Heart Rate Variability analysis in R with RHRV

Use R! Conference 2013

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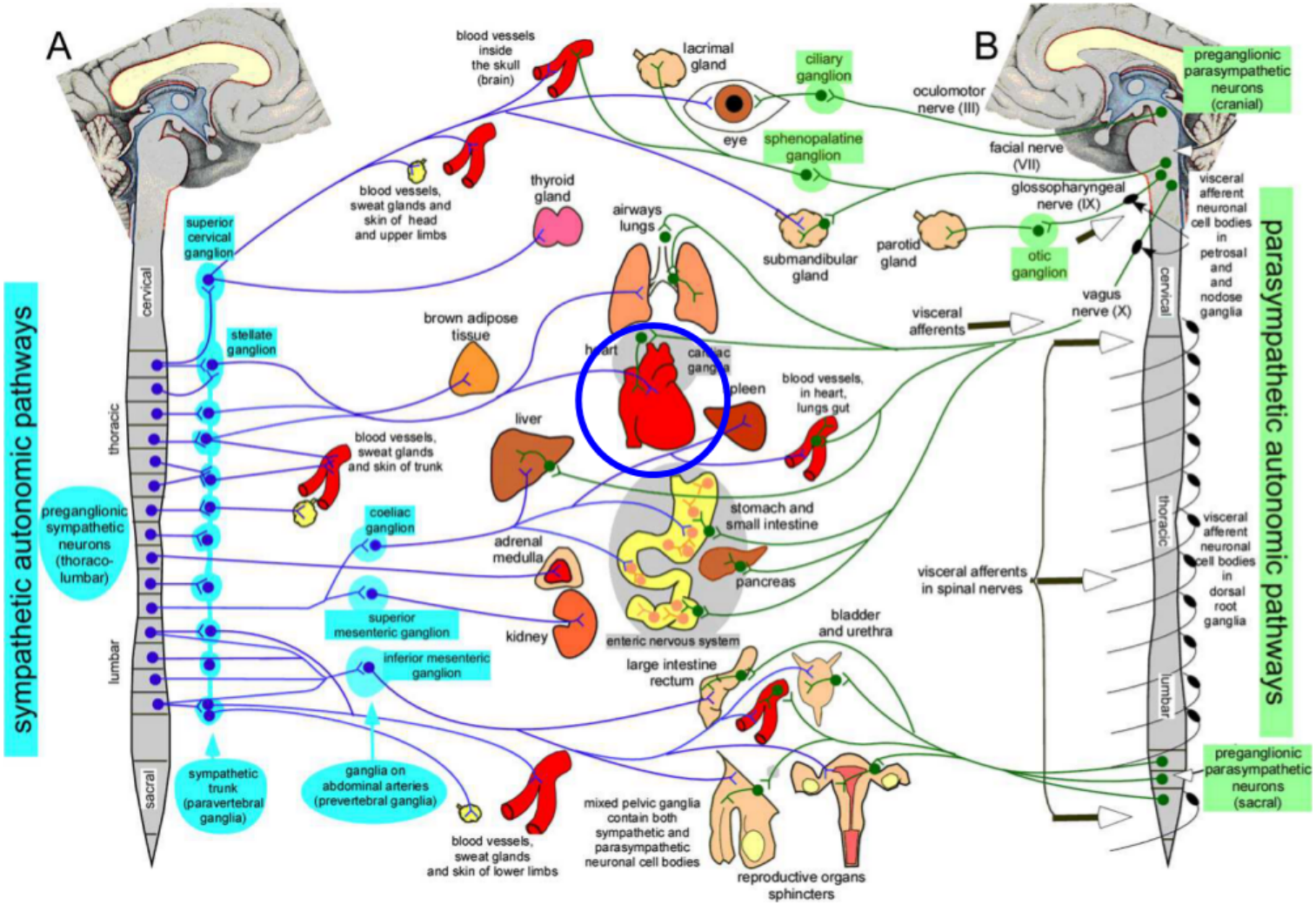
July 16, 2013

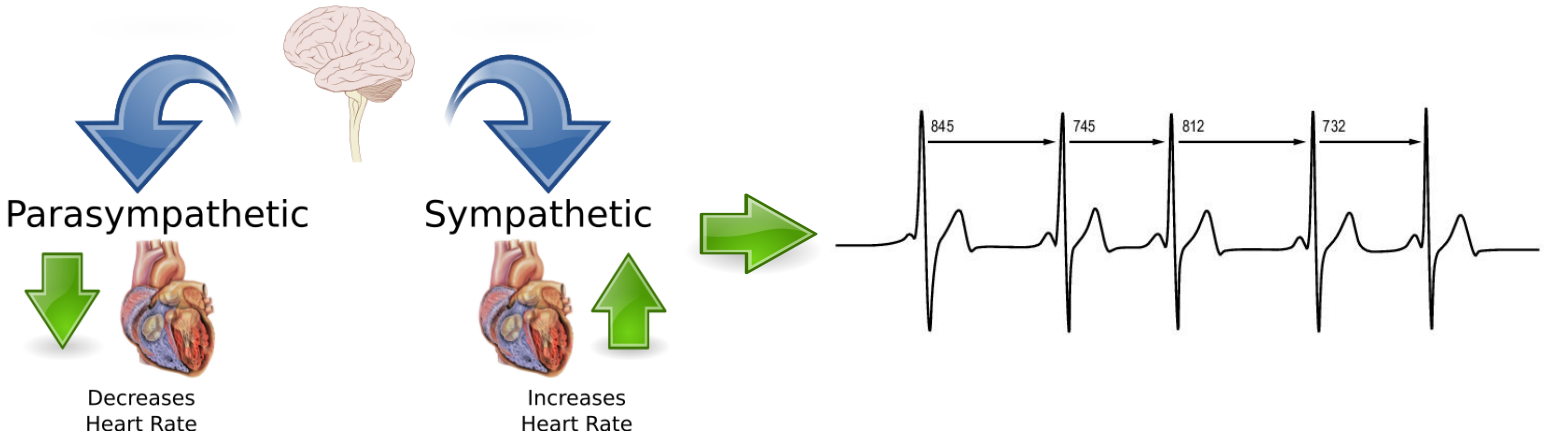
What is Heart Rate Variability?

