

# Heart Rate Variability analysis in R with RHRV

Use R! Conference 2013

Constantino A. García<sup>1</sup>, Abraham Otero<sup>2</sup>, Jesús Presedo<sup>1</sup> and  
Xosé Vila<sup>3</sup>

<sup>1</sup>Centro Singular de Investigación en Tecnoloxías da Información (CITIUS)  
University of Santiago de Compostela, Spain.

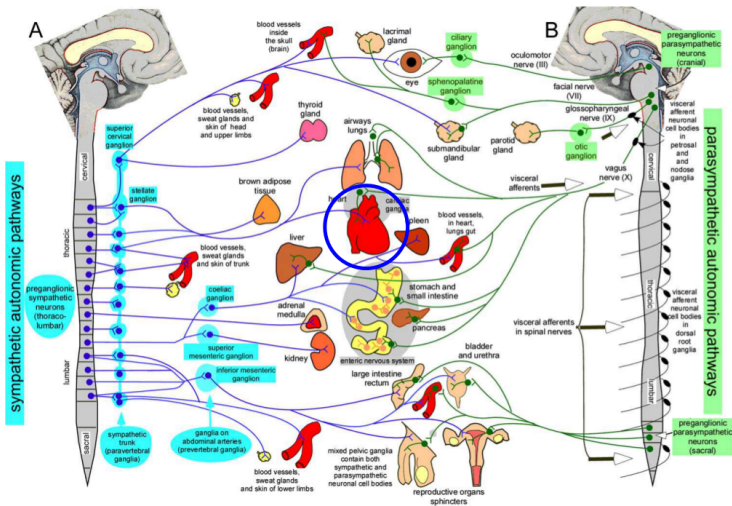
<sup>2</sup>Department of Information and Communications Systems Engineering  
University San Pablo CEU, Spain.

<sup>3</sup>Department of Computer Science  
University of Vigo, Spain.

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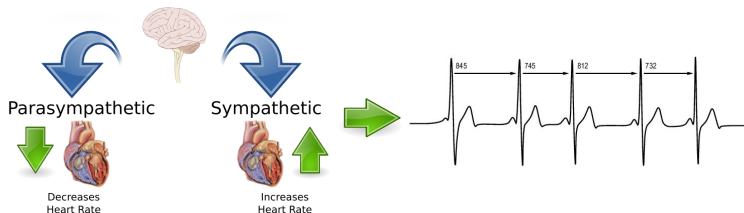
# What is Heart Rate Variability?

The **autonomic nervous system** acts as a control system of blood vessels, glands and muscles, including the **heart**.

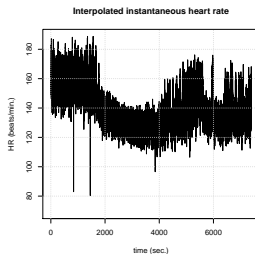


# What is Heart Rate Variability?

Autonomic regulation of heart results in **Heart Rate Variability**



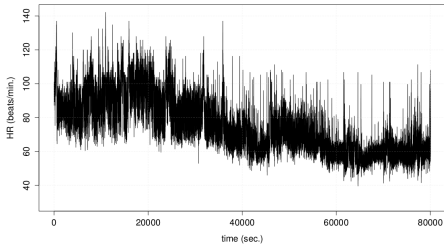
It is possible to build a time series using the interbeat distance



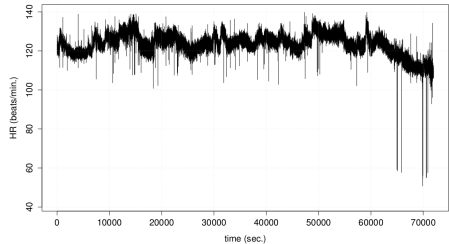
# Why is HRV important?

Who is the healthy subject?

Non-interpolated instantaneous heart rate



Non-interpolated instantaneous heart rate



# Why is HRV important?

## Clinical use of HRV

- Myocardial infarction
- Hypertension
- Chronic obstructive pulmonary disease
- Diabetic neuropathy
- Apnea
- Many more!

