kubios

Kubios HRV

Heart Rate Variability Analysis Software

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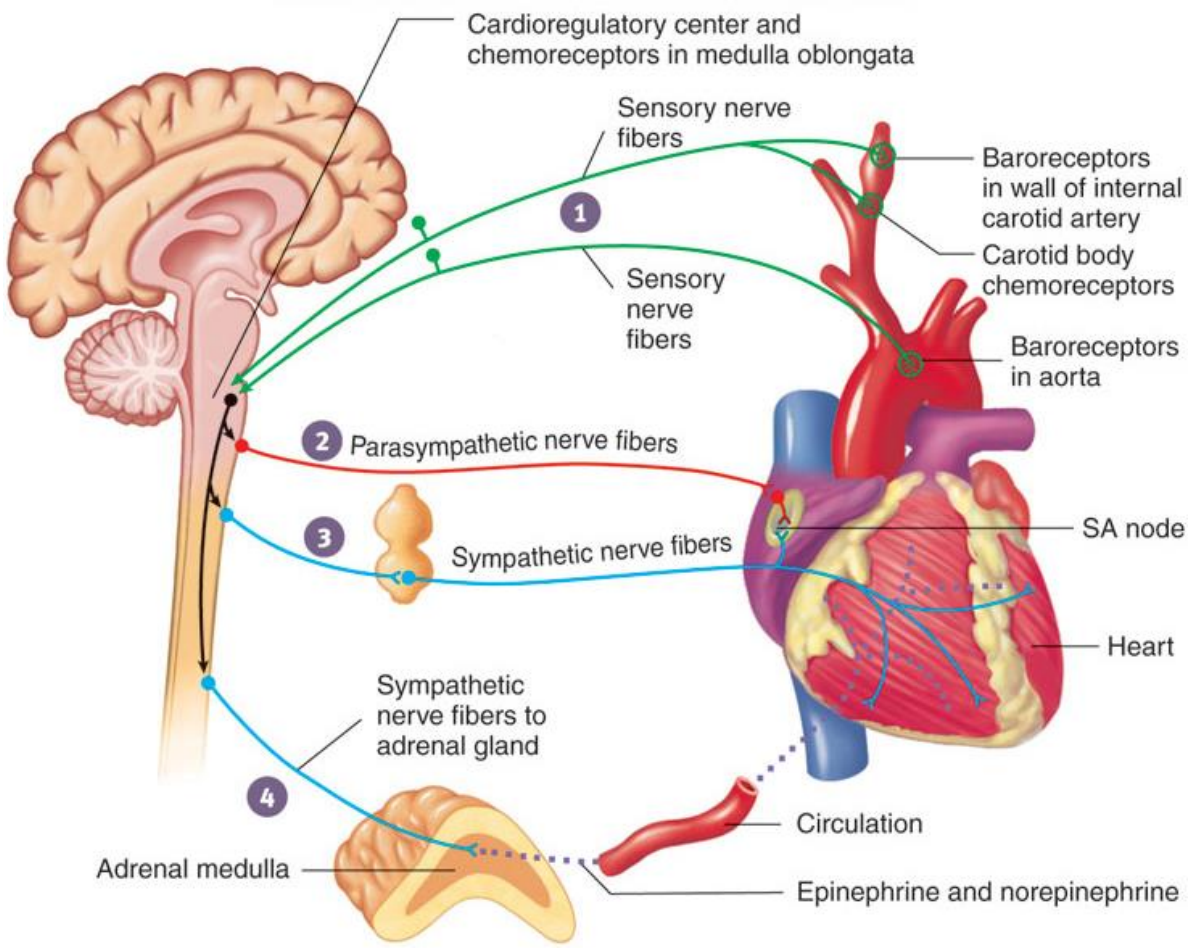
What is HRV
Regulation of heart rate