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

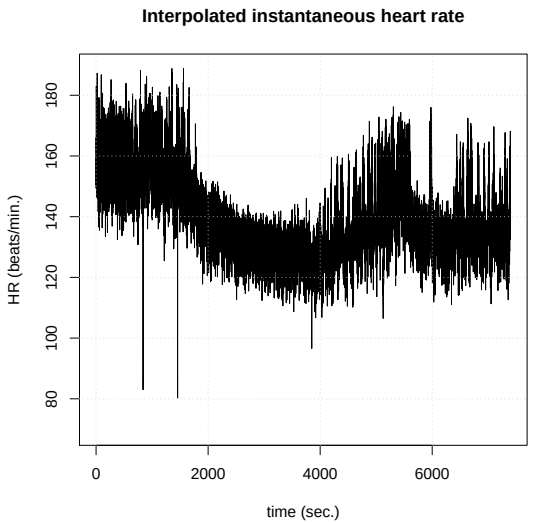


What is Heart Rate Variability?

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

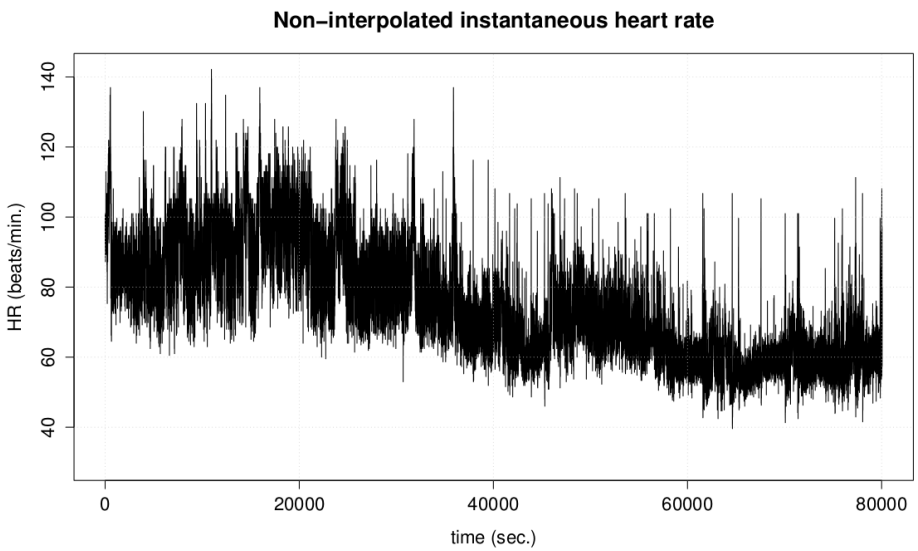


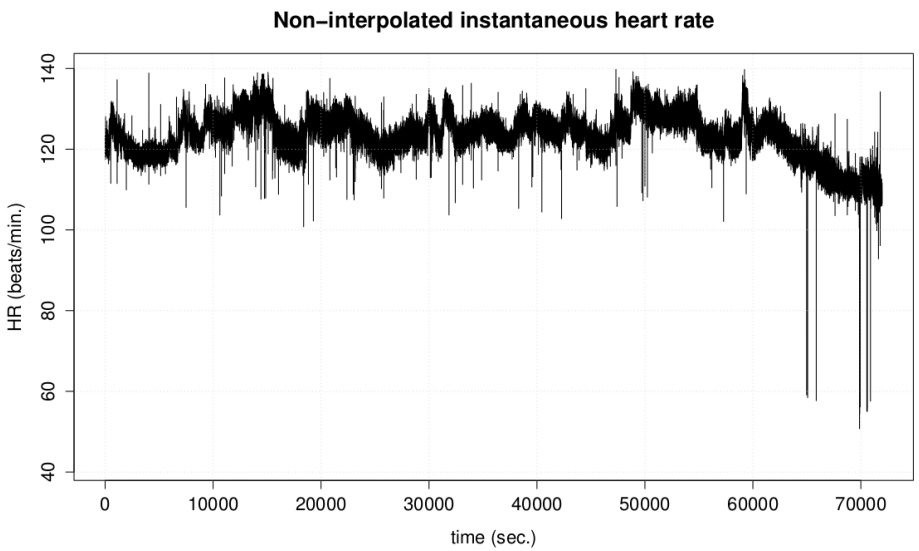
It is possible to build a time series using the interbeat distance



Why is HRV important?

