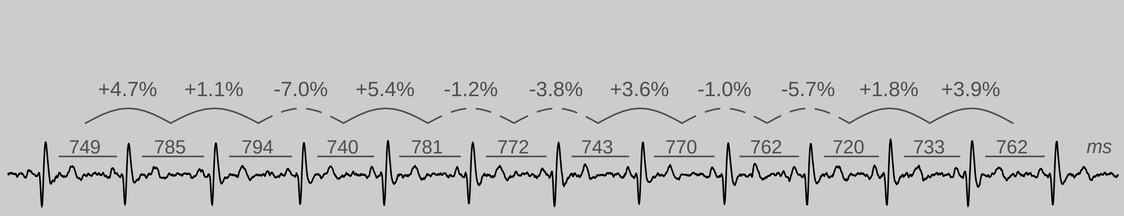
A robust, simple and reliable measure of Heart Rate Variability using relative RR intervals

Marcus Vollmer
Department of Mathematics and Computer Science
University of Greifswald, Germany

Heart Rate Variability

Heart Rate Variability (HRV) characterizes the variation of the heart rate when analyzing successive cardiac cycles over a fixed measuring period. HRV is a measurand of the neurovegetative activity and autonomic function of the heart and describes the ability of the heart to change time intervals from one heart beat to the next, continually and without overloading, and to flexibly adjust to different overloads.[1]



Time Domain Measures[2]

pNNx

$P\,(|\mathrm{RR}_{i+1} - \mathrm{RR}_i| > x \text{ ms})$

SDNN

$$\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\mathrm{RR}_i - \overline{\mathrm{RR}}\right)^2}$$

RMSSD

$$\sqrt{\frac{1}{n-1}\sum_{i=1}^{n-1}\left(\mathrm{RR}_{i+1} - \mathrm{RR}_i\right)^2}$$

Easy to apply
Influenced by outliers and artifacts
Influenced by heart rate changes

Geometric and Spectral Measures

SD1/SD2

$$\frac{\sigma(RR_{i+1} - RR_i)}{\sigma(RR_{i+1} + RR_i)}$$

TINN

$M - N$

LF/HF

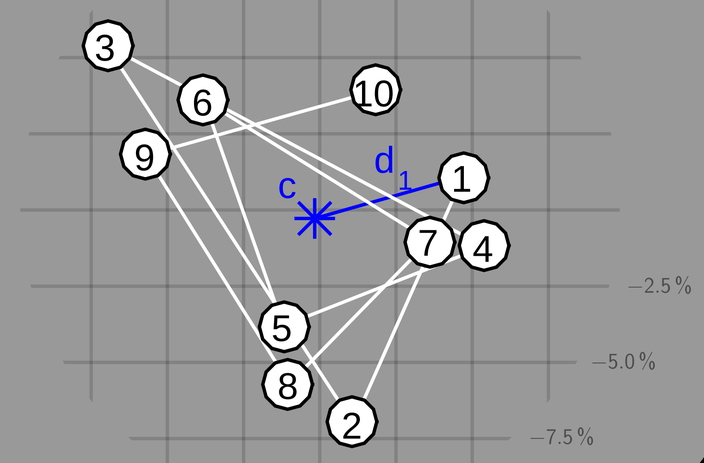
$$\frac{\int_{0.04\,\mathrm{Hz}}^{0.15\,\mathrm{Hz}} f(\lambda)\,d\lambda}{\int_{0.15\,\mathrm{Hz}}^{0.40\,\mathrm{Hz}} f(\lambda)\,d\lambda}$$

power spectrum $f(\lambda)$

Hard to understand
Influenced by outliers and artifacts
Influenced by heart rate changes
Spectrum: How to handle missing values
TINN: Bin width unclear

Relative RR Intervals

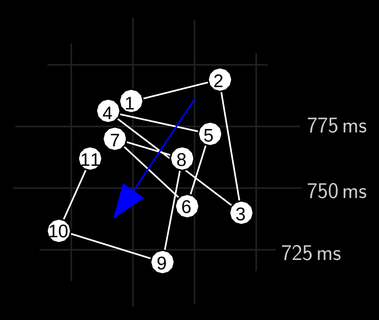
$$\mathrm{rr}_i := \frac{2(\mathrm{RR}_i - \mathrm{RR}_{i-1})}{\mathrm{RR}_i + \mathrm{RR}_{i-1}}$$



rrHRV :=
median $((d_i)_{i=1,\ldots})$

Absolute RR intervals are influenced by heart rate changes. A good measure should be adjusted to the temporary heart rate.

Complex dynamics of heart beat intervals disguised in the Poincaré map.

