

Kubios HRV

Heart Rate Variability Analysis Software

Mika Tarvainen, PhD
CEO, Kubios Oy

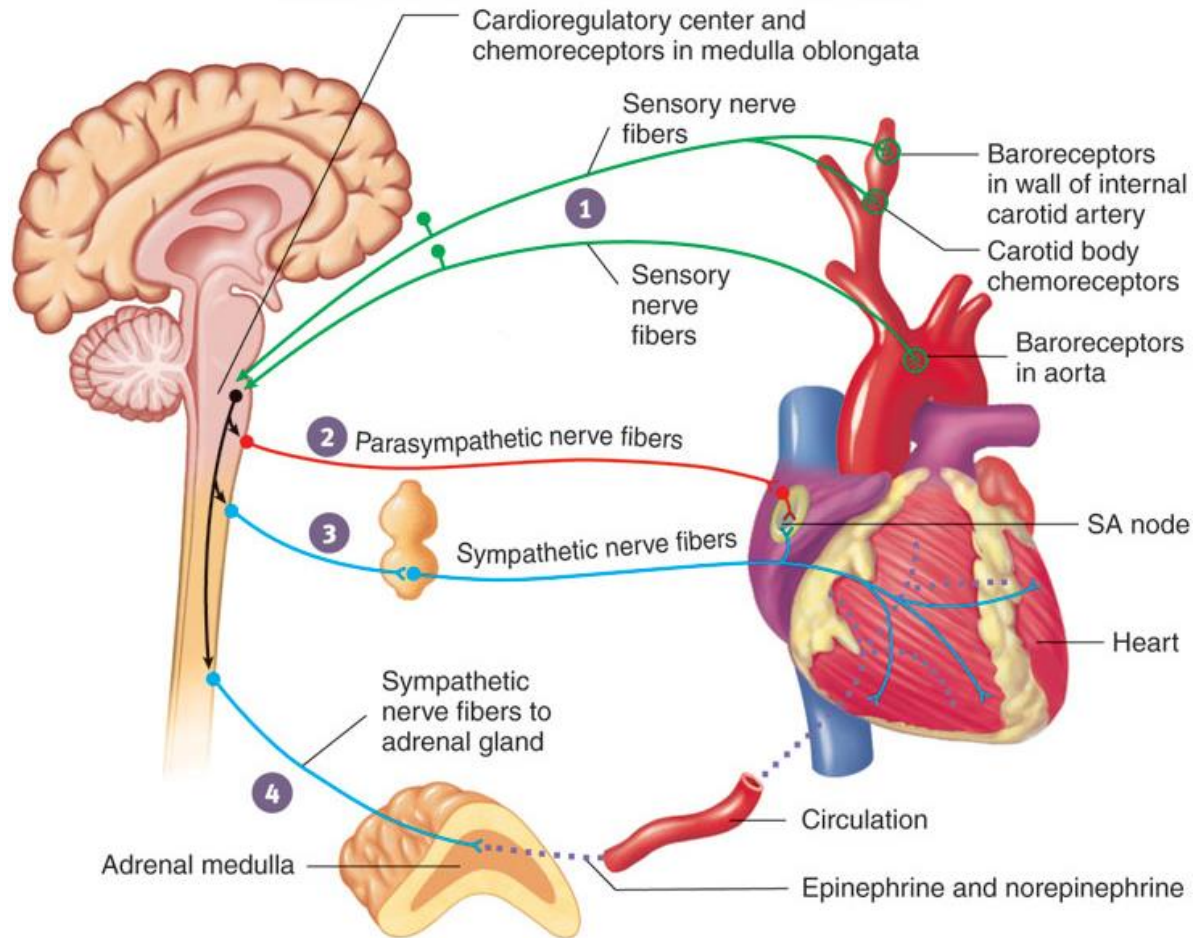


MATLAB EXPO 2018

15.5.2018 Helsinki

What is HRV

Regulation of heart rate

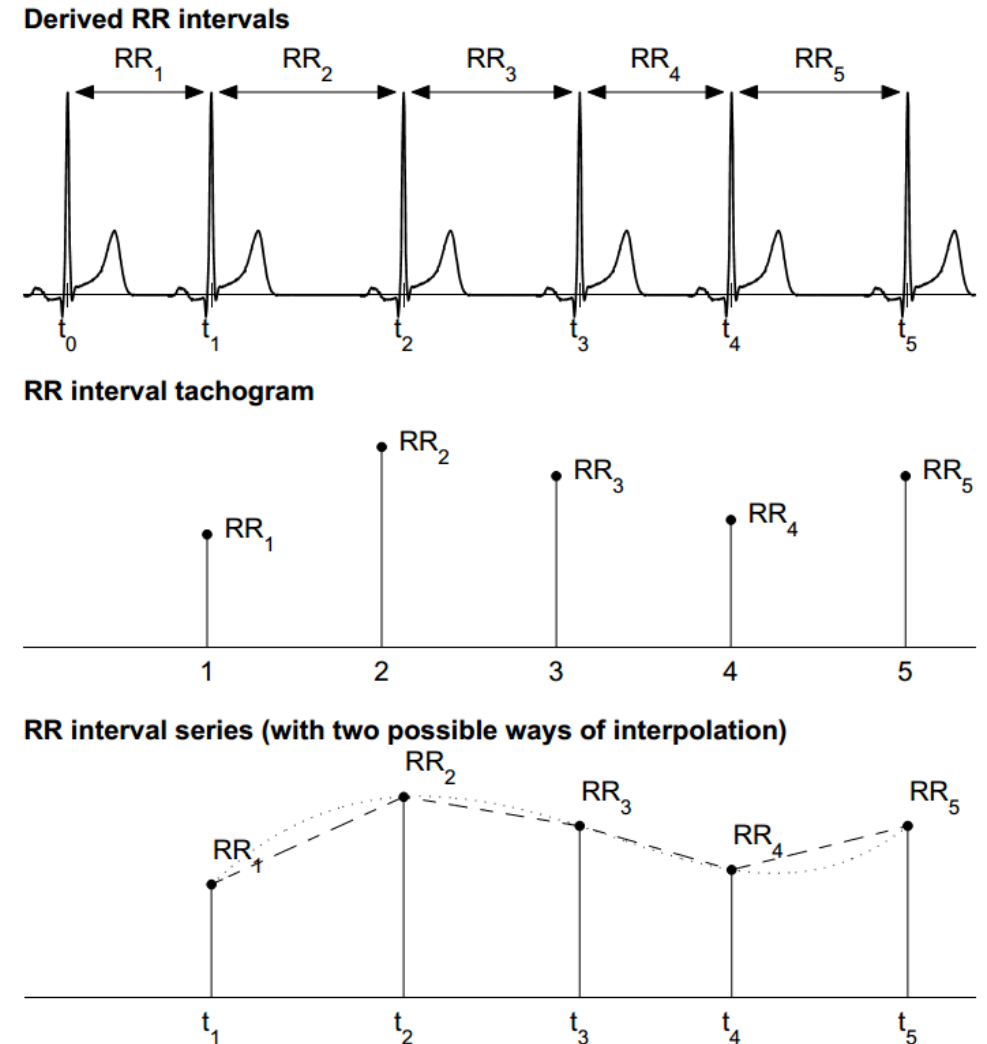


Autonomic nervous system (ANS)

- To preserve blood pressure homeostasis, ANS regulates
 - Heart rate and cardiac function
 - Vasomotor activity
 - Arterial baroreflex
- ANS divided into sympathetic and parasympathetic branches

HRV time series

- Continuous regulation of heart rate (HR) → Heart rate variability (HRV)
- Sympathetic activity (**GAS**)
 - Increases HR and decreases HRV