Who is the healthy subject?



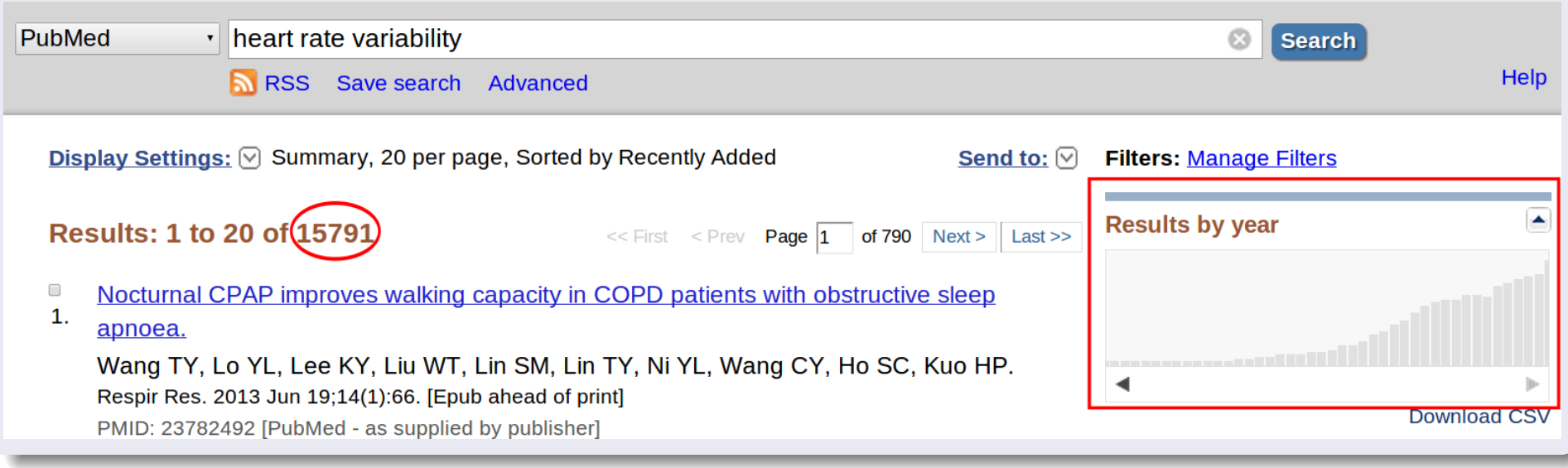


Why is HRV important?

Clinical use of HRV

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

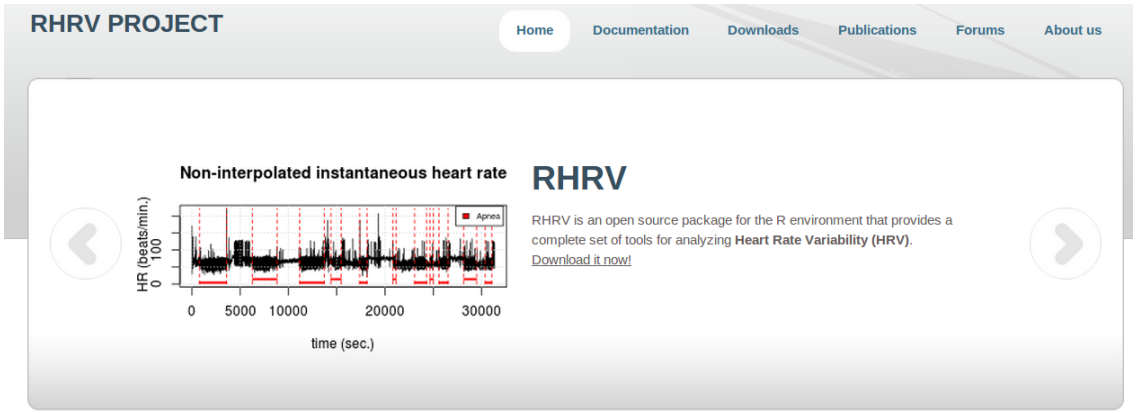
HRV is an active research field



RHRV

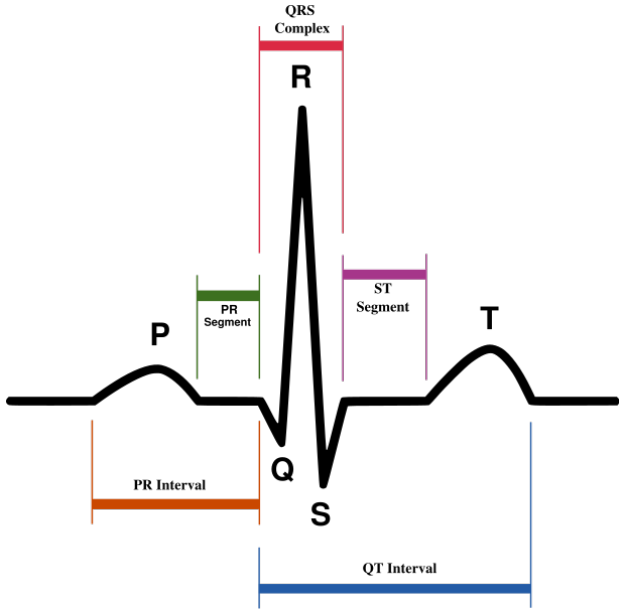
- **RHRV** is an open-source package for the R environment that comprises a complete set of tools for HRV analysis

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



Getting started with RHRV

- Starting point: annotated ECG.



