DY 46.51

ECG curve versus heart rate variability analysis applied to normal and heart-failure patients

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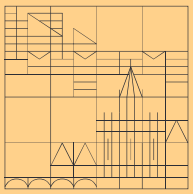
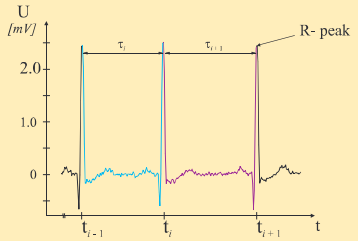


Motivation

Multiresolution wavelet analysis applied to time series generated from **R-R interval time variation** (*"heart rate variability"*) has been shown to be a potential clinical tool to discriminate healthy patients from those with a cardiac pathology [1]. In contrast to this method we apply wavelet analysis to time series generated from the **morphology of electrocardiogram- (ECG) segments** (R-R intervals) by deliberately removing *heart rate variability*.

Data preparation



- Removal of artefacts: elimination of all heartbeats not classified as normal or with R-R intervals not satisfying

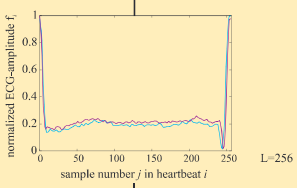
$$0.6\ \overline{\tau}_i < \tau_i < 1.5\ \overline{\tau}_i$$

$\overline{\tau}_i$ moving average over last 30 R-R intervals

Form analysis **vs.** **Heart rate analysis**

Each heart beat in the ECG is normalized in amplitude to the interval [0,1] and re-sampled in time to a fixed number L of data points

→ removal of heart rate variability



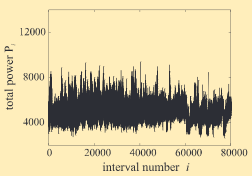
using directly the time between two R-peaks

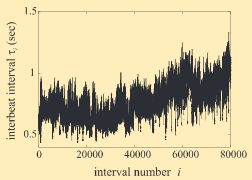
The resulting normalized data in time space (or frequency space) can be represented by a 256-dimensional "form vector" (for more details, see poster DY 46.52)
Here we characterize the morphology of the signal by the modulus of the form vector or, equivalently, by the total power:

$$P_i = L \cdot \sum_{j=0}^{L-1} |f_i(j)|^2$$

R-R interval time τ_i

time series





Wavelet analysis

Discrete wavelet transformation to calculate wavelet coefficients W(m,n) on different scales (*"multiresolution wavelet analysis"*):

$$W(m,n) = 2^{-m/2} \cdot \sum_{i=0}^{M-1} y_i \cdot \psi\left(2^{-m} i - n\right)$$

m ... scale variable
n ... location
$y_i = \tau_i$ or $y_i = P_i$

$\psi(x)$: wavelet basis function (*"mother wavelet"*)

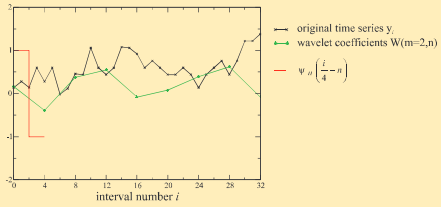
- in our case:

$$\psi_H(x) = \begin{cases} 1 & 0 \le x < \frac{1}{2} \\ -1 & \frac{1}{2} \le x < 1 \\ 0 & \text{otherwise} \end{cases}$$

Haar wavelet

- example:

$$\psi_H(x) = \psi_H\left(2^{-m} i - n\right) \overset{m=2}{=} \psi_H\left(\frac{i}{4} - n\right)$$



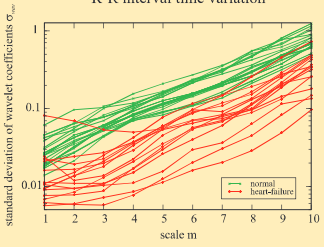
→ new time series: W(m,n) for each scale m

- standard deviation of wavelet coefficients:

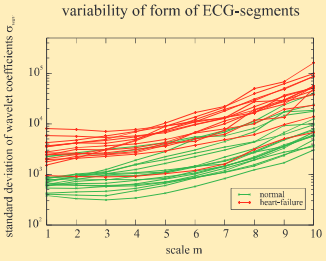
$$\sigma_{wav}(m) = \left[\frac{1}{N-1}\sum_{n=0}^{N-1}\left(W(m,n) - \langle W(m,n)\rangle\right)^2\right]^{\frac{1}{2}} \quad \text{with} \quad N = \text{int}\left(M/2^m\right)$$

Results

R-R interval time variation



variability of form of ECG-segments

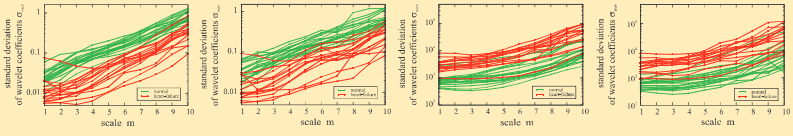


- correct classification of every patient as belonging either to the heart-failure or normal group with 100% accuracy in scale window 4 and 5 (corresponding to 16 and 32 heartbeats)
- analysis based solely on R-R intervals
- heart failure patients have a lower *heart rate variability* in comparison to normal patients

- almost 100% classification on scales m=1-3 for normal and heart-failure patients
- heart failure patients do not have the form-stability as observed for normal subjects

data set from each patient partitioned in day and night sections

day night day night



→ somewhat better separation of heart-failure/normal patients using daytime data

Summary and perspectives

- form variability analysis yields good discrimination of heart-failure and normal patients
- heart-failure patients have a lower *heart rate variability* but higher variability in the form of ECG-segments compared to normal patients

→ interpretation: *heart rate variability* is probing external stimuli (nervous and endocrine system) while morphology based analysis is dominated by the interplay of functional components of

References

[1] St. Thurner, M.C. Feuerstein, M.C. Teich, Phys. Rev. Lett. **80,**