- Parasympathetic activity (**BRAKE**)
 - Decreases HR and increases HRV
- Respiratory sinus arrhythmia (RSA)
- High HRV indicates good recovery and high ability to tolerate stress

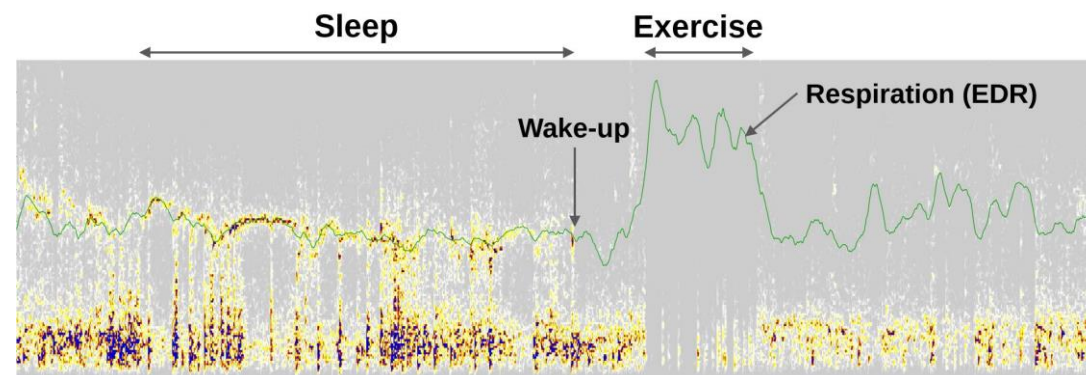
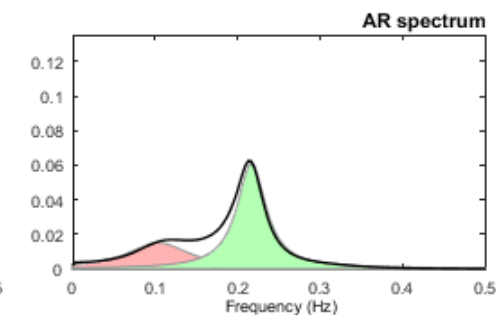
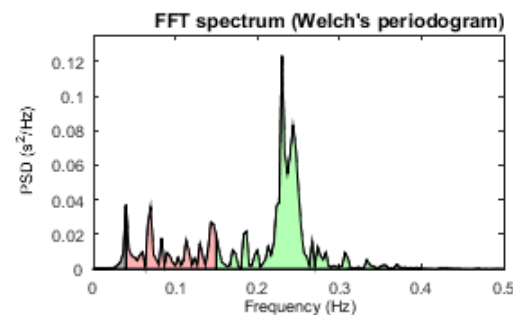
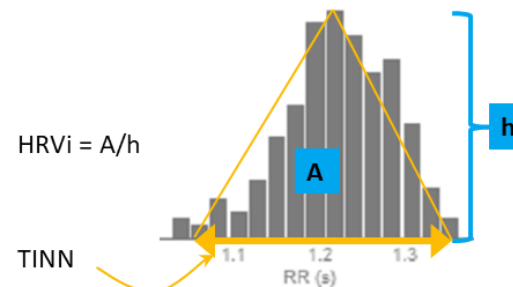


HRV Analysis Methods

- Time-domain (Mean RR, SDNN, RMSSD etc.)
 - Intensity of HRV
- Frequency-domain (LF and HF components, LF/HF ratio etc.)
 - Frequency components of HRV (assessment of sympathovagal balance)
- Nonlinear (Entropy measures etc.)
 - Complexity of HRV
- Time-varying
 - HRV dynamics