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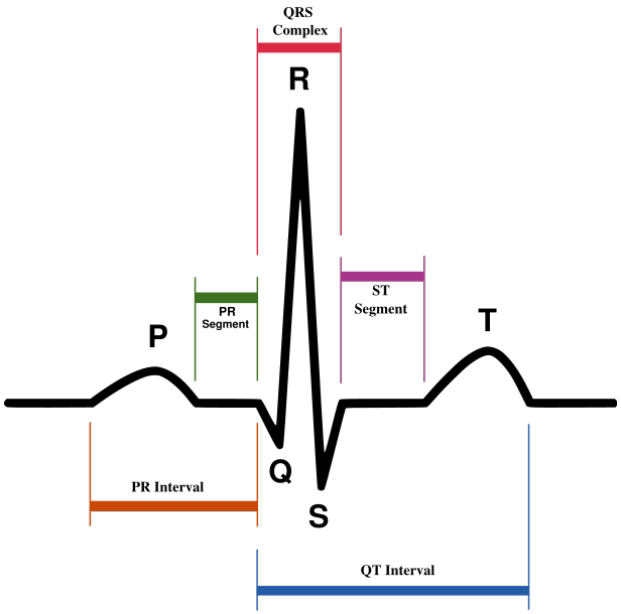

- RHRV allows a wide range of input formats
  - ASCII
  - EDF
  - Polar
  - Suunto
  - WFDB

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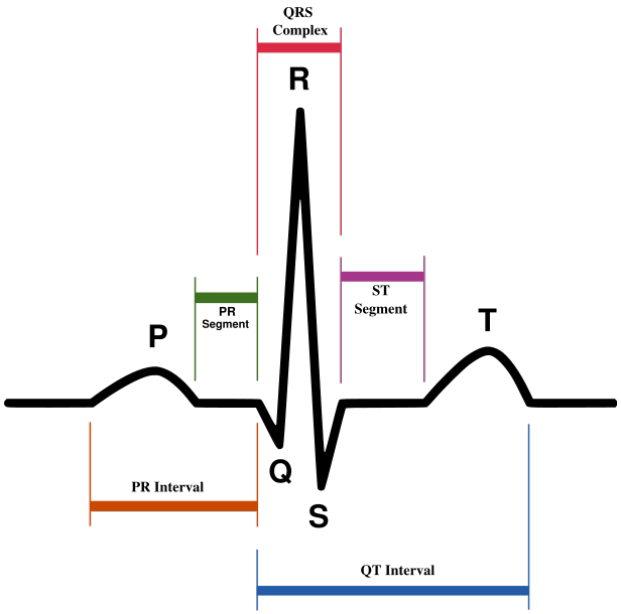

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Example: Let's read the "a03" register from the PhysioBank's Apnea-ECG database (WFDB format).

