Group of Artificial Intelligence and Medical Technologies

Department of Medical Signals

Institute of Scientific Instruments
The Czech Academy of Sciences

HEMATIC RESEARCH FOCUS

Research area

- Biomedical engineering
- Signal processing methods
- Architectures of deep-learning models for ECG analysis
- Software design and development for real-time signal processing
- Cardiac electrophysiology
- Blood circulation control
- Advanced acquisition technologies

Excellence

- Blood circulation and hemodynamic control (stroke volume, pulse wave velocity, heart rate and blood pressure variability)
- Heart repolarization abnormalities identification
- Development of the novel acquisition technologies in cardiology (the multichannel whole-body bioimpedance monitor, PulseWave software, high frequency and dynamic ECG recorders)
- High frequency high dynamic range ECG for early diagnostics of heart pathologies
- New software solutions for large data visualization and processing – SignalPlant open access platform

Mission

To contribute to the development of novel diagnostic markers, technologies, protocols and analytical methods that will allow physicians to see more and that improve the quality of life

UP-TO-DATE ACTIVITIES

Research orientation

- Artificial intelligence in real-time and cloud signal processing
- Design and implementation of new technologies. Includes: high dynamic acquisition system, new software for the analysis of high frequency ECG, interpretation of results and diagnostic applications
- Analysis of time-spatial distribution of electrical heart activation
- Open access tools of large data visualization and processing

Main capabilities

Basic research

- Design and implementation of automated AI-powered server software for processing telemedicine data
- Distribution of high frequency components during ventricular depolarization period, detection of ventricular dyssynchrony in high temporal resolution
- Dynamic properties of blood circulation parameters

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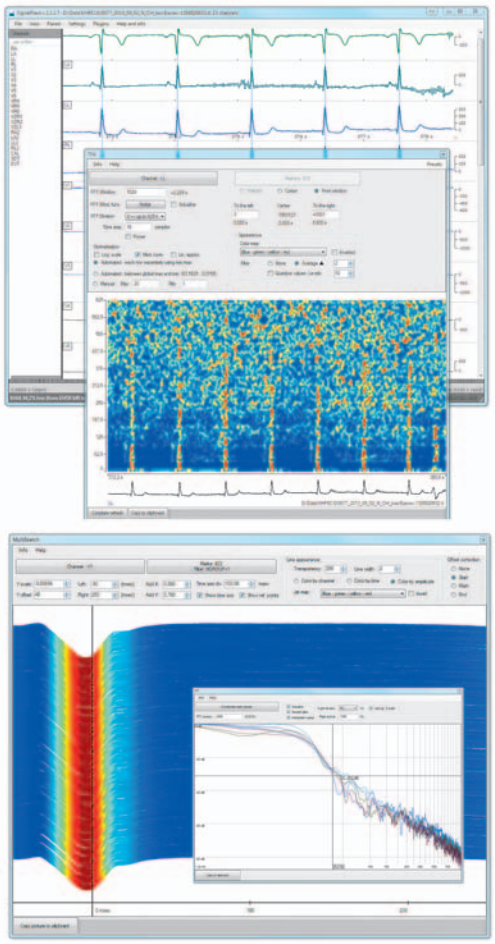


SignalPlant. SignalPlant is free software tool for signal examination, scoring and post-processing. Although it is originally aimed to biological signals, it contains tools useful for any other area of signal processing

Applied research
- Design and implementation of automated AI-powered server software for processing telemedicine data
- Development and realization of Multichannel PulseWave Monitor – medical device intended for novel non-invasive diagnostics of the state of the arterial system
- High frequency ECG monitor – experimental device for advanced acquisition of multi-lead high frequency and high dynamic electrocardiography
- High frequency ECG methods for identification of ventricular dyssynchorny (patent: https://patents.google.com/patent/WO2015090260A3/en)
- Cardiac pacing therapy optimization
- SignalPlant – free signal processing and visualization software tools (https://signalplant.codeplex.com/)