$$SDNN = \sqrt{\frac{1}{N-1} \sum_{j=1}^N (RR_j - \overline{RR})^2}$$

$$RMSSD = \sqrt{\frac{1}{N-1} \sum_{j=1}^{N-1} (RR_{j+1} - RR_j)^2}$$



Applications of HRV

Medical Research



For scientific research and professional use

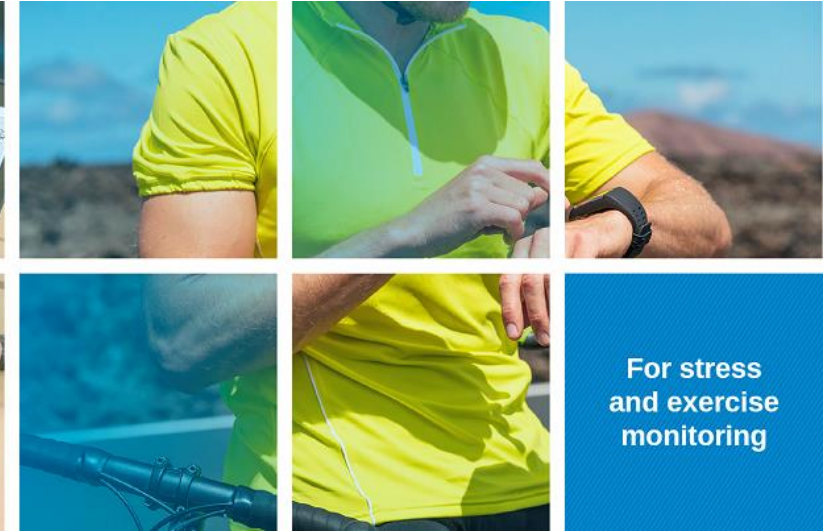
- Risk evaluation after MI
- Evaluation of heart failure
- Marker of diabetic neuropathy
- Evaluation of CAD
- ANS testing
- Sleep apnea
- Affective disorders
- Anesthesia monitoring etc.

Stress and Wellbeing



- Occupational stress
- HRV Biofeedback
- Resonant frequency
- Physiotherapy, yoga etc.

Fitness and Exercise



For stress and exercise monitoring

- Fitness assessment
→ maxHR, anaerobic threshold, energy consumption
- Recovery monitoring
→ Avoiding overtraining
- Coaching
→ HRV based individualized training prescription

Kubios Oy

About the company

- Founded 2016
- Software and algorithms development
- Market leader in HRV analysis software for scientific research and professional use
- Customers: Researchers, wellbeing therapists, sports/exercise coaches and athletes, personal monitoring etc.



Mika Tarvainen, PhD
CEO

15 years of experience in medical signal analysis and physiological modeling



Jukka Lipponen, PhD
COO

Expert on ECG signal analysis and software development



Juha-Pekka Niskanen
CPO

Qualified Medical Physicist, Expert on Matlab software development

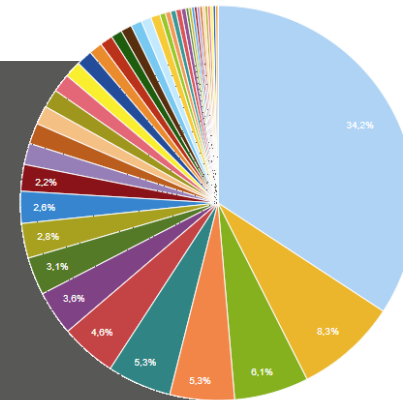


Perttu Ranta-aho
CTO

Expert on signal analysis, IT solutions and software development

Facts and figures

- Golden Standard HRV software
- Used in 1000 scientific studies
- Device independent software
- Over 40 analysis parameters
- Used in 120 countries (6/7 continents)



Products

Kubios HRV Standard (ver. 3.1)

- For non-commercial personal use
- Supports most common HR monitors (RR data)
- Standard HRV analysis
- Freeware



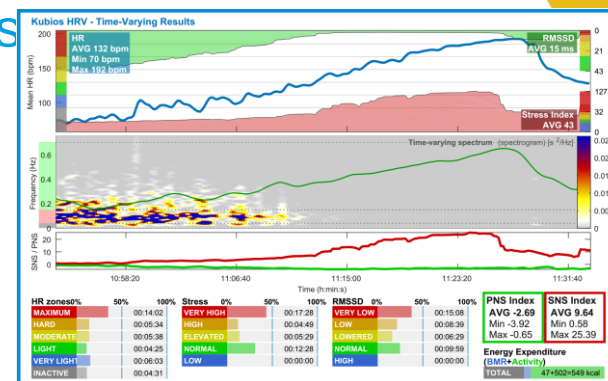
Kubios HRV Premium (ver. 3.1)

- For research and professional use
- Supports several HR monitors, ECG and PPG devices
- Full-featured HRV analysis software
 1. Extended data support (ECG and PPG data)
 2. Built-in beat detection
 3. Automatic correction of missed, extra and misaligned (ectopic) beats
 4. ECG derived respiration (EDR)
 5. Extended analysis features (spectrogram with “fire” colormap)
 6. Extended reports and exporting options (CSV batch file export)



HRV Premium

Kubios HRV Premium is the market leader in heart rate variability (HRV) analysis software for scientific research and professional use.