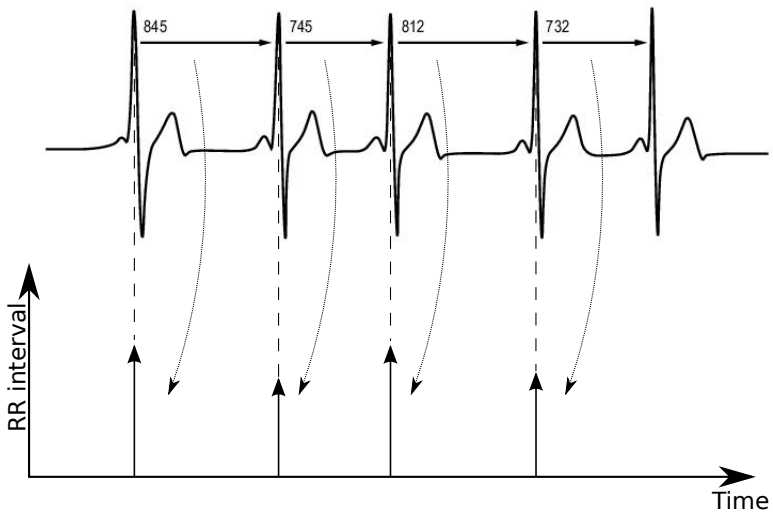
Reading heartbeats

```
> # 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

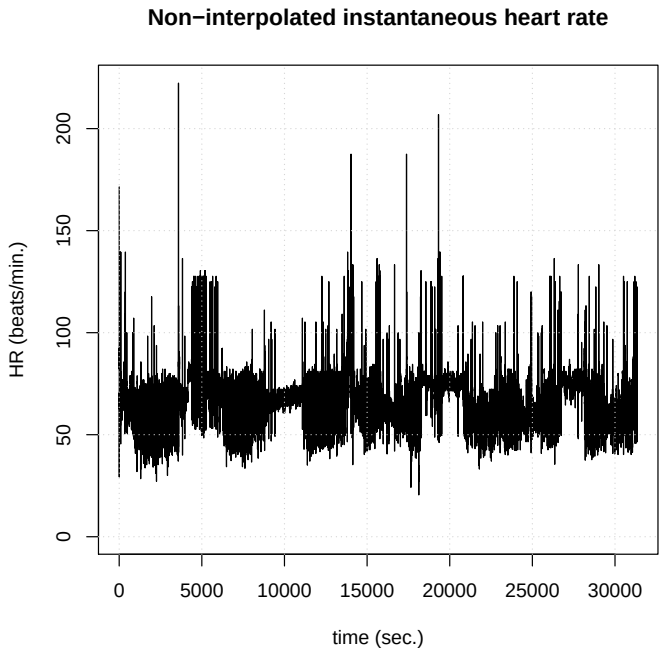
It is possible to build a time series using the interbeat distance

The procedure



The code

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

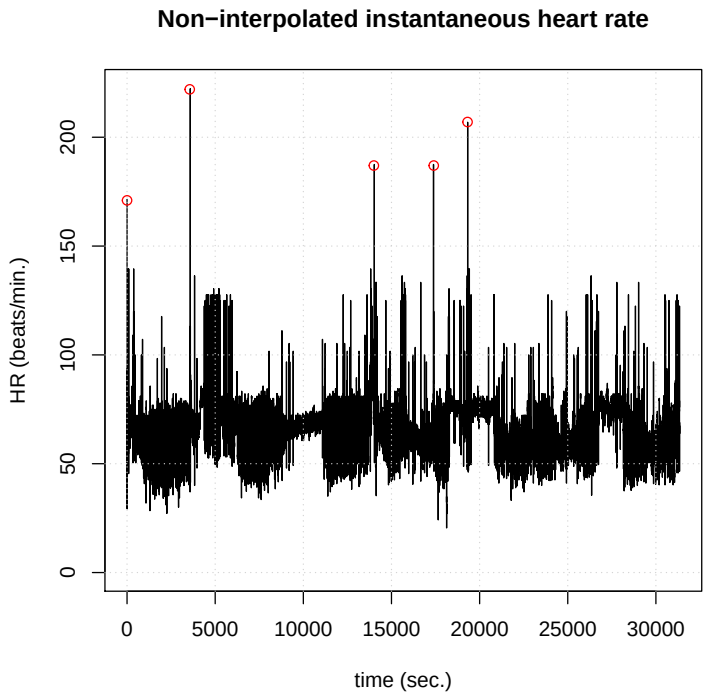


Preprocessing the time series

Warning!!

Presence of outliers!!

The problem



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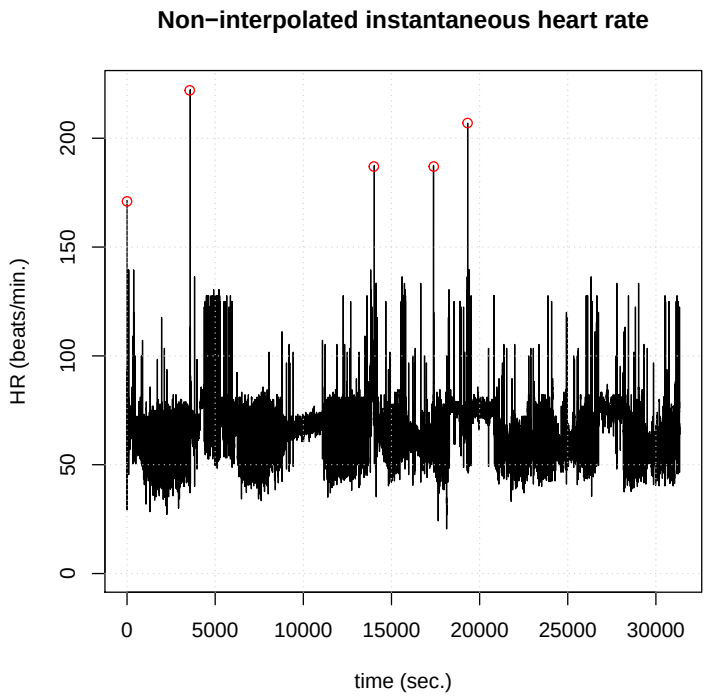
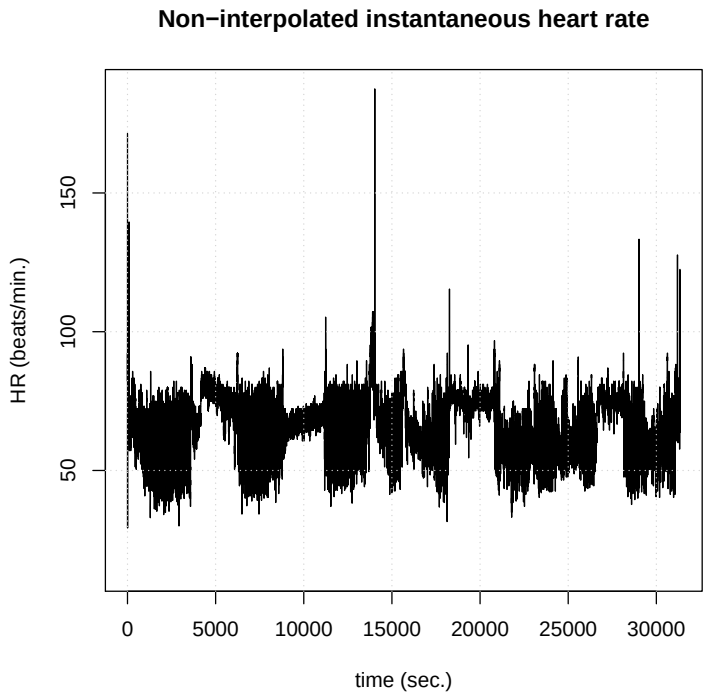


The code

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



Analyzing the time series

Characteristics of the Heart Rate Series and Useful Techniques

