# R Peak Detection in ECG Signal Using Matched Wavelets

Shirin Badizadegan[1], Hamid Soltanian-Zadeh[1, 2],
[1]*Control and Intelligent Processing Center of Excellence, Electrical and Computer Engineering Department, University of Tehran, Tehran 14395-515,Iran.*
[2]*Image Analysis Laboratory, Radiology Department, Henry Ford Health System, Detroit, MI 48202, USA.*

## Objectives and backgrounds

Wavelet transform has been widely used in many signal processing applications including extraction of ECG characteristic points due to its flexibility, efficiency and compactness both in time and frequency domains. Different wavelet-based algorithms have been proposed for extraction of ECG characteristic points which have mainly used quadratic spline and Daubechies wavelets and have lead to excellent results and robustness against noise and baseline drift. However, with the flexibility comes the possibility to directly design the appropriate wavelet. Designing matched wavelets is a possibility in which the wavelet-basis is designed such that the error between the original signal and some finite resolution wavelet representation of it is minimized. In this work, wavelets matched to the ECG signal have been used for decomposing and analyzing the signal and detecting the R peaks.

## Materials and methods

The proposed algorithm can be divided into three main parts: 1) windowing the ECG signal such that 512 data points are analyzed each time. 2) designing matched wavelet for each interval of the ECG signal; and 3) decomposing the ECG interval using the designed matched wavelet into the scales $2^1$ , $2^2$ and analyzing the wavelet coefficients for R peak detection. Using an efficient parameterization of the wavelet basis, the second part of the algorithm is converted into a classic optimization problem, i.e., finding the parameters which minimize the error between the signal and its wavelet representation in some finite resolution. With an explicit parameterization of all M-band wavelet frames, the matched scaling and wavelet functions are numerically designed. Using the matched wavelets for decomposing the ECG signal, high-amplitude transitions are generated at the locations of R peaks in the scales $2^1$ and $2^2$. Thus locating these transitions leads to detection of R peaks in the ECG signal. The algorithm has been evaluated on MIT-BIH Arrhythmia, a standard and manually annotated data-base. The duration of each record is 30 minutes which has been sampled at 360 Hz. Therefore each record has 648,000 data points.

## Experimental Results

The following table shows the results of the proposed algorithm for some of the records from the MIT-BIH Arrhythmia data-base. "FP" is the number of false detected and "FN" is the number of missed R peaks. The total number of failed detections is the sum of FP and FN.

| Record Number | Total beats | FP | FN | Failed detection (%) |
|---|---|---|---|---|
| 100 | 2273 | 0 | 0 | 0 |
| 103 | 2084 | 1 | 4 | 0.24 |
| 109 | 2532 | 3 | 3 | 0.24 |
| 112 | 2539 | 2 | 5 | 0.27 |
| 113 | 1795 | 0 | 0 | 0 |
| 115 | 1953 | 0 | 1 | 0.05 |
| 117 | 1535 | 5 | 0 | 0.32 |
| 122 | 2476 | 3 | 1 | 0.16 |
| 123 | 1518 | 2 | 3 | 0.33 |
| 209 | 3004 | 4 | 3 | 0.23 |
| 212 | 2748 | 4 | 2 | 0.22 |
| 230 | 2256 | 2 | 1 | 0.13 |
| 234 | 2753 | 0 | 0 | 0 |
| Total | 29466 | 26 | 23 | 0.16 |

## Discussion and conclusion

This work presented a new method for wavelet-based R peak detection. The previous works required analyzing the wavelet coefficients in 4 different scales while the proposed method needs analyzing the coefficients of only 2 scales. So, the speed of the algorithm is increased while maintaining the quality of the results. The algorithm is evaluated on real data with the overall success rate of about 99.84%. The reported results from the previous works vary from 82% to 99.91%, but as mentioned before, the wavelet coefficients of at least 4 scales have been analyzed thus needing about twice as much processing as the presented work. The future work will use further processing of the wavelet coefficients in order to increase the efficiency and reduce the effect of noise in the ECG signals.

**Key words**

Wavelets transform, matched wavelets, ECG characteristic points, R peak detection, optimization.