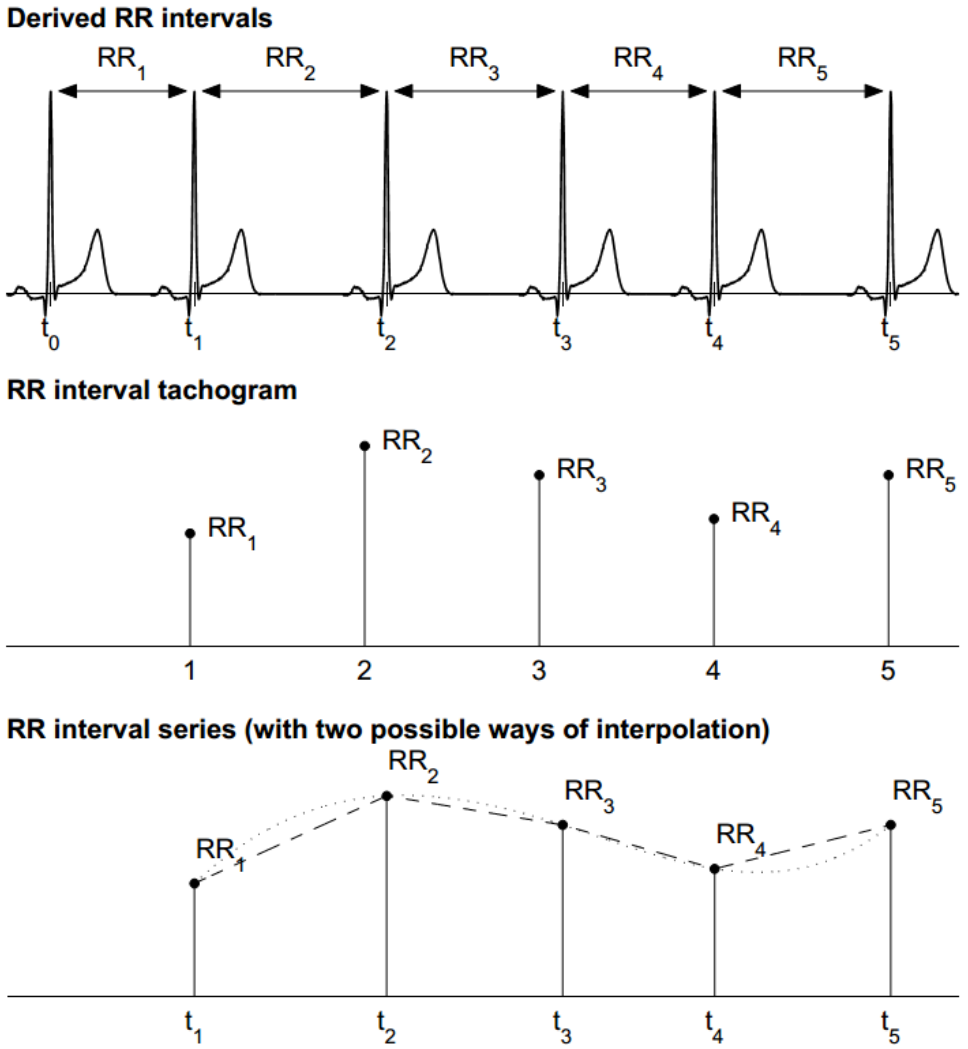


Autonomic nervous system (ANS)

- 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

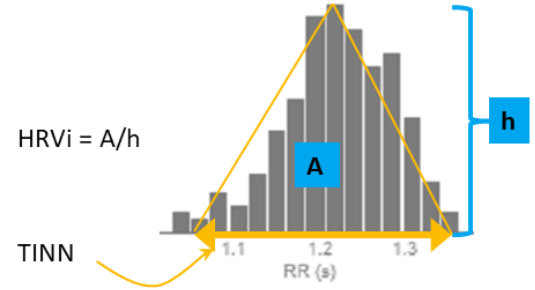


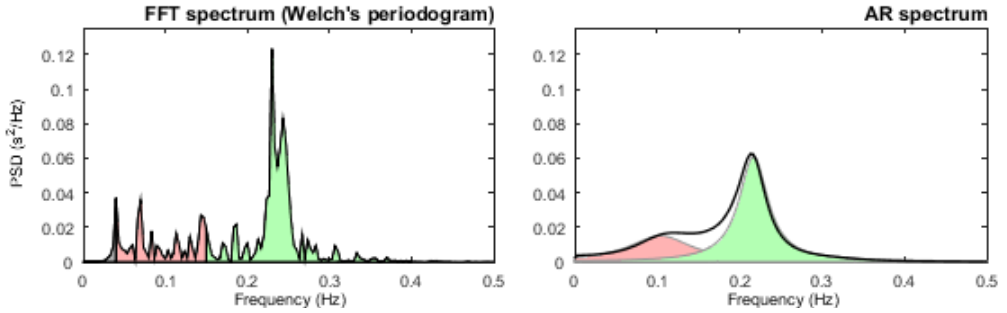
HRV Analysis Methods

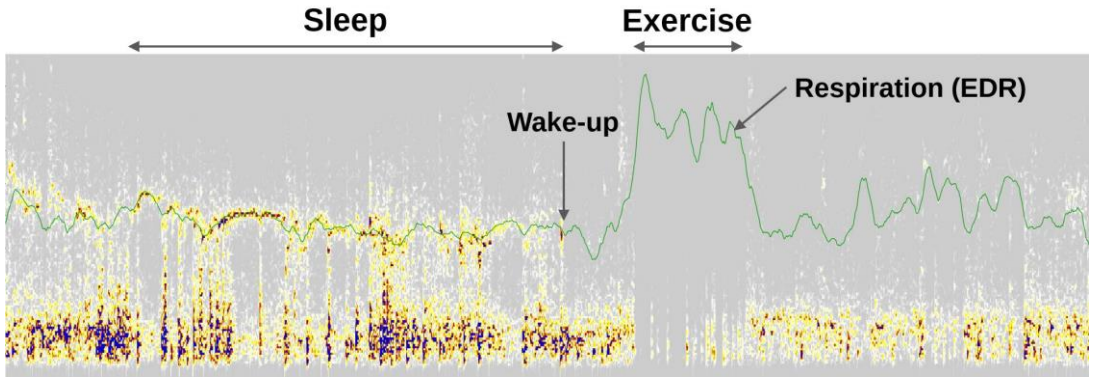
- Time-domain (Mean RR, SDNN, RMSSD etc.)
  - → Intensity of HRV
- Frequency-domain (LF and HF components, LF/HF ratio etc.)
  - → Frequency components of HRV (assessment of sympathovagal balance)
- Nonlinear (Entropy measures etc.)
  - → Complexity of HRV
- Time-varying
  - → HRV dynamics

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

$$\mathrm{RMSSD} = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N-1}(\mathrm{RR}_{j+1} - \mathrm{RR}_j)^2}$$