- Obviously... It is a Time Series!

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  - Statistical techniques in the **Time-domain**
- 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

Analyzing the time series

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 nor the patient has suffered an apnea during each minute of nocturnal rest.

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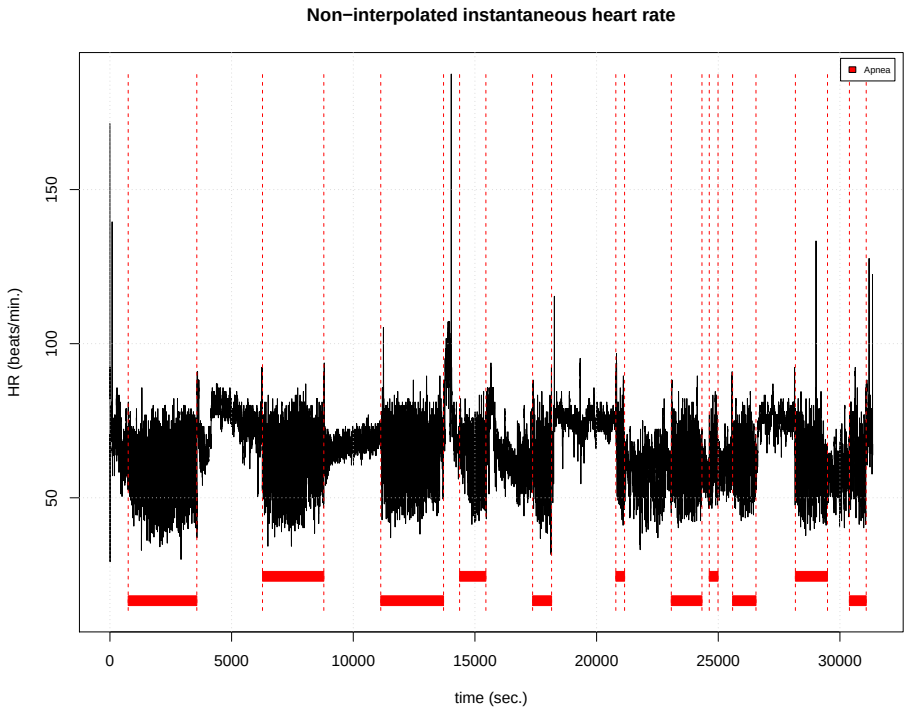
Illustrating HRV techniques

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

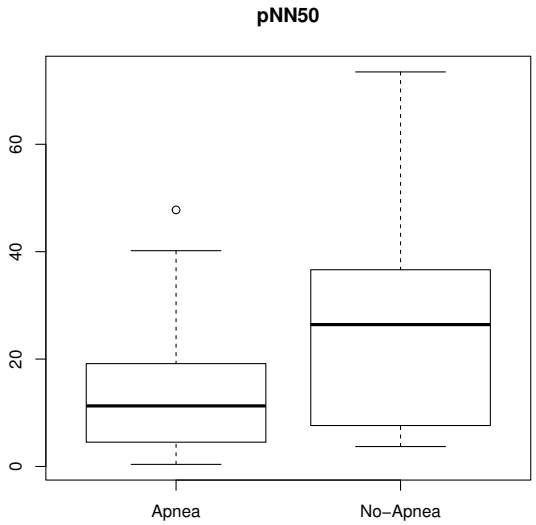
Let's use the Time-domain techniques for the **classification** task.

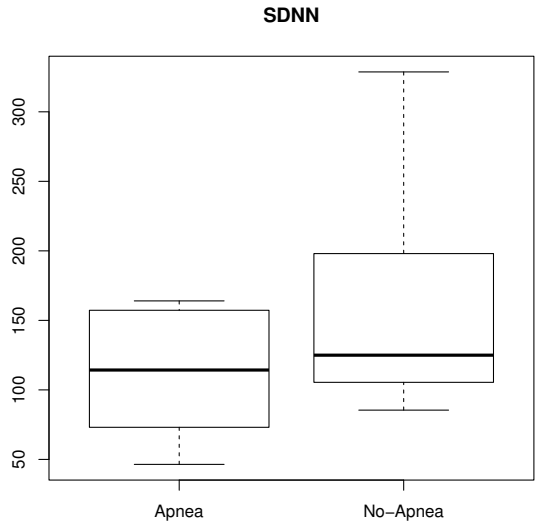
