# TachoE - NL1

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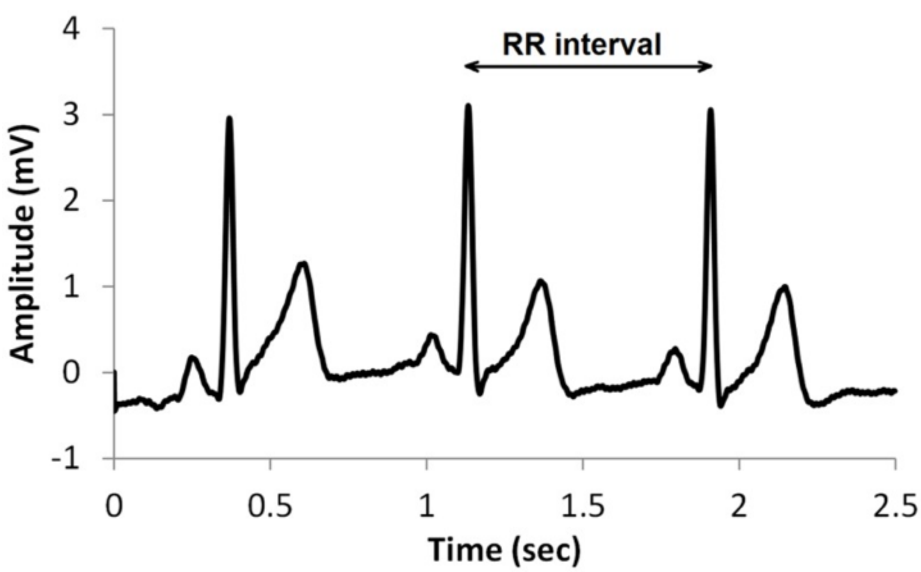
## 1 PRELIMINARY STUDIES

### 1.1 Analysis

The goal was to build a tool to study heart rate variability (HRV). The analysis consisted of calculation of indicators of HRV starting from the time series of two successive R-waves of the QRS signal on the electrocardiogram. [1]




https://www.researchgate.net/figure/A-typical-ECG-signal-showing-the-RR-interval$_{fig}1_2$65461491

### 1.2 Metrics

Metrics Reference papers were read to study the problem, using the methodology provided on the Stanford website. [2] Literature suggested metrics to "be guided by peer-reviewed studies and supplemented by values from specialized populations". [3] The metrics came mainly from the paper suggested by Ph.D. Letizia Clementi (An Overview of Heart Rate variability Metrics and Norms [3]) and from papers found via Google Scholar (The effect of principal component analysis in the diagnosis of congestive heart failure via heart rate variability analysis [4] and Methodology for the prediction of paroxysmal atrial fibrillation based on heart rate variability feature analysis [5]). The following parameters were identified.

### 1.2.1 Time-domain features

· Mean (mean of all RR intervals)

· SDNN(standard deviation of all RR intervals)

· RMSSD (root means square of differences between adjacent NN intervals)

· and SDSD (standard deviation of differences between adjacent NN intervals)

### 1.2.2 Frequency-domain features

The following features are obtained from the power spectral density (PSD) estimation of the HRV data. In this project, the Lomb-Scargle algorithm is used because doesn't require resampling and detrending sub-steps, even though it is a computationally expensive method by comparing to other methods.

· ultralow-frequency band (ULF) between 0 Hz and 3.3 mHz

· very-low-frequency band (VLF) between 3.3 mHz and 40 mHz

· low-frequency band (LF) between 40 mHz and 150 mHz

· high-frequency band (HF) between 150 mHz and 400 mHz

· normalized versions of PLF and PHF

· ratio of the LF to HF

### 1.2.3 Nonlinear features

· Poincare Plot

· Detrended Fluctuation Analysis

· Symbolic. Dynamics

· Sample Entropy

### 1.3 The Dataset

The dataset chosen was: Irurzun, I. M., Garavaglia, L., Defeo, M. M., Thomas Mailland, J. (2021). RR interval time series from healthy subjects (version1.0.0). PhysioNet.
https://doi.org/10.13026/51yd-d219https://doi.org/10.13026/51yd-d219
The main reasons were:

· the dataset is cleaned from artifacts [6]

· the measurements are from 24 hours recordings which satisfy the minimum recording length for some of the metrics [6] [3]

## 2 MINIMUM VIABLE PRODUCT

### 2.1 Necstamp[7] project specifications

"ID5: Cardiac variability assessment tool Autonomic Nervous System (ANS) is responsible for carrying out all the unconscious activities in the body. However, although its centrality, its functioning is vastly still to be unveiled. The most accounted method employed in the State of the Art to assess autonomic activity is the analysis of the cardiac variability, given its close connection to the ANS. Traditionally, this analysis is conducted on time series including RR intervals (tachograms) and is referred to as Heart rate Variability (HRV) analysis. Build a tool to enable both HRV analysis starting from tachograms. The tool should be able to analyze them in the time and spectral domains and through non-linear analysis and to export results. A readme file describing functionalities and a report describing implementation choices must be included.
Paper to read:
https://www.escardio.org/static-file/Escardio/Guidelines/Scientific-Statements/guidelines-Heart-Rate-Variability-FT-1996.pdf Keywords: HRV, autonomic nervous system, signal analysis"

### 2.2 Software requirements specification

Starting from the Necstamp project requirements a very simple doodle and software requirements specifications were created.

