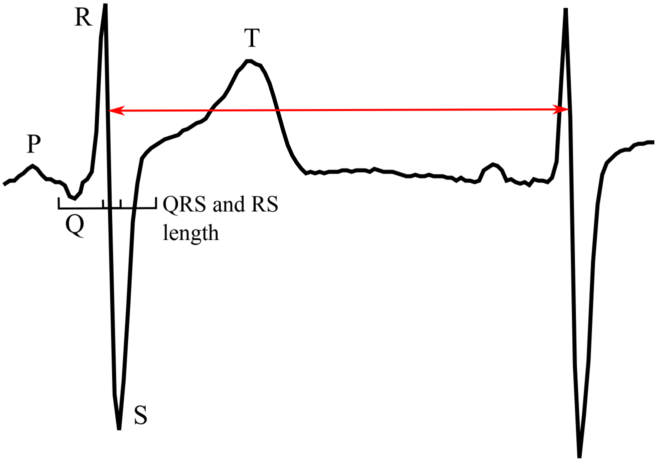
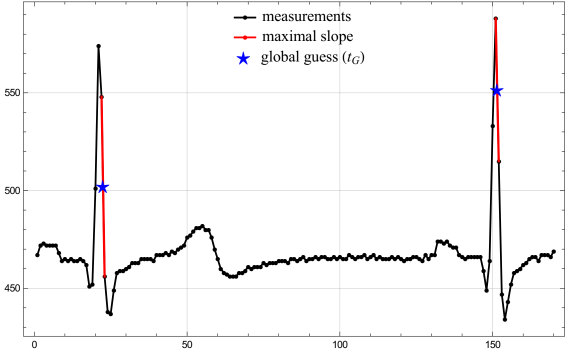


Figure: Beat to beat time between two characteristic points.

Method derivation

- Separated in two stages
  - Coarse global search: *find the most steep downwards slope between two measurements*



  - Fine local search: *approximate the function using MLS and find the root of the second derivative – inflection point*

Method derivation – MLS

- The value of the electrical potential is approximated from the n nearby measurements $\underline{\mathsf{f}}$.
- The approximation $\hat{f}$ is introduced as a linear combination of m arbitrary basis functions $(b_j)_{j=1}^m$

$$\hat{f} = \sum_{j=1}^{m} \alpha_j b_j$$

- Minimize the weighted 2-norm of the residual error

$$\|\underline{\mathsf{f}} - \hat{f}(\underline{\mathsf{t}})\|_w^2 = \sum_{i=1}^{n} \left(f_i - \sum_{j=1}^{m} \alpha_j b_j(t_i) \right)^2 w(t_i)$$

- This defines the unknown coefficients α_j.
- **Note: we are free to choose n and m.**

Example of fit on a heartbeat-like function

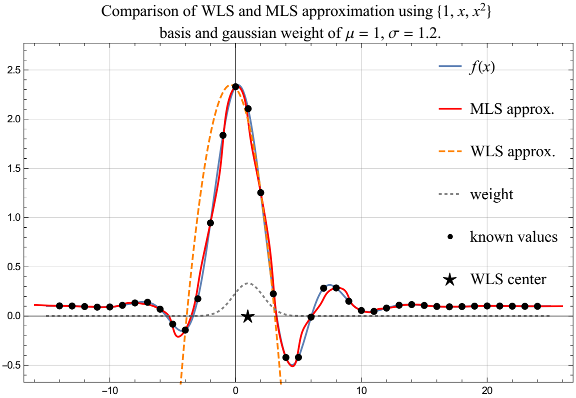
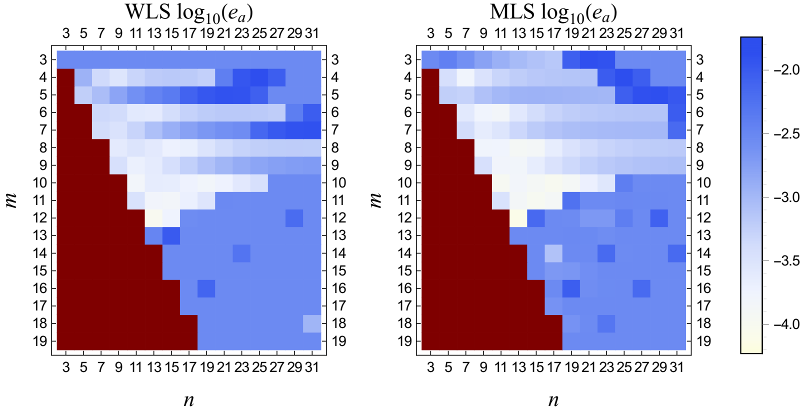


Figure: Approximation of a heartbeat-like function.

Once the approximation is constructed, simply search for the inflection point using bisection.