```
> # load apnea patient into "apnea" structure and
> # healthy subject into "healthy" structure
> apnea = CreateTimeAnalysis(apnea)
> healthy = CreateTimeAnalysis(healthy)
```

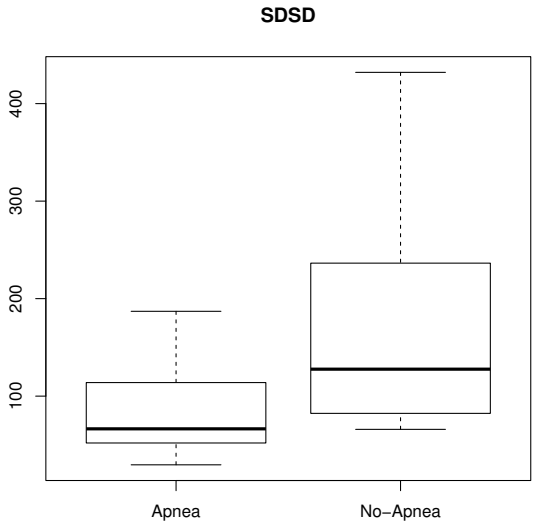
	pNN50	SDNN	SDSD	SDANN
Apnea	15.83	147.66	52.88	86.23
No-Apnea	36.64	328.69	261.24	323.32

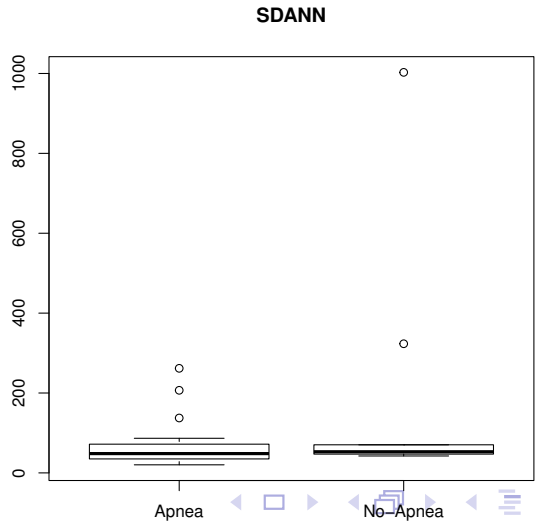
Time-domain analysis

Time-domain analysis over the whole database









Frequency domain analysis

Warning!!

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

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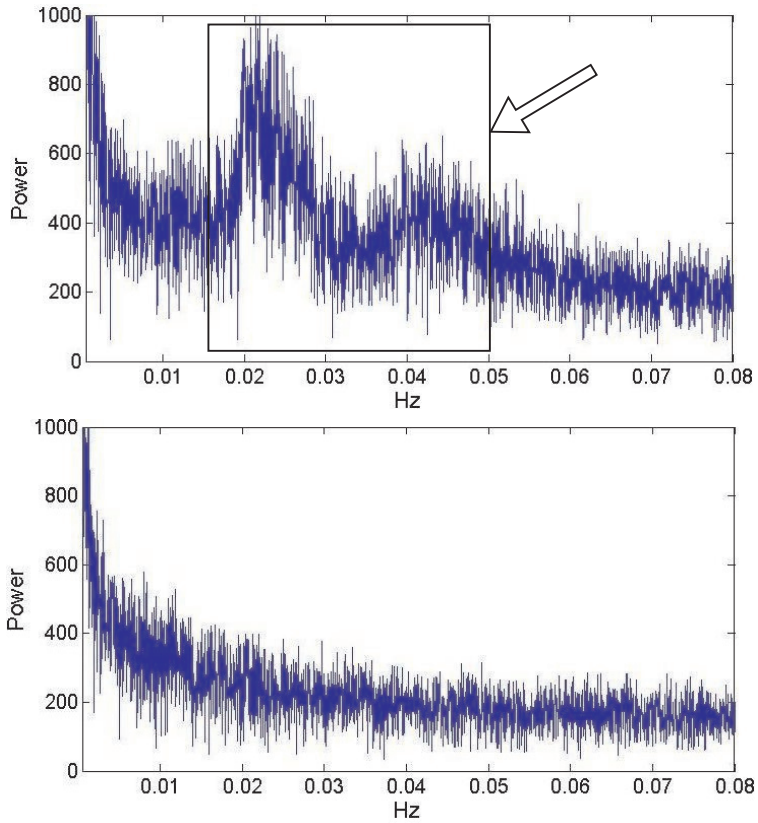
RHRV functionality

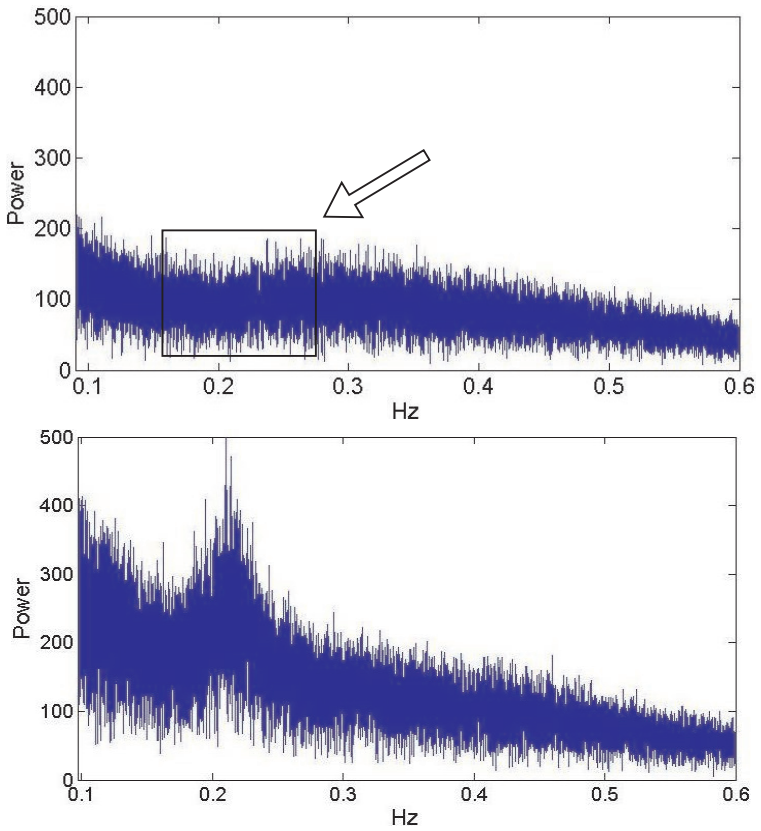
RHRV includes