#### 2.2.1 Action from buttons

· button for selecting dataset, generating indicators and plots, and updating the GUI

· button to export the results

#### 2.2.2 Graphic elements

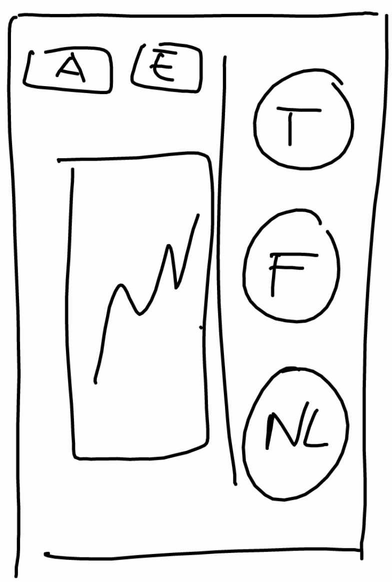
· buttons

· time-series plot

· features parameters:

  · time: mean, sdnn
  · frequency: via Lomb-Scargle periodogram lsULF and lsVLF
  · nonlinear: Sample Entropy

#### 2.2.3 Doodle




### 2.3 Script R

A little script in R was created to get familiar with the dataset and the parameters. It took very little time thanks to previous knowledge in R and the Heart Rate Variability R packages.[8] Link to R code [9]

#### 2.3.1 Tech Stack for the GUI

It was chosen to code entirely in python because:

· I already coded a big project in Java (project ing-soft POLIMI), which shares a lot of commonalities with Python

· I've already coded some little projects in python

· there is a python package, PySimpleGUI [10], for fast coding the frontend

· it is possible to generate from a single codebase both windows and Mac OS application

· I love coding in Python because it's very concise and offers a ton of ready to use packages [11]the other option was Matlab :D (by NECSTcamp requirements)

·

### 2.4 Codebase

Finally, code, tests, readme, and Mac OS and Windows applications were generated. Link github project: [12]

### 2.5 What's next?

The code was written to guarantee the possibility to add new parameters and to further extend the goals of the project. As reference papers shows [13], starting from the identified tachograms parameters, it could be possible to study via datascience and machine learning techniques: -clinical predictions -decision making -emotion and stress estimation -recommender systems Sounds pretty cool to me.

### 2.6 Acnkoweldgemnts

I want to thank NECSTCamp, Prof. Marco D. Santambrogio, Letizia Clementi PhD, and POLIMI for giving me opportunity to play with this project

## References

[1] https://www.sciencedirect.com/topics/medicine-and-dentistry/rr-interval

[2] https://web.stanford.edu/class/ee384m/Handouts/HowtoReadPaper.pdf

[3] An Overview of Heart Rate variability Metrics and Norms : https://www.frontiersin.org/articles/10.3389/fpubh.2017.00258/full

[4] The effect of principal component analysis in the diagnosis of congestive heart failure via heart rate variability analysis: https://journals.sagepub.com/doi/pdf/10.1177/09544119211036806

[5] Methodology for the prediction of paroxysmal atrial fibrillation based on heart rate variability feature analysis: https://www.sciencedirect.com/science/article/pii/S2405844021023471

[6] Irurzun, I. M., Garavaglia, L., Defeo, M. M., Thomas Mailland, J. (2021). RR interval time series from healthy subjects (version1.0.0). PhysioNet. https://doi.org/10.13026/51yd-d219"

[7] https://necstcamp.necst.it/

[8] https://cran.r-project.org/web/packages/varian/index.html , https://cran.r- project.org/web/packages/pracma/index.html , https://cran.r- project.org/web/packages/lomb/index.html

[9] https://github.com/eric0111/TachoE-NL1-0.0.1/blob/master/bin/tachoE-0.0.0.R

[10] https://pysimplegui.readthedocs.io/en/latest/

[11] https://www.python.org/

[12] https://github.com/eric0111/TachoE-NL1-0.0.1

[13] The effect of principal component analysis in the diagnosis of congestive heart failure via heart rate variability analysis https://journals.sagepub.com/doi/pdf/10.1177/09544119211036806 Feature Comparison of Emotion Estimation by EEG and Heart Rate Variability Indices and Accuracy Evaluation by Machine Learning $https://link.springer.com/chapter/10.1007/978-3-030-80285-1_27$ , Heart rate variability feature selection method for automated prediction of sudden cardiac death $https://www.sciencedirect.com/science/article/pii/S1746809420304286$ , Heart Rate Variability and Decision-Making: Autonomic Responses in Making Decisions https://www.mdpi.com/2076-3425/11/2/243, A Machine Learning model of the combination of normalized SD1 and SD2 indexes from 24h- Heart Rate Variability as a predictor of myocardial infarction , https://arxiv.org/abs/2102.09410, Prediction of atrial fibrillation based on nonlinear modeling of heart rate variability signal and SVM classifier https://link.springer.com/article/10.1007/s42600-021-00175-y , Alternative Devices for Heart Rate Variability Measures: A Comparative Test–Retest Reliability Study **https://www.mdpi.com/2076-328X/11/5/68**, Efficient methods for acute stress detection using heart rate variability data from Ambient Assisted Living sensors https://biomedical-engineering-online.biomedcentral.com/articles/10.1186/s12938-021-00911-6 , I Can Feel You: A Self-Trained Therapeutic Music Recommender System https://ieeexplore.ieee.org/abstract/document/9548471