Applications of HRV

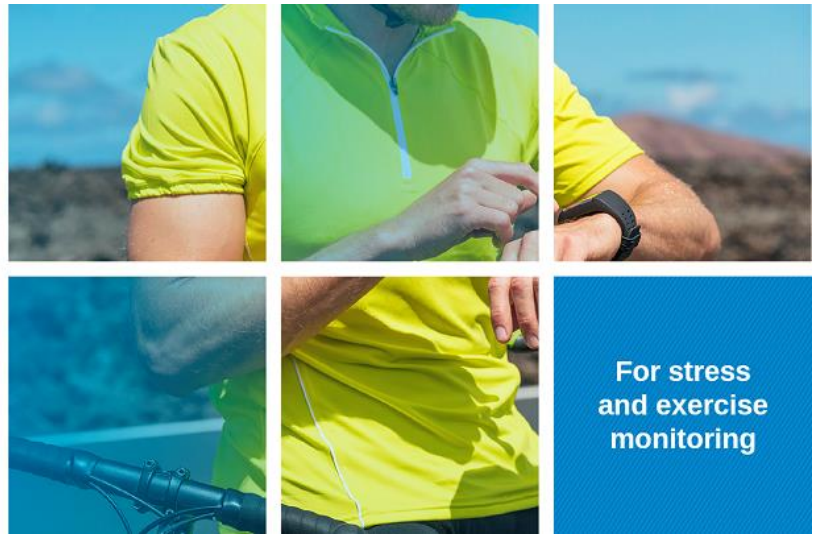
Medical Research

- 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



- 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

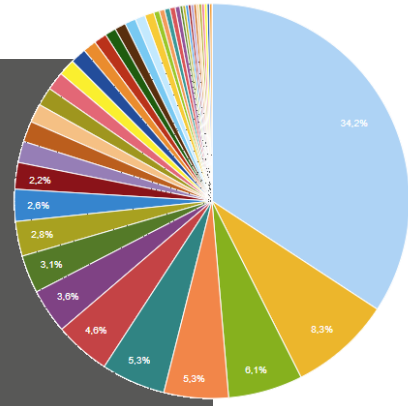
Jukka Lipponen, PhD
COO
Expert on ECG signal analysis and software development

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)



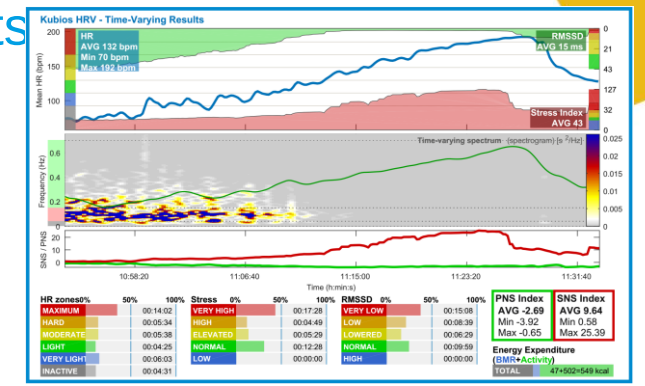
Products

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)