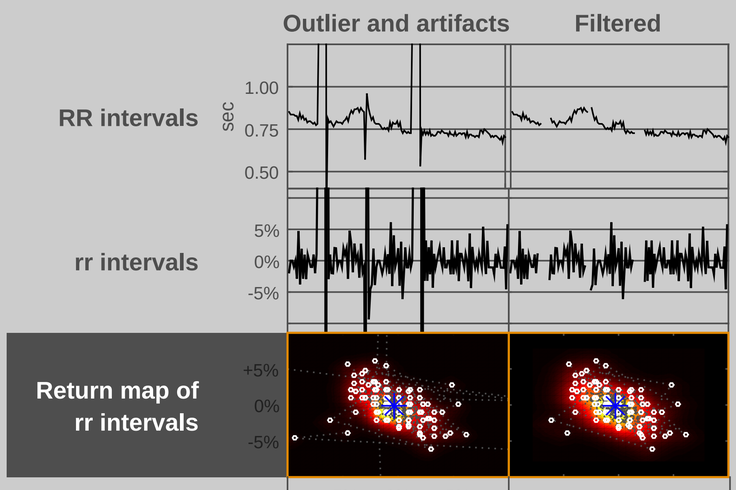


d_i is the **euclidean distance** between $(\mathrm{rr}_i, \mathrm{rr}_{i+1})$ and center point c, which is the average of relative RR intervals for which $|\mathrm{rr}_i| < 20\%$.

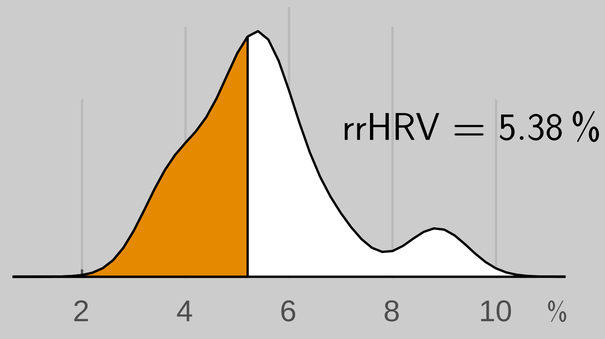
The interquartile range (IQR) of (d_i) provides information about the **annular intensity**.

Center point c provides information about **increasing (c>0)** or **decreasing heart rates (c<0)**.

Outliers and Artifacts — excerpt of nsr2db/nsr037[3]



Center point		(-0.32,-0.14)	(-0.25,-0.11)
HRV measures			
Euclidean distance to center point	Median	2.52	2.37
	IQR	3.06	2.45
SDNN (ms)		453.8	49.0
RMSSD (ms)		678.9	17.6
pNN50 (%)		6.25	0.00
HRV triangular index		10.4	9.9
TINN (ms)		156	156
LF/HF Ratio		1.30	NaN
SD1/SD2 Ratio		1.12	0.18

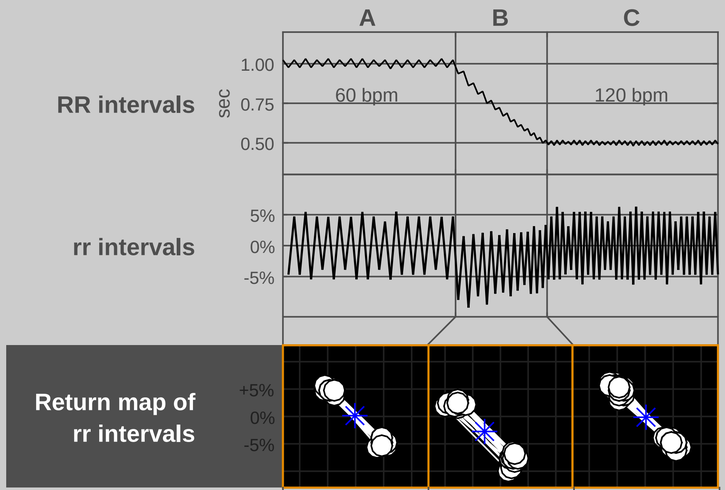


Distance to c

Robust against outliers and artifacts.

Invariant against linear transformations.

Heart Rate Changes



Center point		(-0.15,+0.17)	(-2.87,-2.79)	(+0.09,-0.07)
HRV measures				
Euclidean distance to center point	Median	6.88	7.19	7.27
	IQR	1.05	1.02	1.13
SDNN (ms)		24.2	134.8	12.9
RMSSD (ms)		48.2	41.1	25.7
pNN50 (%)		30.0	26.1	0.0
HRV triangular index		2.8	12.0	2.2
TINN (ms)		23	16	16
LF/HF Ratio		0.28	1.53	0.24
SD1/SD2 Ratio		8.09	0.14	6.85

Try yourself!

[1] K. Hottenrott, "Grundlagen zur Herzfrequenzvariabilität und Anwendungsmöglichkeiten im Sport," in *Herzfrequenzvariabilität im Sport - Prävention, Rehabilitation und Training*, vol. 129, pp. 9–26, Edition Czwalina Feldhaus Verlag Hamburg, 2002.
[2] M. Malik, J. T. Bigger, A. J. Camm, R. E. Kleiger, A. Malliani, A. J. Moss, and P. J. Schwartz, "Heart rate variability," *European Heart Journal*, vol. 17, no. 3, pp. 354–381, 1996.
[3] A. L. Goldberger, L. A. N. Amaral, L. Glass, J. M. Hausdorff, P. C. Ivanov, R. G. Mark, J. E. Mietus, G. B. Moody, C.-K. Peng, and H. E. Stanley, "PhysioBank, PhysioToolkit, and PhysioNet: Components of a new research resource for complex physiologic signals," *Circulation*, vol. 101, no. 23, pp. e215–e220, 2000 (June 13).

GitHub
Analyzing Heart Rate Variability
MarcusVollmer.github.io/HRV

Computing in Cardiology
Nice, France, September 6-9, 2015

Marcus Vollmer
marcus.vollmer@uni-greifswald.de