Sub-fields of group activities
- Artificial intelligence (Machine learning & Deep learning models)
- Clinical end experimental medicine – cardiology
- Biomedical engineering
- Signal acquisition and processing

KEY RESEARCH EQUIPMENT

List of devices
- GPU server for training deep-learning models: Supermicro SYS-4029GP-TRT with 8× GPU Quadro RTX 5000
- Computing facilities intended for large data interactive processing (64 core parallel computing, high-speed SSD storages, SW support)
- Software for FPGA development – signal processing tool (Xilinx System Generator for DSP), logic analyser tool (Xilinx ChipScope Pro)

ACHIEVEMENTS

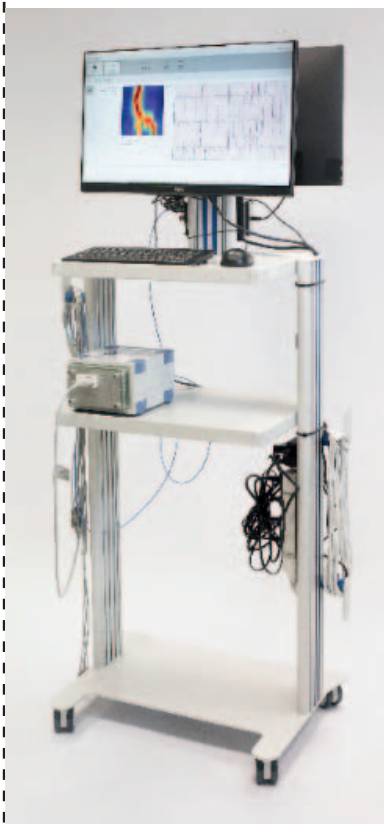
Awards
- 2014: ESGCO 2014 Award for Technology Transfer, Infl uence of Tilt Load on Pulse Wave Velocity in Lower Limbs
- 2014: Physionet challenge, Robust Detection of Heart Beats in Multimodal Data, 4th prize (Boston, USA) for QRS multimodal detection algorithm.
- 2015: Physionet challenge (Nice, France), Reducing False Arrhythmia Alarms in the ICU, the 1st and 2nd prize (two different categories) for arrhythmias detection methods.
- 2017: Clinical Needs Translational Award (CTA), European Society of Cardiology, Rennes, France
- 2018: 1st prize, LBBB Initiative of the International Society for Computerized Electrocardiology (Park City, Utah, USA)