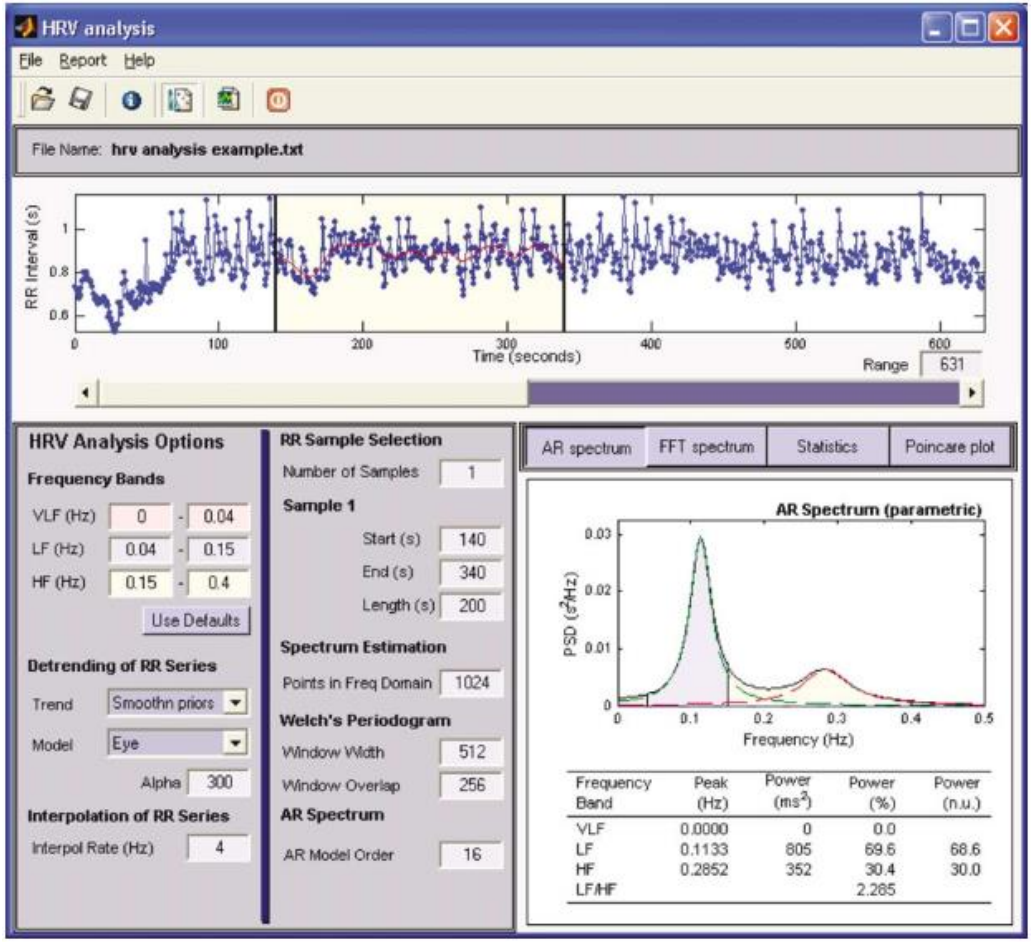


How we use MATLAB

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



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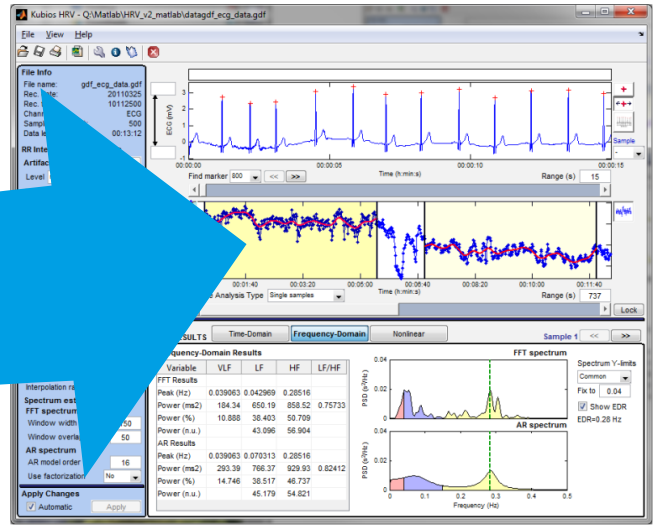


Ver. 1.1 (9/2002)

- ✓ 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 → **MATLAB Compiler Runtime**

Limited functionality (no MCR)

Still relying on MATLAB

1. Optimal for algorithm development and testing

Example: Signal baseline fitting

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

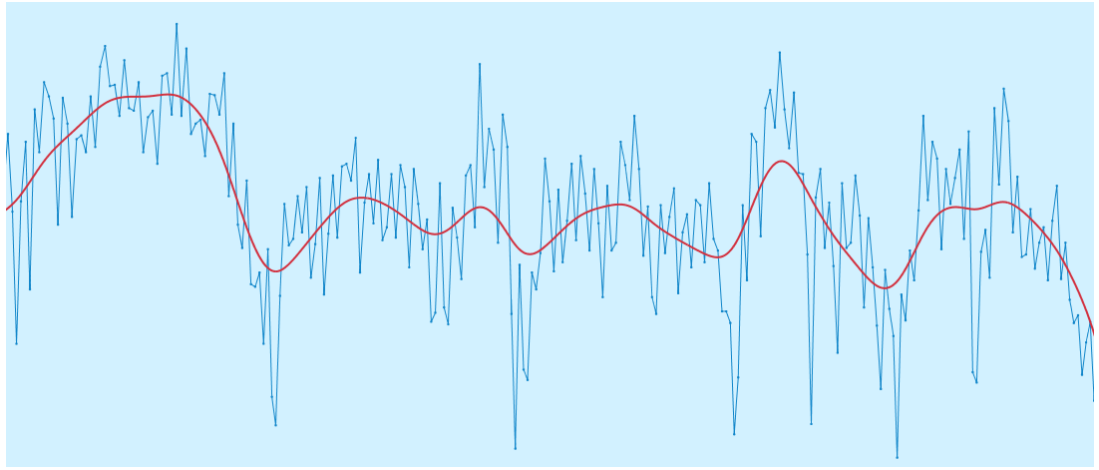
$$\hat{\theta}_\lambda = \left(H^T H + \lambda^2 H^T D_d^T D_d H\right)^{-1} H^T z$$