## HRV is an active research field

The screenshot shows a PubMed search interface. The search bar contains 'heart rate variability' and the 'Search' button is visible. Below the search bar, there are links for 'RSS', 'Save search', and 'Advanced'. The 'Display Settings' section shows 'Summary, 20 per page, Sorted by Recently Added'. The 'Send to' section has a dropdown menu. The 'Filters' section has a link to 'Manage Filters'. The 'Results' section shows 'Results: 1 to 20 of 15791', with '15791' circled in red. The first result is 'Nocturnal CPAP improves walking capacity in COPD patients with obstructive sleep apnoea' by Wang TY, Lo YL, Lee KY, Liu WT, Lin SM, Lin TY, Ni YL, Wang CY, Ho SC, Kuo HP. The result is from 'Respir Res. 2013 Jun 19;14(1):66. [Epub ahead of print]' with PMID: 23782492. A 'Results by year' bar chart is shown on the right, with a red box around it. The chart shows a steady increase in the number of publications from 2000 to 2013. A 'Download CSV' link is at the bottom right of the chart area.

PubMed heart rate variability Search

RSS Save search Advanced Help

Display Settings: Summary, 20 per page, Sorted by Recently Added Send to: Filters: Manage Filters

Results: 1 to 20 of 15791 << First < Prev Page 1 of 790 Next > Last >>

1. [Nocturnal CPAP improves walking capacity in COPD patients with obstructive sleep apnoea.](#)  
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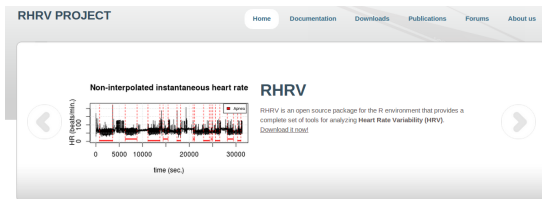
Results by year

Download CSV

- **RHRV** is an open-source package for the R environment that comprises a complete set of tools for HRV analysis



- RHRV project: <http://rhrv.r-forge.r-project.org/>



## Latest news

- RHRV will present its new nonlinear analysis functionality in the Computing in Cardiology conference 2013!
- [Computing in Cardiology 2013](#)
- RHRV participates in the Use R! conference 2013. See you in Athens!
- [The use R! conference 2013](#)

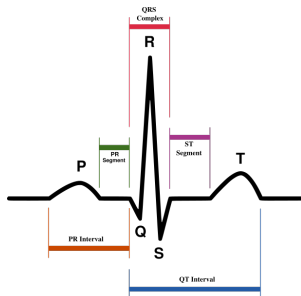
## R Heart Rate Variability (RHRV)

RHRV, an opensource package for the R environment that comprises a complete set of tools for **Heart Rate Variability analysis**. RHRV allows the user to import data files containing heartbeat positions in the most broadly used formats; eliminating outliers or spurious points present in the time series with unacceptable physiological values; plotting HRV data and performing time domain, frequency domain and nonlinear HRV analysis. RHRV is the first R package for HRV analysis.

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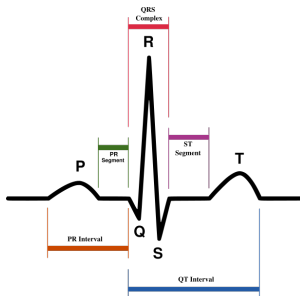
# Getting started with RHRV

- Starting point: annotated ECG.



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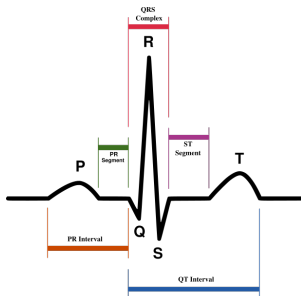


- RHRV allows a wide range of input formats

- ASCII
- EDF
- Polar
- Suunto
- WFDB

# Getting started with RHRV

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Example: Let's read the "a03" register from the PhysioBank's Apnea-ECG database (WFDB format).

# Reading heartbeats

```
> # Example: Read the "a03" register from  
> # the PhysioBank's Apnea-ECG database.  
> library(RHRV)  
> hrv.data = CreateHRVData()  
> hrv.data = LoadBeat(hrv.data, fileType = "WFDB",  
+                      "a03", RecordPath = "beatsFolder/",  
+                      annotator = "qrs")
```

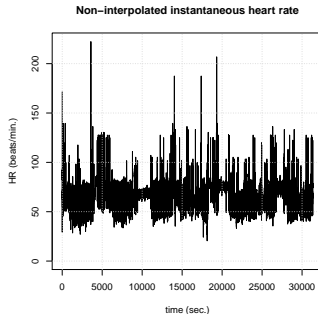
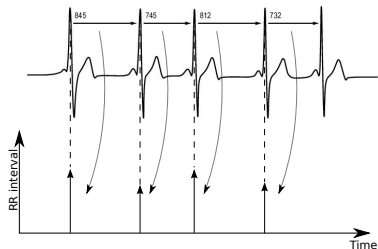
# Building the time series

