Group of Computational Neuroscience
Department of Medical Signals

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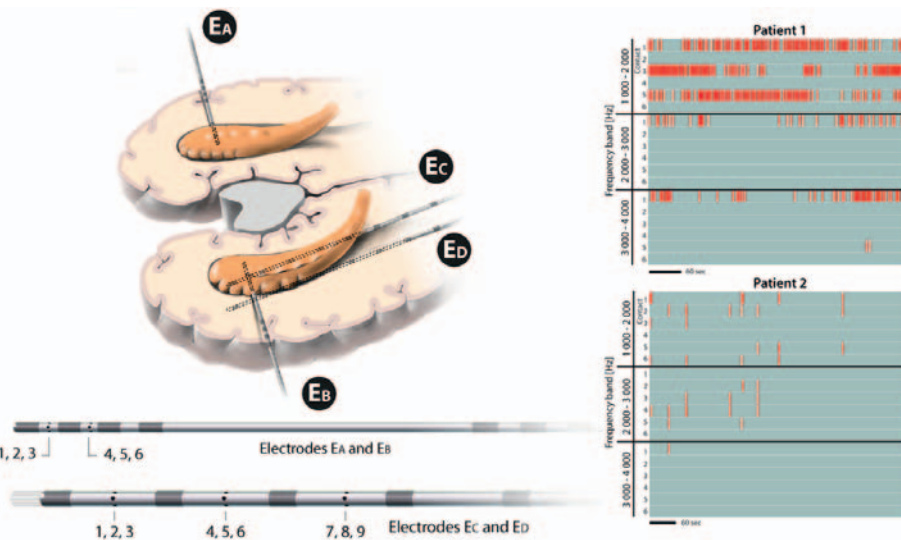
THEMATIC RESEARCH FOCUS

Research area
– Biomedical engineering
– Signal processing
– Neuro electrophysiology, electro-encephalography (EEG)
– Advanced acquisition technologies
– Epileptic seizure localization
– Surgical outcome prediction (Epilepsy, Parkinson's disease)
– Motor and cognitive processes of the human brain

Excellence
– Deep brain electrophysiology – basic neuroscience research regarding the spatio-temporal distribution of brain activities
– Predictive models for rapid identification and localization of epileptic sources
– Advanced statistical and machine learning models for artifact rejection and detection of pathological events in EEG
– Development of open-source signal processing toolboxes and libraries for computational neurology and neuroscience

Mission
Development of advanced technologies in computational neuroscience and subsequent implementation of these tools to basic research and clinical practice in order to improve medical treatment, lower risk and reduce patient's time in a hospital.

Implantation of human hippocampus by depth macro and micro electrodes (left). Detection of ultra fast oscillations in epileptic (patient 1) and non-epileptic (patient 2) hippocampus.

UP-TO-DATE ACTIVITIES

Research orientation
– Methods for broadband EEG signal analysis
– Detection of pathological waveforms in EEG traces, e.g. interictal epileptic discharges and ultra-high frequency oscillations
– Connectivity and mutual interactions between anatomical structures of the human brain

Main capabilities

Basic research
– The basic research of motor and cognitive processes of human brain
– Spectral analysis of invasive and scalp EEG signals
– Analysis of the epileptogenic zone function and dynamics of epileptic seizures

Applied research
– Effectivity of deep brain stimulation (DBS) in epilepsy, Parkinson's disease
– Machine learning models:
    ○ localization of the epileptogenic zone
    ○ prediction of surgical outcome in epilepsy surgery
    ○ seizure forecasting and seizure prediction
    ○ prediction of the effect of vagal nerve stimulation (non-invasive scalp EEG study).
    ○ Implementation of the developed tools into clinical practice.

Sub-fields of group activities
– Clinical and experimental medicine – neurology
– Biomedical engineering
– Signal acquisition and processing

KEY RESEARCH EQUIPMENT

List of devices
– Computing facilities intended for large data interactive processing (64 core parallel computing, high-speed SSD storages, SW support)

ACHIEVEMENTS

Awards
– Dr. Klimeš received The Molson Neuro-Engineering Fellowship – "Towards a more accurate and time efficient presurgical epilepsy work-up: development of seizure-independent biomarkers of the epileptic focus". Awarded by The Montreal Neurological Institute and Hospital, QC, Canada, 2019.
– Dr. Josef Halámek received "František Křižík" Honorable Medal from the Czech Academy of Sciences for his lifetime work in the field of signal processing in medicine. 2018.
– Poster "Relative entropy between iEEG signals as a powerful tool for localization of epileptogenic tissue" by Dr. Klimeš et al. was shortlisted for the Best Poster Award at the European Congress on Epileptology (ECE), Vienna, 2018.