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

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

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

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



Untitled

EDITOR PUBLISH VIEW

```
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

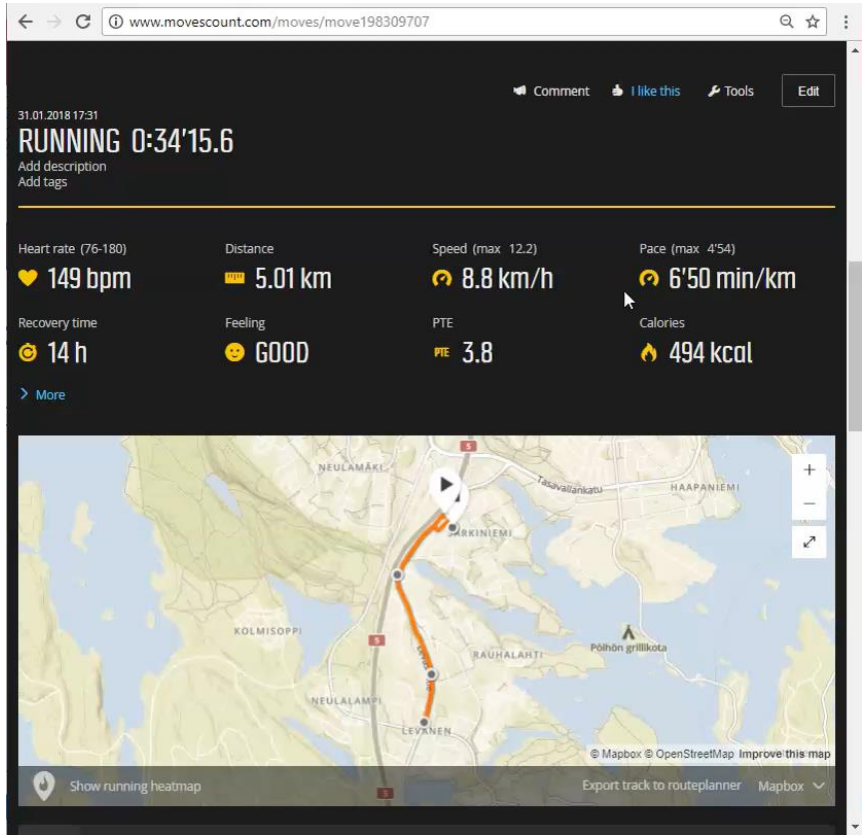
Kubios HRV Premium – DEMO

✓ **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