Search for optimal parameters

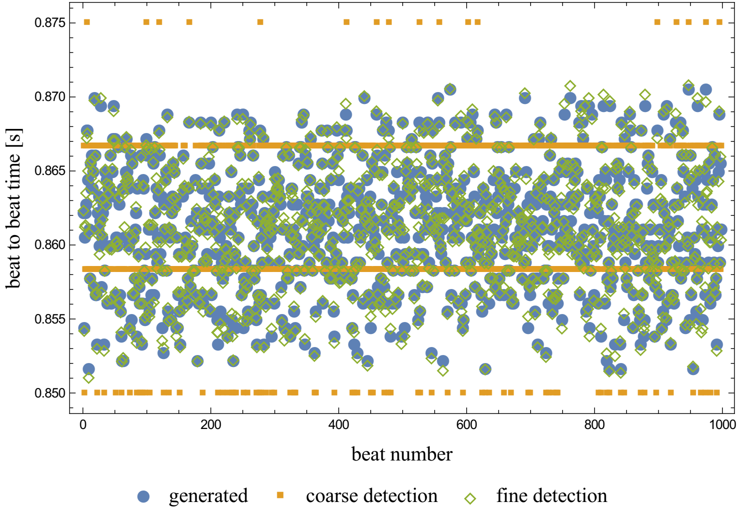
Optimize the support size and number of basis against simulated heartbeat.



Conclusion: 10 basis functions and 15 support values.

Also: MLS is unnecessary.

Generated and detected times



Generated and detected times

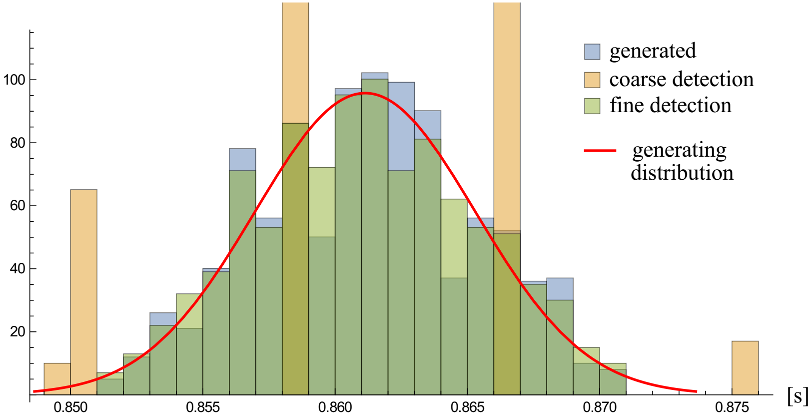


Figure: Generated BTB times and their global detection.

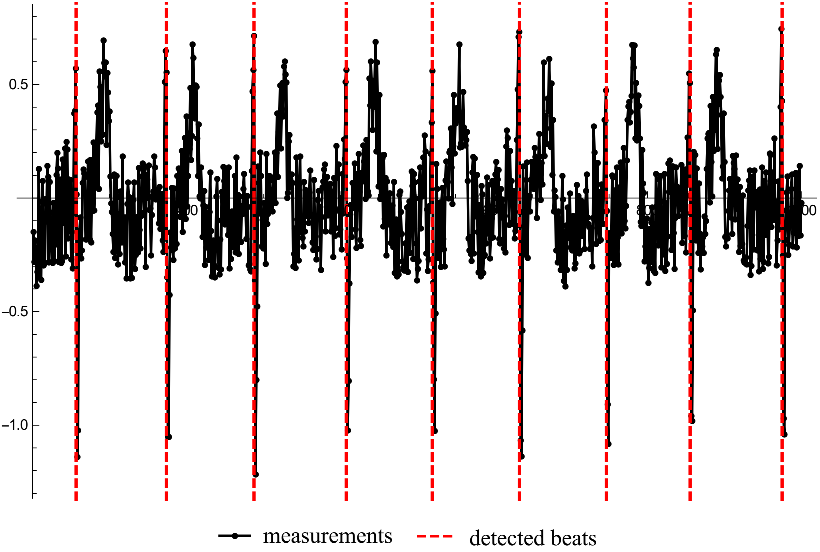
Results

Some properties of the algorithm:

- Average error of BTB times: $0.263\,\mathrm{ms}$
- Maximal error of BTB times: $0.829\,\mathrm{ms}$
- Error of the HRV: $0.035\,\mathrm{ms}$

- Computational complexity: $O(b + n^3 + m\log(1/\varepsilon))$
- C++ implementation analyses 1000 heartbeats ($\approx 10^5$ measurements) in 0.27 s.
- Can withstand 25 % noise

Detecting 25 % noised signal



Actual heartbeat example

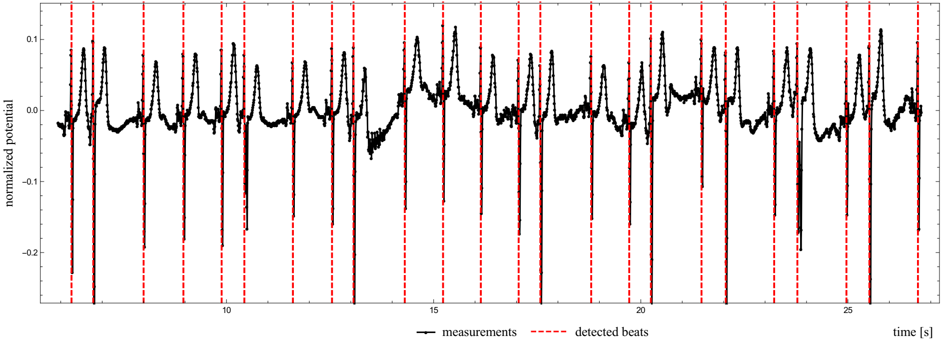


Figure: Detection of heart beat from the input measured by wearable sensor.

Conclusion

Thank you!

Questions?