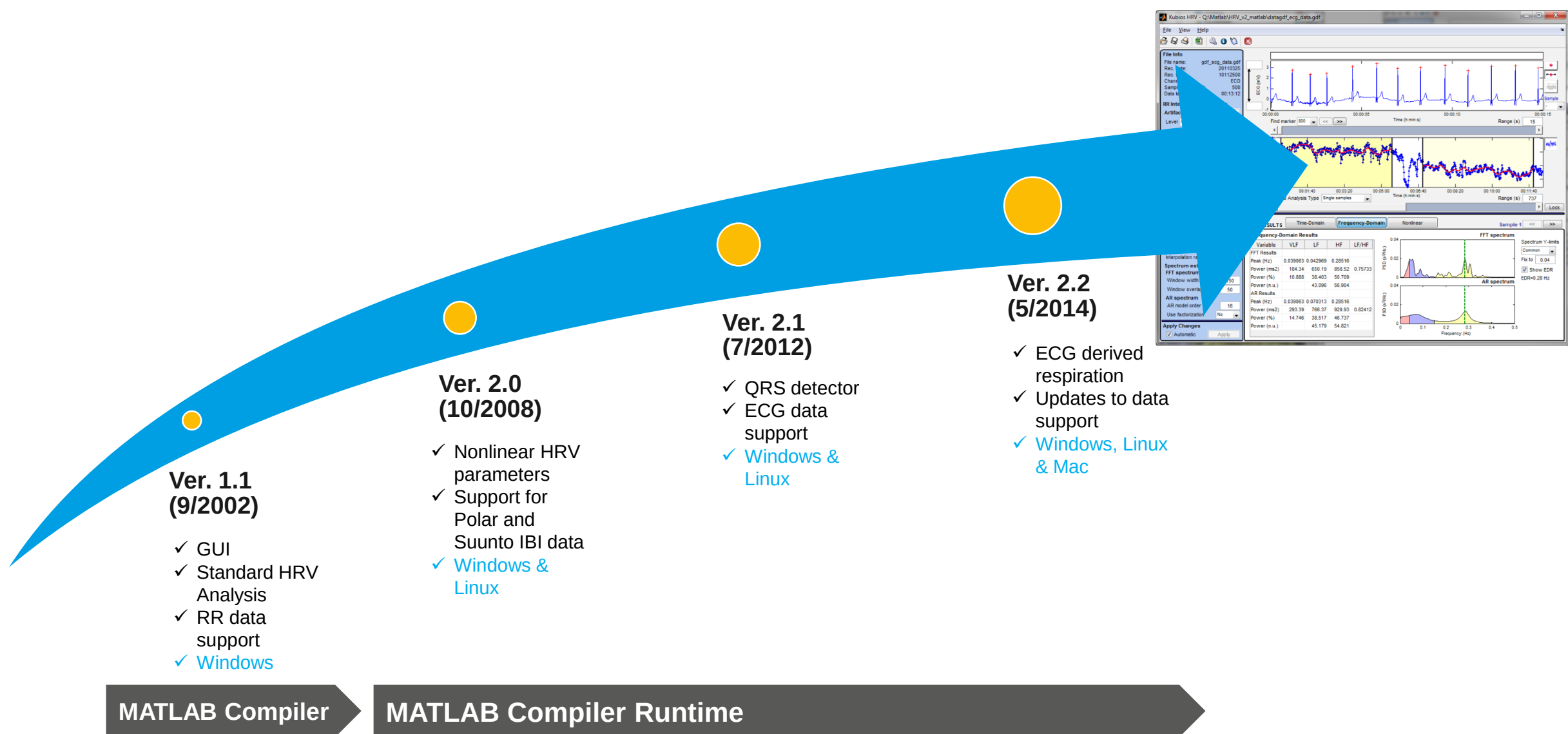
How we use MATLAB

How it all started?

- MATLAB 4.2 and 5 (1994-1999)
 - MSc studies in Medical Physics
 - Used in many courses for practical works and exercises

 - MATLAB 6, 7 and 8 (2000-2014)
 - PhD research in Medical Signal Analysis
 - Development of HRV analysis software started
- Ver. 1.1 released in Sep 2002





**Ver. 1.1
(9/2002)**

- ✓ GUI
- ✓ Standard HRV Analysis
- ✓ RR data support
- ✓ Windows

**Ver. 2.0
(10/2008)**

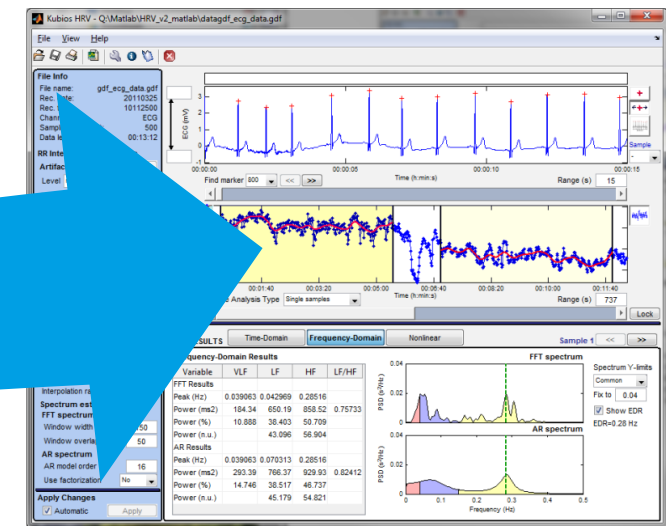
- ✓ Nonlinear HRV parameters
- ✓ Support for Polar and Suunto IBI data
- ✓ Windows & Linux

**Ver. 2.1
(7/2012)**

- ✓ QRS detector
- ✓ ECG data support
- ✓ Windows & Linux

**Ver. 2.2
(5/2014)**

- ✓ ECG derived respiration
- ✓ Updates to data support
- ✓ Windows, Linux & Mac



MATLAB Compiler

Limited functionality
(no MCR)

MATLAB Compiler Runtime



Still relying on MATLAB

1. Optimal for algorithm development and testing

Example: Signal baseline fitting

$$\hat{\theta}_\lambda = \arg \min_{\theta} \{ \|H\theta - z\|^2 + \lambda^2 \|D_d(H\theta)\|^2 \}$$

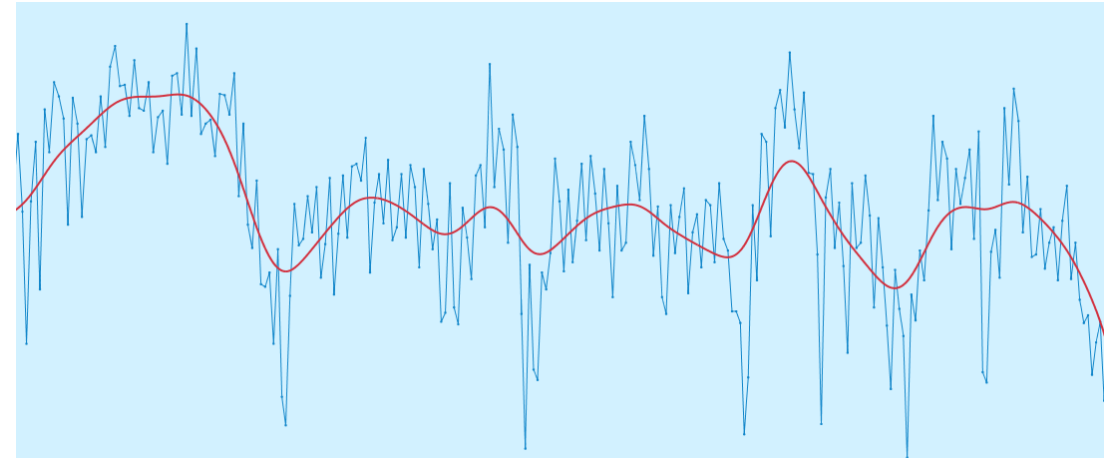
$$\hat{\theta}_\lambda = (H^T H + \lambda^2 H^T D_d^T D_d H)^{-1} H^T z$$