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

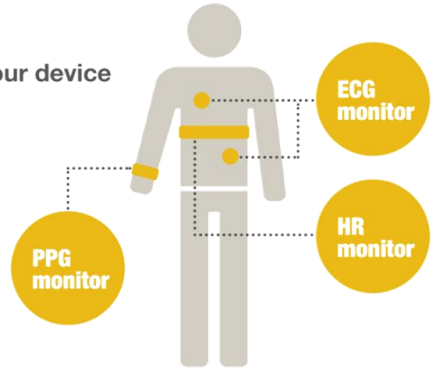
Kubios HRV Premium – DEMO

✓ **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)

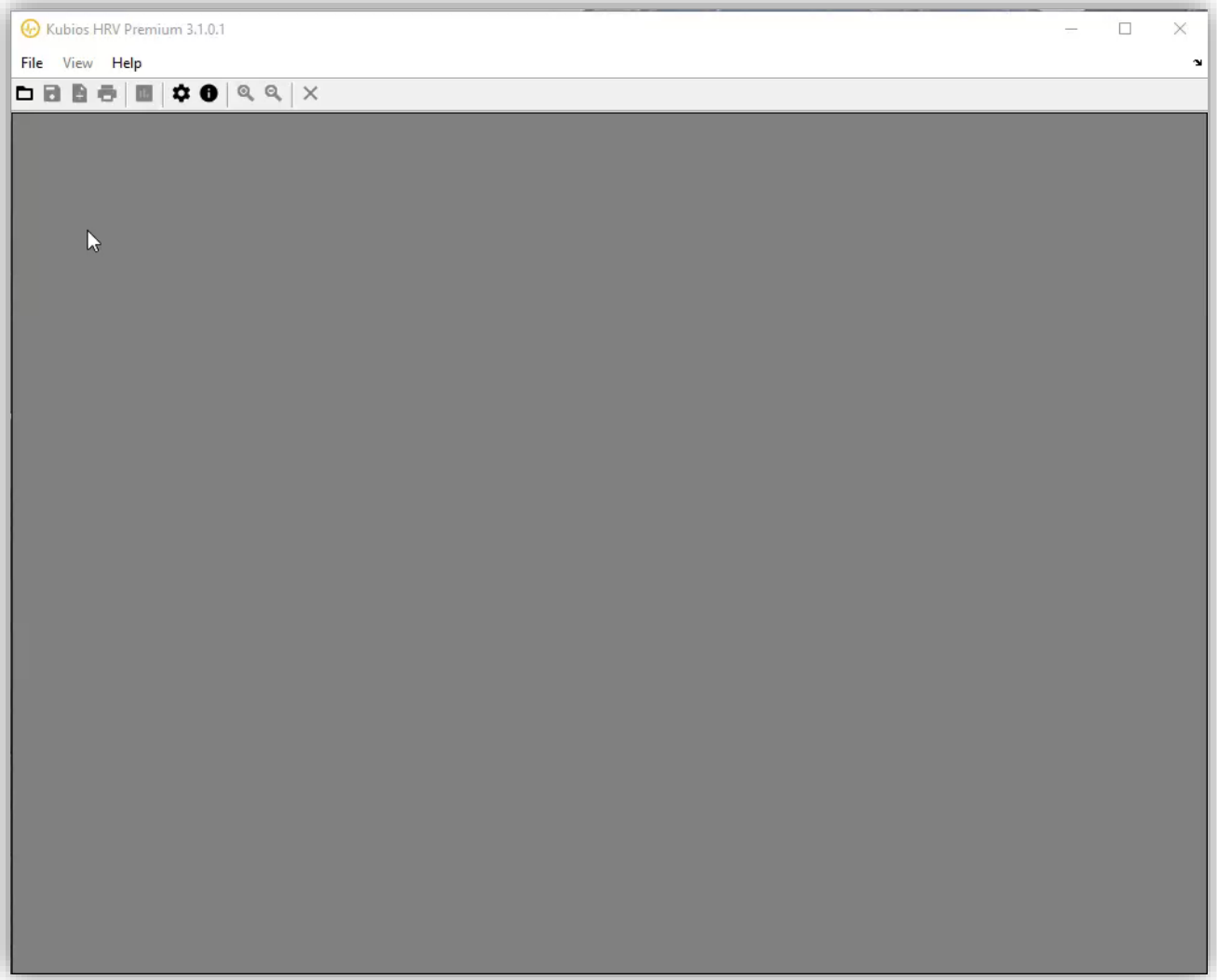
etc.



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

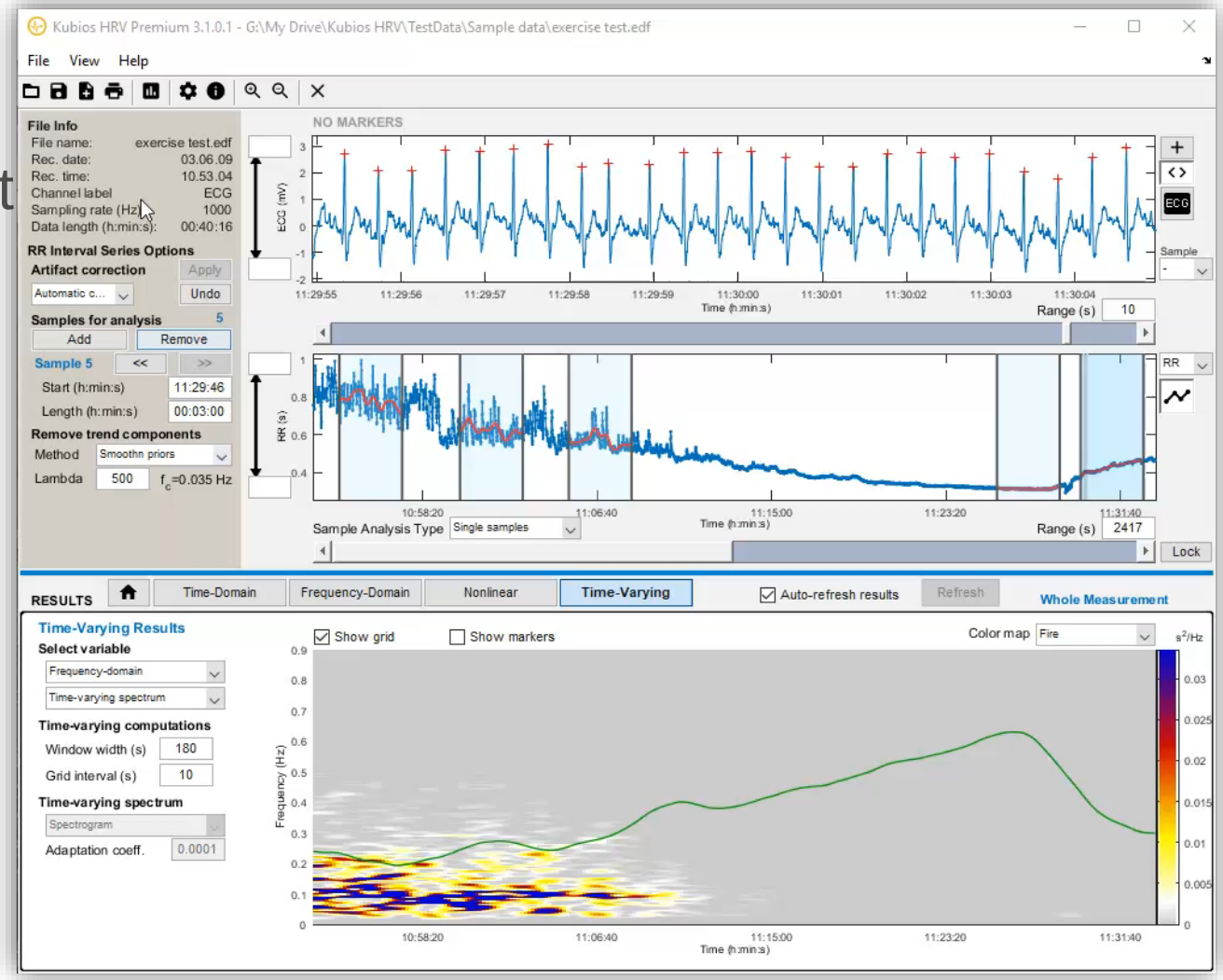
1) Opening a recording
2) Check beat detection and correct artefacts if necessary
