# Estimating Heart Rate Turbulence from a Single Ectopic Beat with Robust Processing

Óscar Barquero-Pérez[1], José Luis Rojo-Álvarez[1] Estrella Everss[1] Ana Belén Rodríguez-González[2] Arcadi García-Alberola[3]
[1] Department of Signal Theory and Communications, University Rey Juan Carlos, Madrid, Spain
[2] Department of Signal Theory and Communications, University Carlos III of Madrid, Spain
[3] Unit of Arrhythmias, Hospital Universitario Virgen de la Arrixaca, Murcia, Spain
E-mail to: joseluis.rojo@urjc.es

## *Background*

*Heart Rate Turbulence (HRT) is defined as the increase and subsequent deceleration of the heart rate after a Premature Ventricular Complex (PVC). Current HRT measurements require a number of PVC which is not always present in all the patients, and more, it is unclear whether the averaging of turbulence in different PVC masks physiological changes instead of just cancelling noise.*

## *Hypothesis*

*Efficient cancellation of physiological noise from each isolated Post-PVC Tachogram (PPT) will allow the quantification of HRT in a higher number of patients.*

## *Methods*

*PPTs were recorded:*

*(a) In 10 patients during Electrophysiologycal Study (EPS), which were used as gold standard (patient in rest, with low electrophysiological noise);*

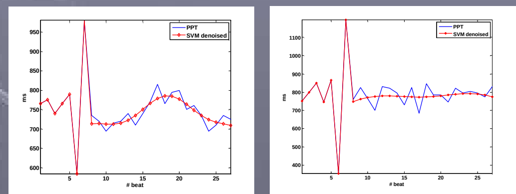
*(b) In 61 patients with post-myocardial infarction with 24-hour Holter monitoring.*

*PPTs were extracted according to conventional procedures in all cases. A robust algorithm for denoising the PPT was developed, based on Support Vector Machine (SVM) interpolation, and optimized to work with a low number (15) of time samples, still avoiding overfitting.*

*Three different filtering methods were compared for each isolated PPT: Finite Impulse Response (FIR) filter, median filter, and nonlinear SVM-based filter.*

**Conclusion**. It is possible to obtain time-local HRT measurements without averaging, by using robust digital signal processing. This allows us to measure the HRT in patients with Holter, even with a low number of PVC.

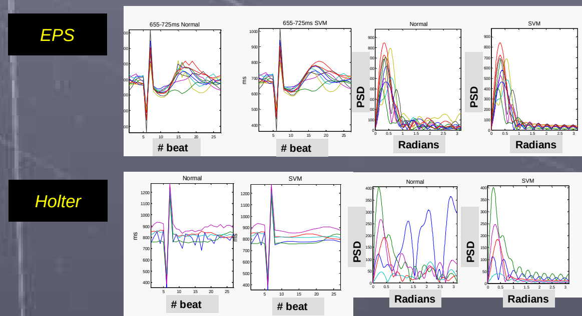
**Results**. Filtered PPTs exhibited the behaviour that is expected from the HRT physiological definition. Qualitatively, there was an excellent agreement between the EPS oscillations and the Holter-denoised PPTs. Quantitatively, for each patient we obtained the following sequence: first minimum, first maximum, and second minimum, for the raw and for the filtered PPTs. This gives a measurement of the similarity between the turbulence waveform and the postulated mechanism in the HRT definition (deceleration, acceleration, and oscillation). A significant increase (*$p<0.001$, paired t-Student when compared with unfiltered tachograms) was observed in the number of beats container between both minima, as shown in the table.




*Examples of tachograms and HRT (solid), and nonlinear filtering with SVM (dots). PVC initially produces a cycle acceleration, inmediatly followed by a deceleration response, which can be observed as a tachogram oscillation. The amplitude of this oscillation is a measurement of the physiological response level, and it can be normal (left) or be pathologically reduced (right).*

*Oscillations are often masked by physiological noise, and due to the short signal length, it can not be cacelled with conventional filtering.*

*SVM denoising allows to cancel the noise without modifying the oscillation pattern in the HRT in both examples.*

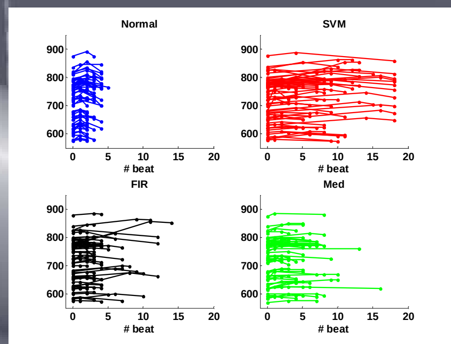



*Examples of HRT tachograms in EPS (up) and in 24h Holter (down), and SVM-filtered tachograms.*

*EPS tachograms suffer almost no change after filtering, as they have very little noise. Changes in filtered Holter-tachograms are visible, and restored waveform is more coherent with HRT mechanisms.*

*Frequency domain representation shows that HRT are not modified after filtering in EPS, whereas spectra from HRT in Holter recover their similarity to EPS spectral pattern.*

*Conventional filtering is not always capable of recovering HRT.*




| | Tacogram | SVM | FIR | Median |
|---|---|---|---|---|
| EPS | 5.2±1.7 | 10.9±3.0* | 9.7±2.5* | 7.2±2.4* |
| Holter | 3.0±0.7 | 11.2±2.6* | 7.6±2.7* | 5.3±1.6* |