$$\hat{z}_{\text{trend}} = H\hat{\theta}_\lambda$$

$$\hat{z}_{\text{stat}} = z - H\hat{\theta}_\lambda = (I - (I + \lambda^2 D_2^T D_2)^{-1}) z$$

$$H = I \in \mathbb{R}^{(N-1) \times (N-1)}$$

$$D_2 = \begin{pmatrix} 1 & -2 & 1 & 0 & \cdots & 0 \\ 0 & 1 & -2 & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & 1 & -2 & 1 \end{pmatrix} \in \mathbb{R}^{(N-3) \times (N-1)}$$



```

Untitled
EDITOR PUBLISH VIEW
1
N = length(z);
lambda = 500;
I = speye(N);
D2 = spdiags(ones(N-2,1)*[1 -2 1],[0:2],N-2,N);
z_stat = (I-inv(I+lambda^2*D2'*D2))*z;
script Ln 1 Col 1

```

2. Graphics

MATLAB figure

- ✓ uimenu and toolbar
- ✓ 2D & 3D visualisations
- ✓ Highly customizable controls for GUI design
- ✓ Mouse/keyboard interactions

MATLAB UI figure (App designer)

- ✓ Interesting, but still some limitations (mouse/keyboard interaction, UImenu support)



3. Fast to build applications

MATLAB Compiler

- ✓ Matlab code → Windows, macOS and Linux applications
- ✓ deploytool – easy to use, but we need to customize our installers
- ✓ Code signing
- ✓ Agile software development



Kubios HRV Premium – DEMO

- ✓ Export data from your measurement device



Kubios HRV Premium – DEMO

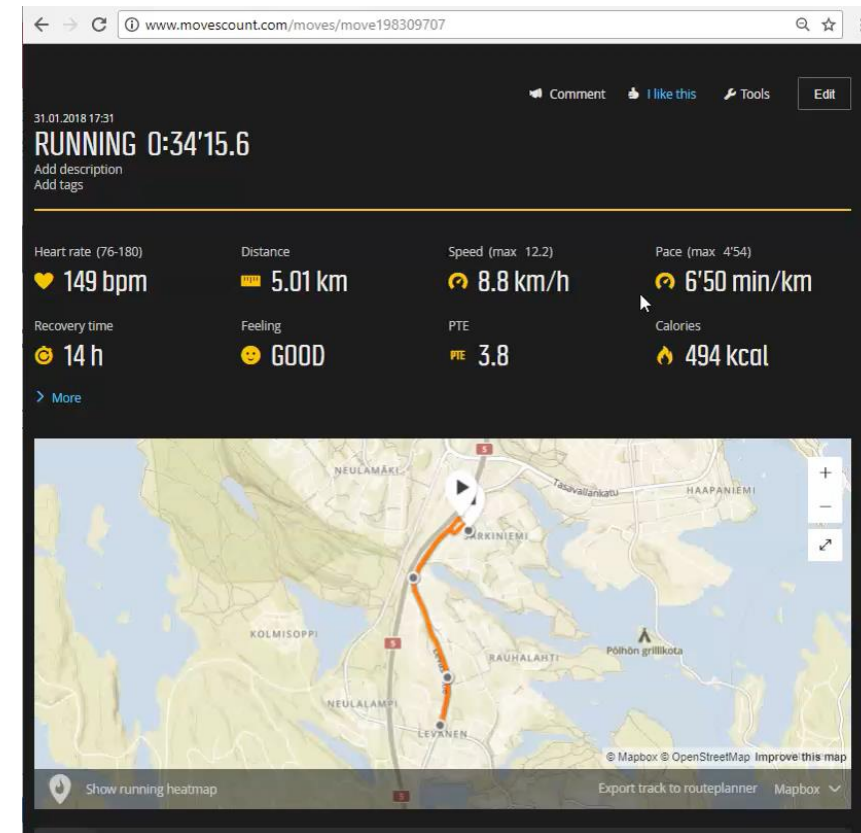
✓ Export data from your measurement device



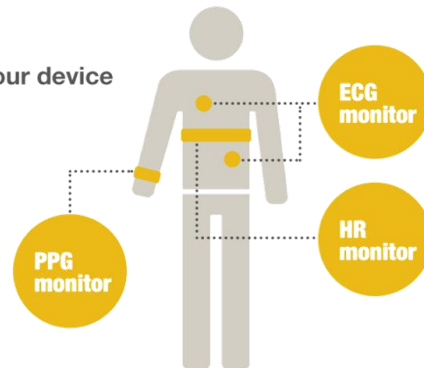
Suunto HR monitors (www.suunto.com)

- ✓ T6 series and Memorybelt
- ✓ Ambit 1, 2 and 3 series
- ✓ Spartan series

→ Export FIT file from Movescout



← ← Data from your device



Kubios HRV Premium – DEMO

- ✓ Export data from your measurement device



Garmin HR monitors (www.garmin.com)

- ✓ Forerunner 235, 620, 630, 920XT, 735 XT, 935
- ✓ Fenix 3, 3HR, and 5; Edge 520, 820, 1000

NOTE: Turn on HRV recording by changing “Log HRV” setting (Fenix 5 and Forerunner 935) or follow the steps give in <https://sporttracks.mobi/blog/tracking-hrv-garmin-watches>

→ Export FIT file from Garmin Connect



Kubios HRV Premium – DEMO

✓ Export data from your measurement device



Polar HR monitors (www.polar.com)