3) Place as many analysis samples as you want (select stationary time periods)
4) All HRV analysis results are computed and visualised immediately
5) Apply time-varying analysis

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

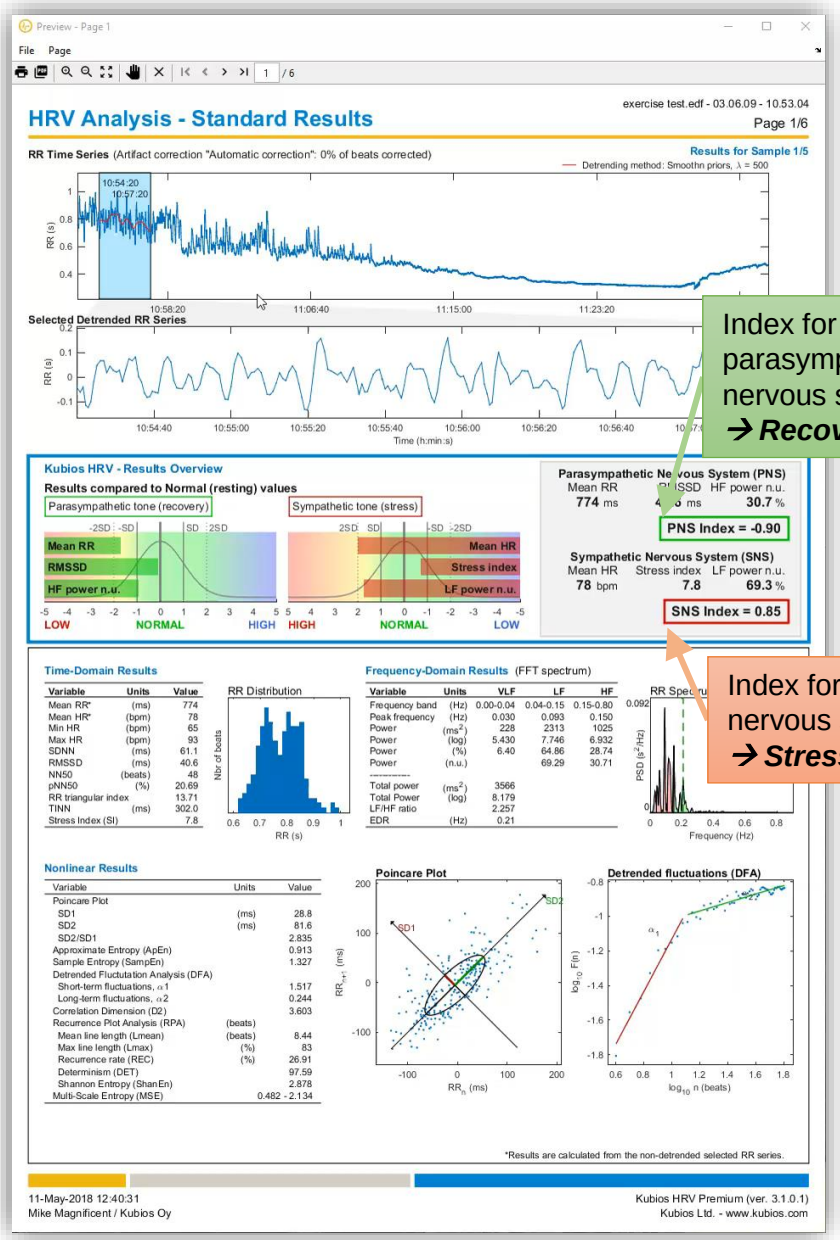
→ PDF, TXT, MAT + “SPSS friendly” batch file



Kubios HRV Premium – DEMO

✓ **Kubios HRV Premium reports**