It is possible to build a time series using the interbeat distance

The procedure

The code

```
> hrv.data = BuildNIHR(hrv.data)  
> PlotNIHR(hrv.data)
```

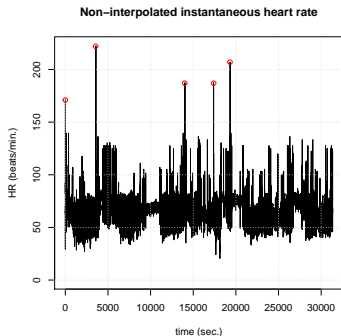


# Preprocessing the time series

**Warning!!**

**Presence of outliers!!**

The problem

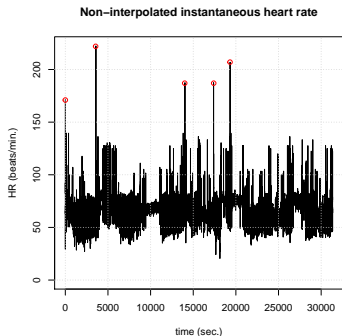


# Preprocessing the time series

Warning!!

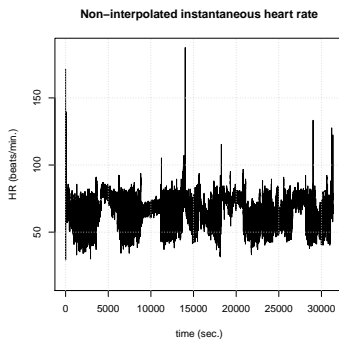
Presence of outliers!!

The problem



The code

```
> hrv.data = FilterNIHR(hrv.data)
```



## Characteristics of the Heart Rate Series and Useful Techniques

- Obviously... It is a Time Series!

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- The Sympathetic System has a slower response than the Parasympathetic System...
  - **Frequency domain** techniques
- Heart Rate Variability is determined by complex interactions of electrophysiological variables...
  - **Nonlinear analysis** techniques

## Motivating example

- PhysioNet/Computers in Cardiology Challenge 2000:
  - ① Developing a diagnostic test for Obstructive Sleep Apnea-Hypopnea (OSAH) Syndrome from a single ECG lead.
  - ② Detecting whether or not the patient has suffered an apnea during each minute of nocturnal rest.

# Analyzing the time series

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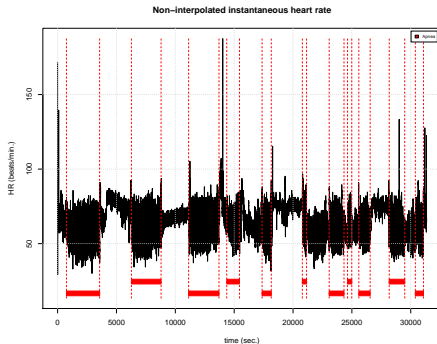
## Illustrating HRV techniques

- ① We shall use Time-domain techniques for the whole recording study.
- ② We shall use Frequency-domain techniques for the minute by minute study.

# Analyzing the time series

It may be useful to distinguish the “episodes” of the recordings...

```
> hrv.data = LoadApneaWFDB(hrv.data, RecordName="a03", Tag="Apnea",  
+                           RecordPath="beatsFolder/")  
> PlotNIHR(hrv.data, Tag="all")
```



# Time-domain analysis

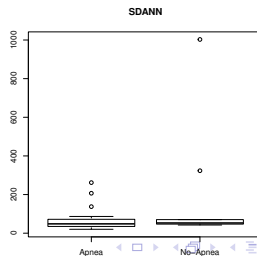
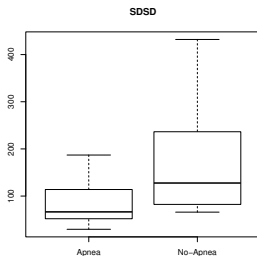
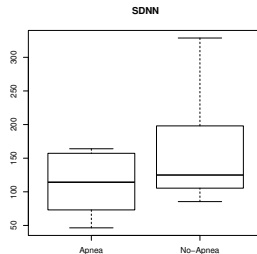
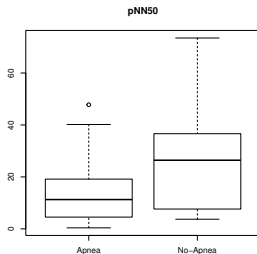
Let's use the Time-domain techniques for the **classification** task.

```
> # load apnea patient into "apnea" structure and  
> # healthy subject into "healthy" structure  
> apnea = CreateTimeAnalysis(apnea)  
> healthy = CreateTimeAnalysis(healthy)
```

	pNN50	SDNN	SDSD	SDANN
Apnea	15.83	147.66	52.88	86.23
No-Apnea	36.64	328.69	261.24	323.32

# Time-domain analysis

## Time-domain analysis over the whole database



## Warning!!

The Heart Rate time series is a **non-stationary** signal!!  
Thus, Fourier analysis is not a suitable technique.