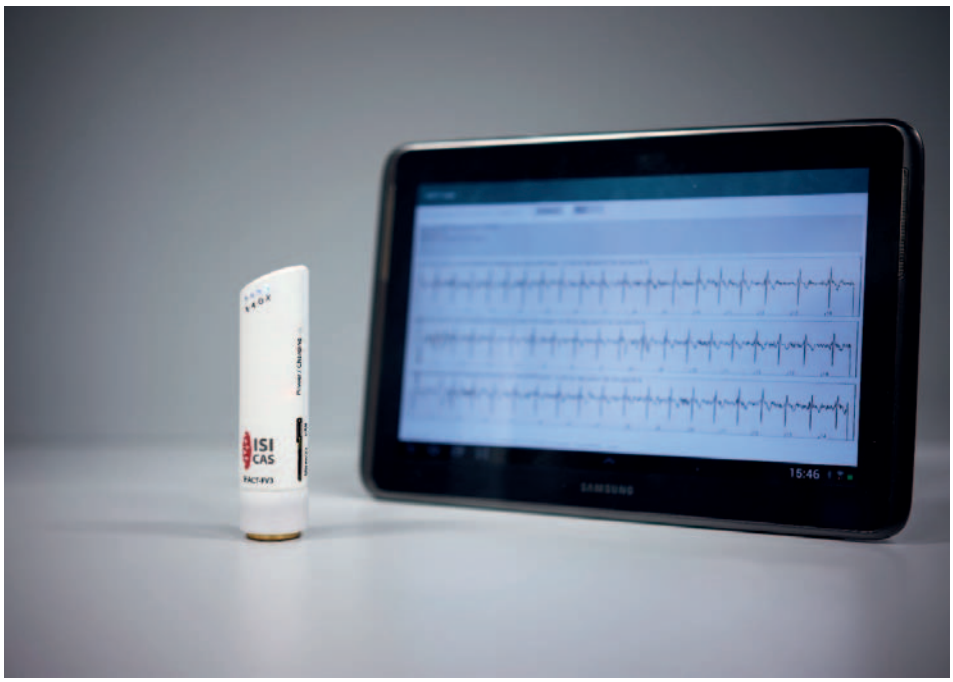
Publications

- **J. Halámek, J.P. Couderc, P. Jurák, V. Vondra, W. Zareba, I. Viščor, P. Leinveber:**
  "Measure of the QT-RR Dynamic Coupling in Patients with the Long QT Syndrome", Annals of Noninvasive Electrocardiology 17, 4, 323–330, 2012

- **F. Plesinger, J. Jurco, J. Halamek, P. Jurak:**
  "SignalPlant: an open signal processing software platform", Physiol Meas 37(7), 38–48, 2016

VDI system to asses electrical ventricular dyssynchrony in a real-time





A hend-held device for instant screening of the heart activity (HACT-FV3) implements machine learning embeded on the FPGA chip

- **P. Jurak, J.Halamek, J. Meluzin, F. Plešinger, T. Postranecka, J. Lipoldova,M. Novak,V. Vondra, I. Viščor, L. Soukup, P. Klimeš, P. Vesely, J. Šumbera, K. Zeman, S. Asirvatham, J. Tri, S.J. Asirvatham, P. Leinveber:** *"Ventricular dyssynchrony assessment using ultra-high frequency ECG technique"*, Journal of Interventional Cardiac Electrophysiology 49, 3, 245–254, 2017

- **F. Plesinger, P. Jurak, J. Halamek, P. Nejedly, P. Leinveber, I. Viscor, V. Vondra, S. McNitt, B. Polonsky, A. J. Moss, W. Zareba, and J. P. Couderc:** *"Ventricular Electrical Delay Measured From Body Surface ECGs Is Associated With Cardiac Resynchronization Therapy Response in Left Bundle Branch Block Patients From the MADIT-CRT Trial (Multicenter Automatic Defibrillator Implantation-Cardiac Resynchronization Therapy)"*, Circulation: Arrhythmia and Electrophysiolog, 2018;11:e005719

- **K. Curila, R. Prochazkova, P. Jurak, M. Jastrzebski, J. Halamek, P. Moskal, P. Stros, J. Vesela, P. Waldauf, I. Viscor, F. Plesinger, O. Sussenbek, D. Herman, P. Osmancik, R. Smisek, P. Leinveber, D. Czarnecka, P. Widimsky:** *"Both selective and nonselective His bundle, but not myocardial, pacing preserve ventricular electrical synchrony assessed by ultra-high-frequency ECG"*, HEART RHYTHM, 17(4), 607-614 (2020), best of Heart Rhythm Journal 1–6 2020.

- **P. Jurak, K. Curila, P. Leinveber, FW. Prinzen, I. Viscor, F. Plesinger, R. Smisek, R. Prochazkova, P. Osmancik, J. Halamek, M. Matejkova, J. Lipoldova, M. Novak, R. Panovsky, P. Andrla, V. Vondra, P. Stros, J. Vesela, D. Herman:** *"Novel ultra-high-frequency electrocardiogram tool for the description of the ventricular depolarization pattern before and during cardiac resynchronization"*, JOURNAL OF CARDIOVASCULAR ELECTROPHYSIOLOGY, 31(1), 300–307 (2020),