1) Report pages (1 page/sample)



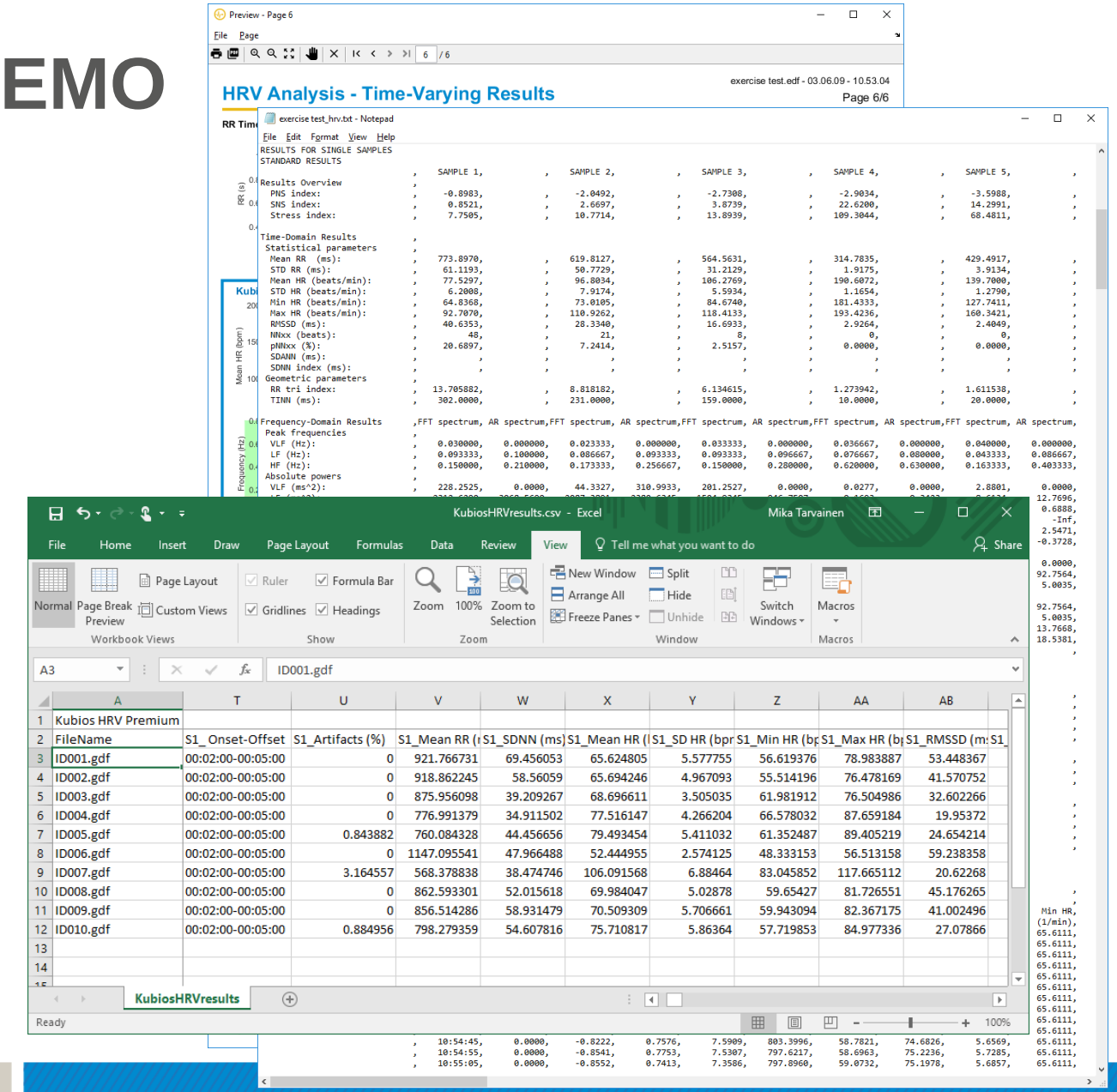
Index for parasympathetic nervous system activity
→ ***Recovery***

Index for sympathetic nervous system activity
→ ***Stress***

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



Thank you

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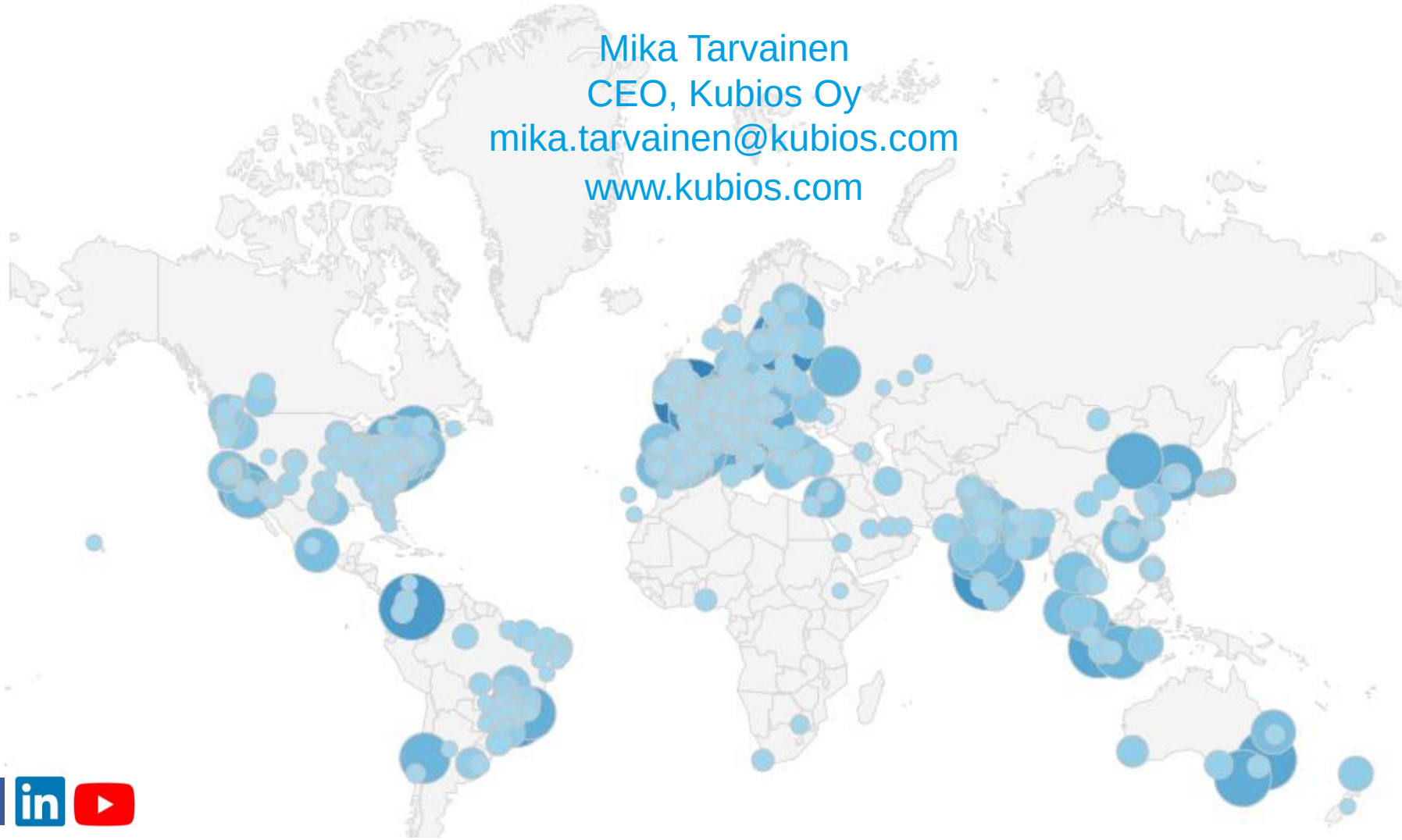

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