✓ V800, RS800, RS800CX, CS600, S810

→ Perform RR recording test and export RR data from Polar Flow web service

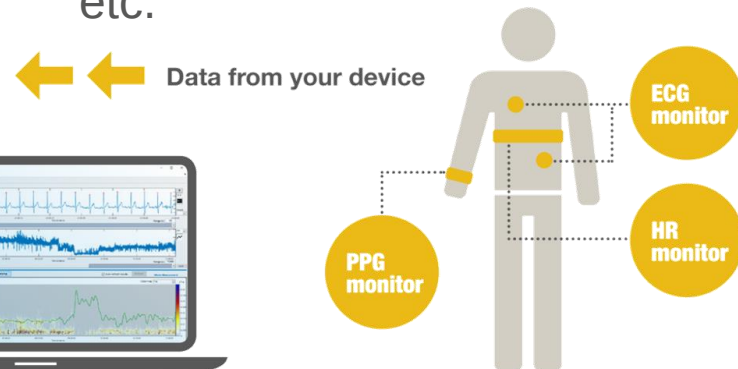


Kubios HRV Premium – DEMO

- ✓ Export data from your measurement device

Supported ECG and PPG devices

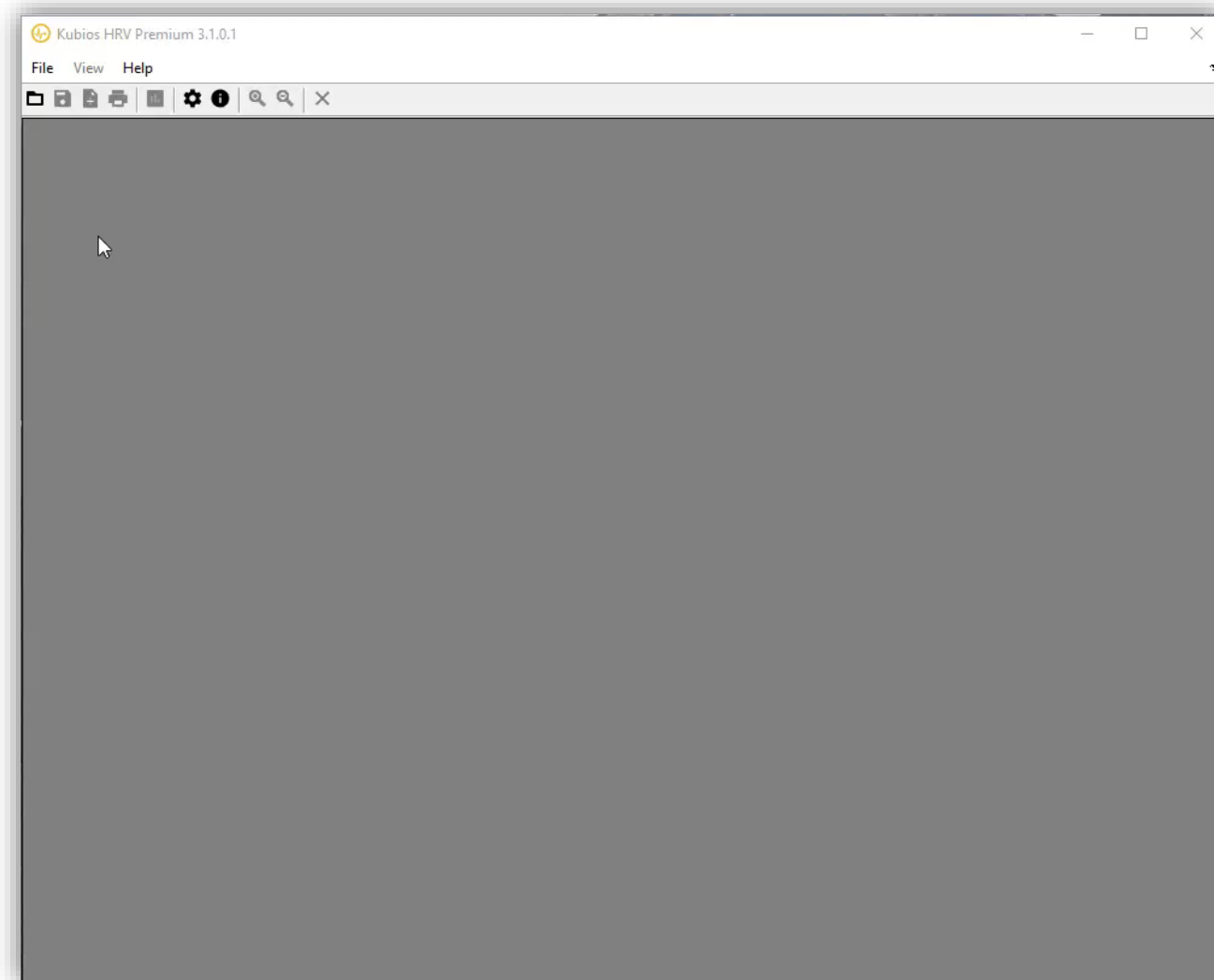
- ✓ Actiheart and Actiwave Cardio (www.camntech.com)
 - ✓ Alivecor Kardia (www.alivecor.com)
 - ✓ Biopac ECG and PPG devices (www.biopac.com)
 - ✓ Bittium Faros ECG (www.bittium.com)
 - ✓ Empatica E4 (www.empatica.com)
 - ✓ FirstBeat Bodyguard (www.firstbeat.com)
 - ✓ Mindfield MindMaster (www.mindfield.de)
 - ✓ Shimmer ECG and PPG devices (www.shimmersensing.com)
 - ✓ Zephyr Bioharness (www.zephyranywhere.com)
- etc.