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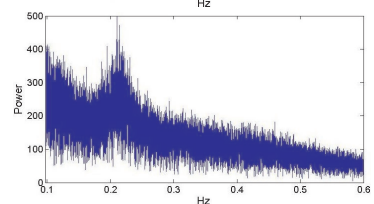
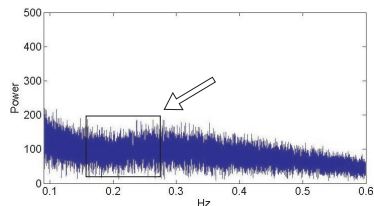
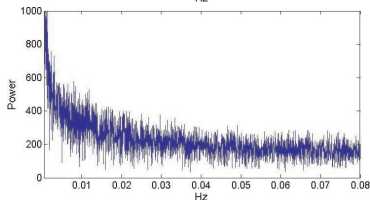
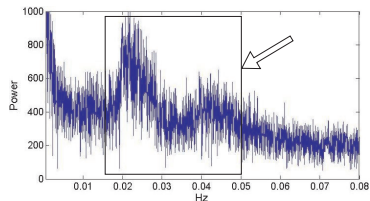
## RHRV functionality

RHRV includes

- Short Time Fourier Transform analysis.
- Wavelet transform analysis.

# Frequency domain analysis

Power spectrum for both apnea-patients (top) and healthy patients (bottom).



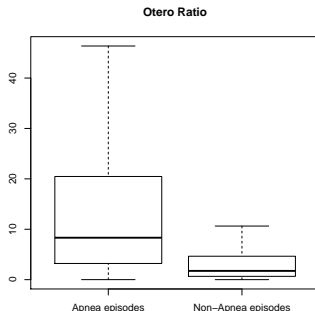
## Minute by minute classification

We shall use the “Otero” ratio, defined as

$$R_o = \frac{\text{Power}([0.026, 0.06] \text{ Hz})}{\text{Power}([0.06, 0.25] \text{ Hz})}.$$

# Frequency domain analysis

```
> # ...  
> hrv.data = InterpolateNIHR(hrv.data, freqhr = 4)  
> hrv.data = CreateFreqAnalysis(hrv.data)  
> hrv.data = CalculatePowerBand( hrv.data , indexFreqAnalysis= 1,  
+   type = "wavelet", wavelet = "la8", bandtolerance = 0.001,  
+   LFmin = 0.02, LFmax = 0.05, HFmin = 0.05, HFmax = 0.25)  
> epis.data = SplitPowerBandByEpisodes(hrv.data, indexFreqAnalysis = 1,  
+                                       Tag = c("Apnea"))
```



# More functionality!

## More techniques implemented in RHRV

- Complete tutorial in: <http://rhrv.r-forge.r-project.org/>

## Nonlinear analysis in RHRV

- Beta phase.
- Functionality for:
  - Nonlinearity Tests.
  - Generalized Correlation Dimension.
  - Sample Entropy.
  - Maximum Lyapunov exponent.
  - Recurrence Quantification Analysis.
  - Detrended Fluctuation Analysis.

# Conclusions

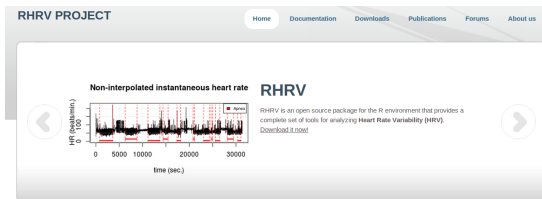
## HRV

- It is a very important research field!
- Creation of markers for several diseases.

## RHRV allows the user...

- Importing data files in the most broadly used formats.
- Eliminating outliers or spurious points present in the time series.
- Analyzing the time series using
  - Time-domain techniques.
  - Frequency domain techniques
  - Nonlinear HRV techniques.
- Performing statistical analysis in and out relevant physiological episodes.

Please, visit: <http://rhrv.r-forge.r-project.org/>



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- [Computing in Cardiology 2013](#)
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# Bibliography I

## About Heart Rate Variability



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## About RHRV



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# Questions?