Publications

▌ **D. DEUTSCHOVÁ, P. KLIMEŠ, Z. JORDAN, P. JURÁK, L. EROSS, M. LAMOŠ, J. HALÁMEK, P. DANIEL, I. REKTOR, D. FABO:**
"Thalamic oscillatory activity may predict response to deep brain stimulation of the anterior nuclei of the thalamus". Epilepsia. 2021, https://doi.org/10.1111/epi.16883.

▌ **J. CIMBALNIK, M. PAIL, P. KLIMES, V. TRAVNICEK, R. ROMAN, A. VAJCNER, M. BRAZDIL:**
"Cognitive Processing Impacts High Frequency Intracranial EEG Activity of Human Hippocampus in Patients With Pharmacoresistant Focal Epilepsy". Frontiers in neurology. 2020, 11, 578571. ISSN 1664-2295.
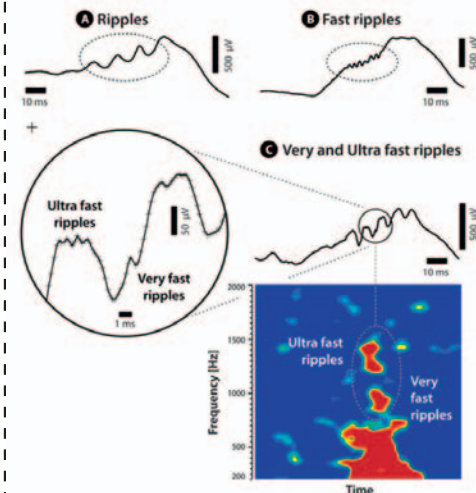
Examples of different types of oscillation recorded at high frequencies with high dynamicity (Brazdil et al., 2017).

■ P. NEJEDLY, V. KREMEN, V. SLADKY, J. CIMBALNIK, P. KLIMES, F. PLESINGER, F. MIVALT, V. TRAVNICEK, I. VISCOR, M. PAIL, J. HALAMEK, B. H. BRINKMANN, M. BRAZDIL, P. JURAK, G. WORRELL:
"Multicenter intracranial EEG dataset for classification of graphoelements and artifactual signals". Nature – Scientific Data. 2020, doi:10.1038/s41597-020-0532-5

■ L. PETER-DEREX, P. KLIMES, V. LATREILLE, S. BOUHADOUN, F. DUBEAU, B. FRAUSCHER:
"Sleep Disruption in Epilepsy: Ictal and Interictal Epileptic Activity Matter". Annals of neurology. 2020, 88(5), 907–920. ISSN 0364-5134.

■ P. KLIMES, J. CIMBALNIK, M. BRAZDIL, J. HALL, F. DUBEAU, J. GOTMAN, B. FRAUSCHER:
"NREM sleep is the state of vigilance that best identifies the epileptogenic zone in the interictal electroencephalogram". Epilepsia. 2019, 60(12), 2404–2415. ISSN 0013-9580.

■ J. CIMBALNIK, P. KLIMES, V. SLADKY, P. NEJEDLY, P. JURAK, M. PAIL, R. ROMAN, P. DANIEL, H. GURAGAIN, B. BRINKMANN, M. BRAZDIL, G. WORRELL:
"Multi-feature localization of epileptic foci from interictal, intracranial EEG". Clinical neurophysiology. 2019, 130(10), 1945–1953. ISSN 1388-2457.

■ P. NEJEDLY, V. KREMEN, V. SLADKY, J. CIMBALNIK, P. KLIMES, F. PLESINGER, I. VISCOR, M. PAIL, J. HALAMEK, B. H. BRINKMANN, M. BRAZDIL, P. JURAK, G. WORRELL:
"Exploiting Graphoelements and Convolutional Neural Networks with Long Short Term Memory for Classification of the Human Electroencephalogram". Nature – Scientific reports. 2019, 9(1), 11383. ISSN 2045-2322.

■ P. NEJEDLY, V. KREMEN, V. SLADKY, M. NASSERI, H. GURAGAIN, P. KLIMES, J. CIMBALNIK, Y. VARATHARAJAH, B. H. BRINKMANN, G. A. WORRELL:
*"Deep-learning for seizure forecasting in canines with epilepsy"*. Journal of neural engineering. 2019, 16(3), 036031. ISSN 1741-2560.