Kubios HRV Premium – DEMO

✓ Analysing data in Kubios HRV

1) Opening a recording



Kubios HRV Premium – DEMO

✓ Analysing data in Kubios HRV

- 1) Opening a recording
- 2) Check beat detection and correct artefacts if necessary



Kubios HRV Premium – DEMO

✓ Analysing data in Kubios HRV

- 1) Opening a recording
- 2) Check beat detection and correct artefacts if necessary
- 3) Place as many analysis samples as you want (select stationary time periods)
- 4) All HRV analysis results are computed and visualised immediately



Kubios HRV Premium – DEMO

✓ Analysing data in Kubios HRV

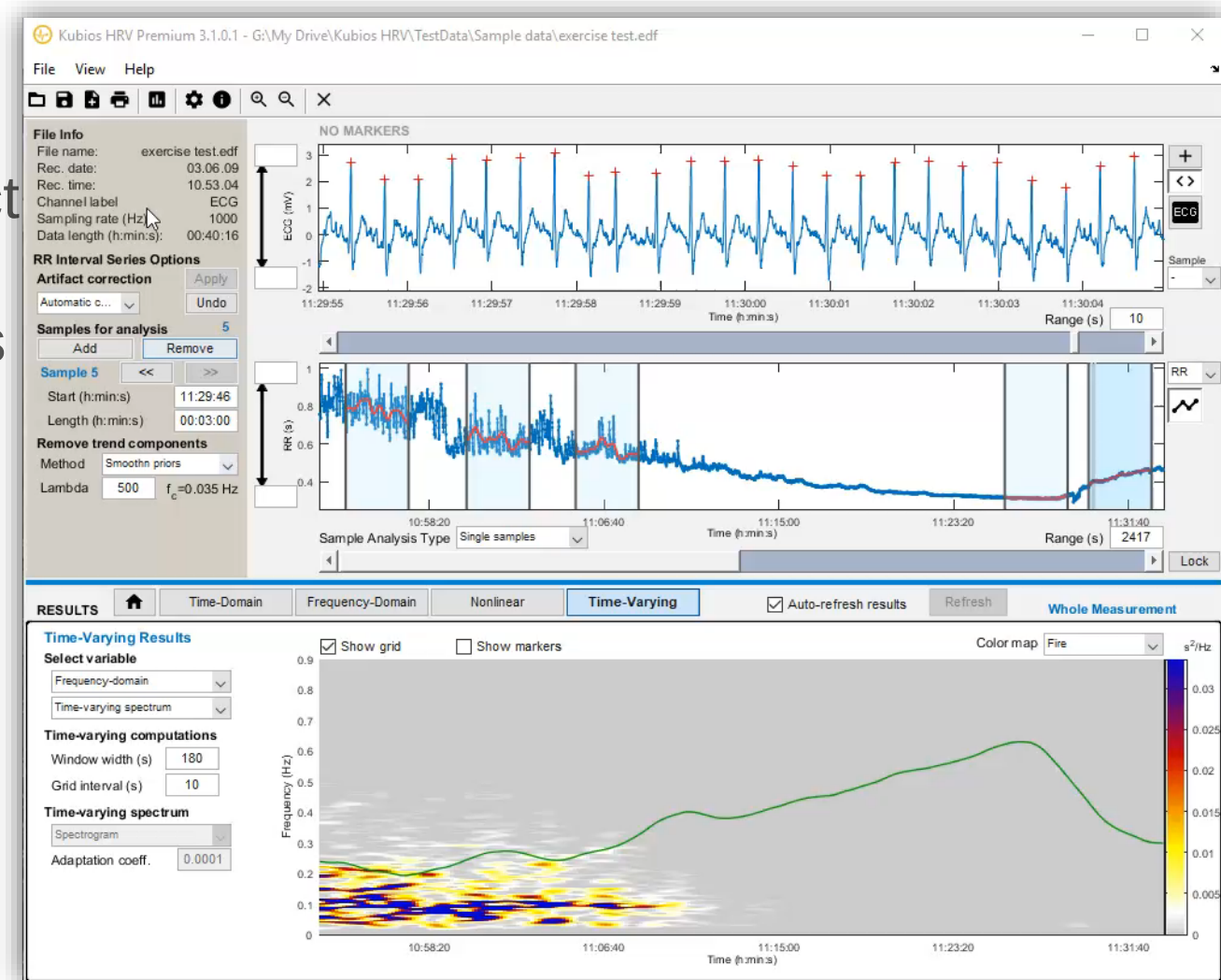
- 1) Opening a recording
- 2) Check beat detection and correct artefacts if necessary
- 3) Place as many analysis samples as you want (select stationary time periods)
- 4) All HRV analysis results are computed and visualised immediately
- 5) Apply time-varying analysis



Kubios HRV Premium – DEMO

✓ Analysing data in Kubios HRV

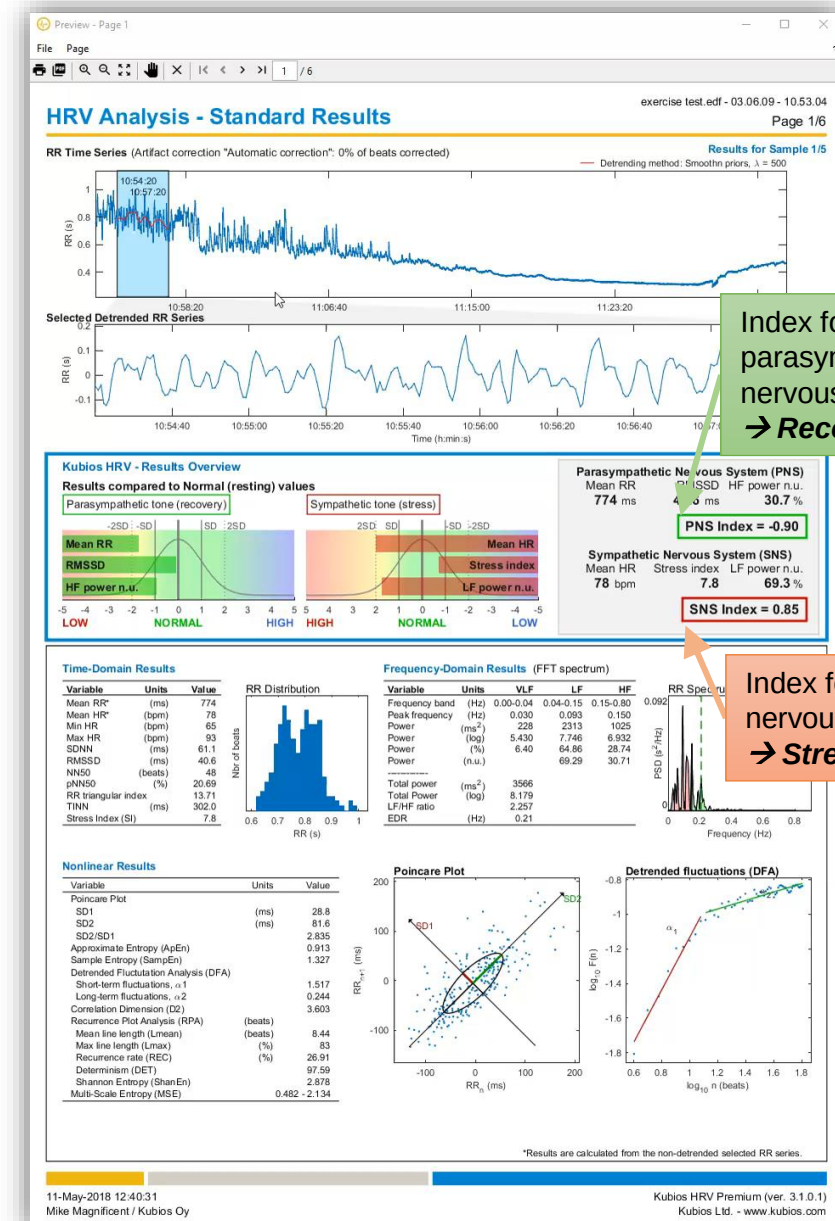
- 1) Opening a recording
- 2) Check beat detection and correct artefacts if necessary
- 3) Place as many analysis samples as you want (select stationary time periods)
- 4) All HRV analysis results are computed and visualised immediately
- 5) Apply time-varying analysis
- 6) Save results
 → PDF, TXT, MAT + “SPSS friendly” batch file