Patents:

- Method of ventricular repolarization analysis: U.S. Pat. No. 8,600,485 B2, 2013
- Device for blood flow property measurement and method of its connection: U.S. Pat. No. 9,167,984 B2, 2015
- Ultra-high-frequency ECG technology: U.S. Pat. No. 9,949,655, 2018; European Patent Application, EP 19212534.2., 2019, 2020

MAIN COLLABORATING PARTNERS

Collaboration with academic partners

- International Clinical Research Centre (St. Anne's University Hospital, Brno, CZ)
- Fakulty hospital Kralovske Vinohrady (Prague, CZ)
- Maastricht University (Maastricht, NL)
- University of Rochester (Rochester, NY, USA)
- Imperial College London (London, UK)
- Brno University of Technology (Brno, CZ)
- Masaryk University (Brno, CZ)
- National Institute of Mental Health (Klecany, CZ)

Collaboration with companies

- M&I (Prague, CZ)
- Cardion (Brno, CZ)
- MDT – medical data transfer (Brno, CZ)

EXPECTATIONS

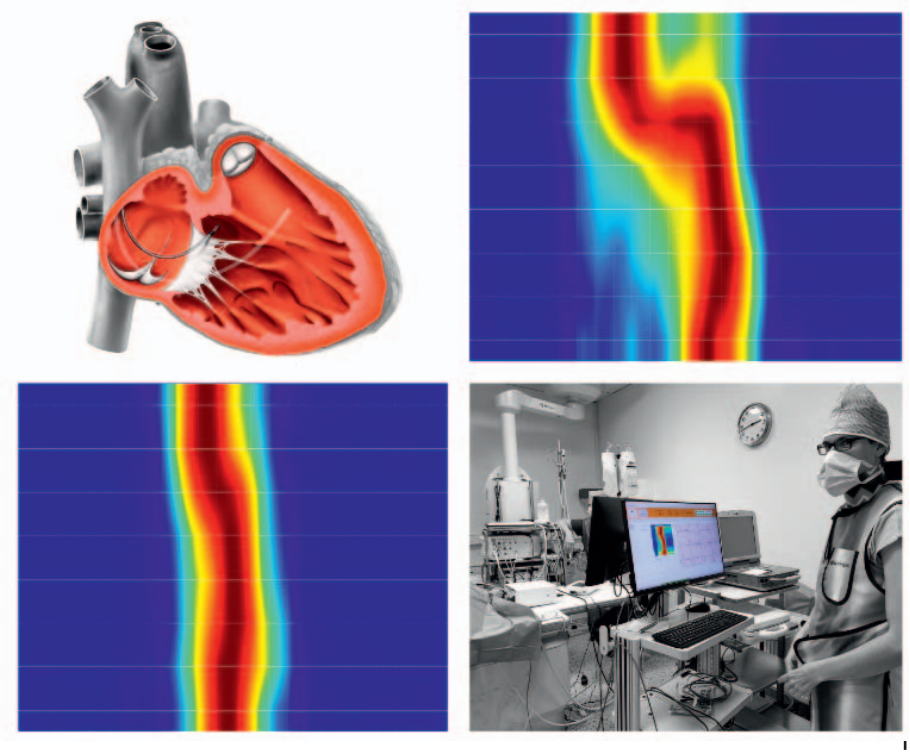
Offers

We offer collaboration in the areas of our expertise:

- Machine learning methods for ECG signal analysis
- Biomedical signal acquisition and analysis
- Development of diagnostic technologies and data processing methods
- Cooperation in clinical evaluation of new technologies
- Partnership in international scientific and technology-transfer projects

Requirements

We look for cooperation with academic partners as well as companies in the fields of signal processing and application of new analysis and technologies especially in cardiology and artificial intelligence.



Real-time UHF-ECG analysis shows direct effect of electrode placement on heart dyssynchrony