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

Frequency domain analysis

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





Frequency domain analysis

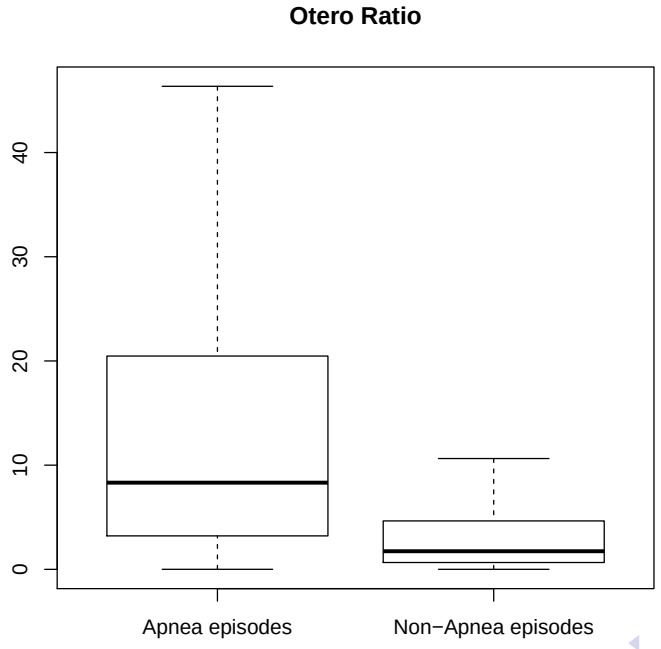
Minute by minute classification

We shall use the "Otero" ratio, defined as

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

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

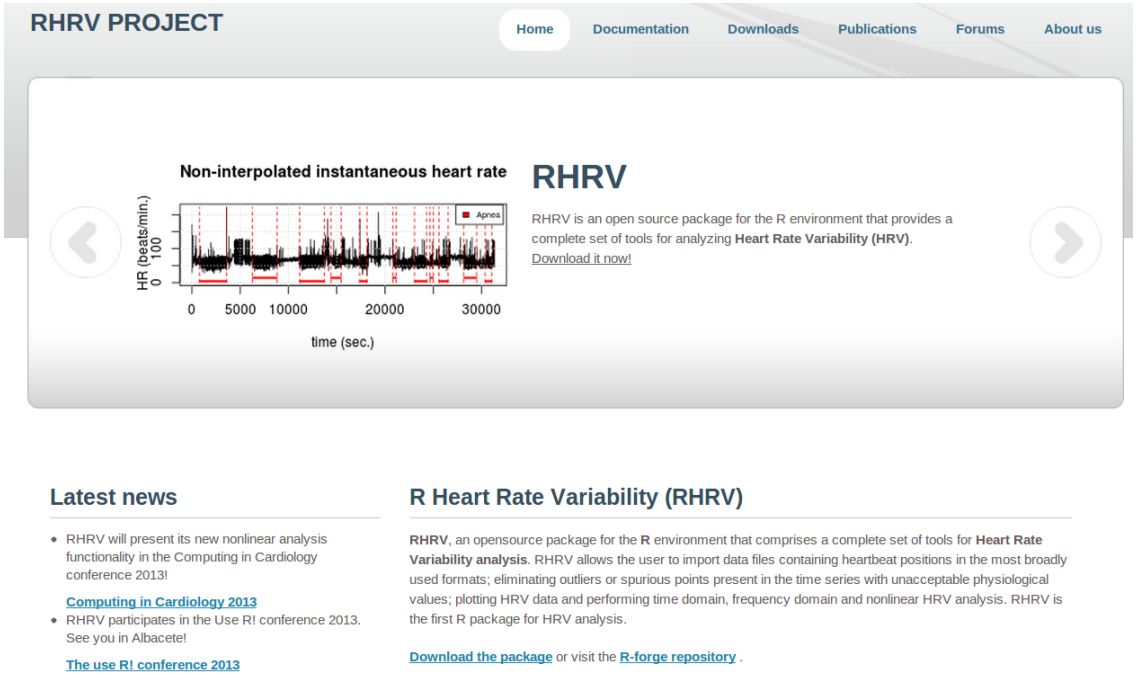
- It is a very important research field!
- Creation of markers for several diseases.

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.

RHRV homepage

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



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Questions?