Kubios HRV Premium – DEMO

✓ Kubios HRV Premium reports

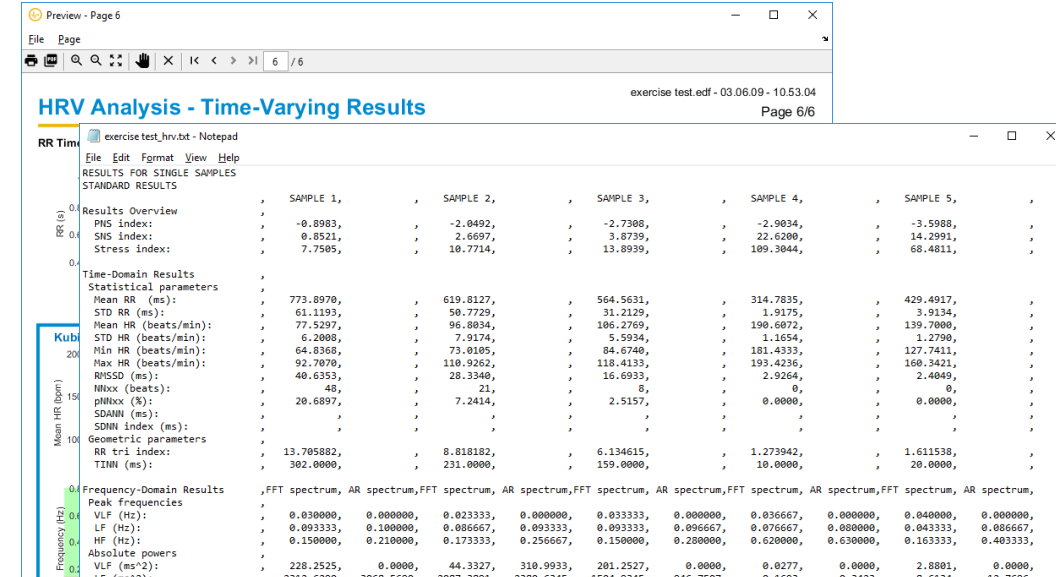
1) Report pages (1 page/sample)



Kubios HRV Premium – DEMO

✓ Kubios HRV Premium reports

- 1) Report pages (1 page/sample)
- 2) Report page for time-varying analysis
- 3) CSV-file
- 4) MAT-file
- 5) “SPSS friendly” batch file



The screenshot shows an Excel spreadsheet titled 'KubiosHRVresults.csv'. The data is organized in columns for time (T), artifacts (U), and various HRV parameters (V, W, X, Y, Z, AA, AB). The rows represent individual samples (ID001.gdf to ID010.gdf).

	T	U	V	W	X	Y	Z	AA	AB	
1	Kubios HRV Premium									
2	FileName	S1_Onset-Offset	S1_Artifacts (%)	S1_Mean RR (r)	S1_SDNN (ms)	S1_Mean HR (l)	S1_SD HR (bpr)	S1_Min HR (b)	S1_Max HR (b)	S1_RMSSD (m;S1
3	ID001.gdf	00:02:00-00:05:00	0	921.766731	69.456053	65.624805	5.577755	56.619376	78.983887	53.448367
4	ID002.gdf	00:02:00-00:05:00	0	918.862245	58.560259	65.694246	4.967093	55.514196	76.478169	41.570752
5	ID003.gdf	00:02:00-00:05:00	0	875.956098	39.209267	68.696611	3.505035	61.981912	76.504986	32.602266
6	ID004.gdf	00:02:00-00:05:00	0	776.991379	34.911502	77.516147	4.266204	66.578032	87.659184	19.95372
7	ID005.gdf	00:02:00-00:05:00	0.843882	760.084328	44.456656	79.493454	5.411032	61.352487	89.405219	24.654214
8	ID006.gdf	00:02:00-00:05:00	0	1147.095541	47.966488	52.444955	2.574125	48.333153	56.513158	59.238358
9	ID007.gdf	00:02:00-00:05:00	3.164557	568.378838	38.474746	106.091568	6.88464	83.045852	117.665112	20.62268
10	ID008.gdf	00:02:00-00:05:00	0	862.593301	52.015618	69.984047	5.02878	59.65427	81.726551	45.176265
11	ID009.gdf	00:02:00-00:05:00	0	856.514286	58.931479	70.509309	5.706661	59.943094	82.367175	41.002496
12	ID010.gdf	00:02:00-00:05:00	0.884956	798.279359	54.607816	75.710817	5.86364	57.719853	84.977336	27.07866

Thank you

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