■ P. NEJEDLY, J. CIMBALNIK, P. KLIMES, F. PLESINGER, J. HALAMEK, V. KREMEN, I. VISCOR, B. H. BRINKMANN, M. PAIL, M. BRAZDIL, G. WORRELL, P. JURAK:
"Intracerebral EEG Artifact Identification Using Convolutional Neural Networks". Neuroinformatics. 2019, 17(2), 225–234. ISSN 1539-2791.

■ M. BRÁZDIL, M. PAIL, J. HALÁMEK, F. PLEŠINGER, J. CIMBÁLNÍK, R. ROMAN, P. KLIMEŠ, P. DANIEL, J. CHRASTINA, E. BRICHTOVÁ, I. REKTOR, G. A. WORRELL, P. JURÁK:
"Very high-frequency oscillations: Novel biomarkers of the epileptogenic zone". Annals of neurology. 2017, 82(2), 299–310. ISSN 0364-5134.
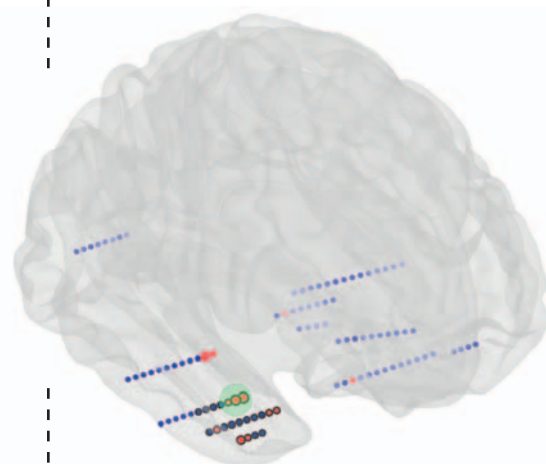
Schematic illustration of the pathological tissue localization using machine learning model based on multiple EEG features. Red disks represent the channels identified by the model as pathological. The cluster (green circle) with the highest mean probability is selected as the final localization (Cimbalnik and Klimes et al., 2019)

MAIN COLLABORATING PARTNERS

Collaboration with academic partners
– International Clinical Research Center (ICRC), St. Anne's University Hospital, Brno (CZ)
– Medical Faculty, Masaryk University, Brno (CZ)
– Central European Institute of Technology (CEITEC), Brno (CZ)
– Mayo Clinic, Rochester (MN, USA)
– Montreal Neurological Institute and Hospital (QC, Canada)

**Collaboration with companies**
– M&I (Prague, CZ)

EXPECTATIONS

Offers
We offer collaboration in the areas of our expertise:
– Biomedical signal acquisition and analysis
– Development of diagnostic technologies and data processing methods 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 in neurology.
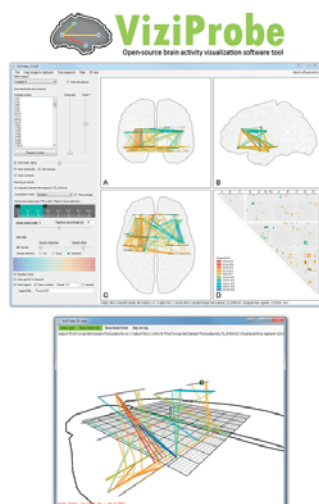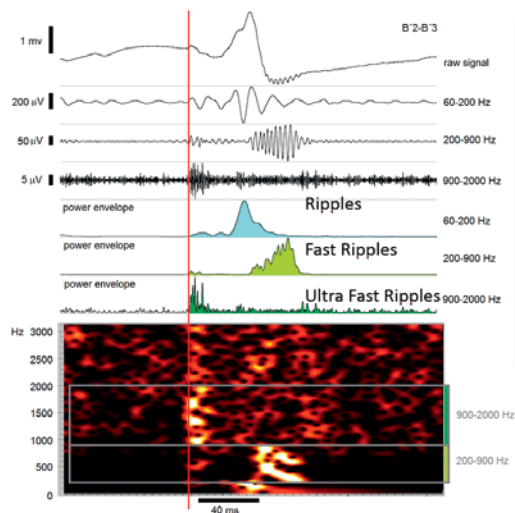
Intracerebral EEG recordings and analysis – brain structures involvement in cognition process, pathological and functional connectivity.