Challenges in signal processing in complex applications

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Content

- Biomedical signals and their properties
- Multilevel analysis
- Classification
- Visualization
- Conclusion

Real clinical signals (instead of introduction)

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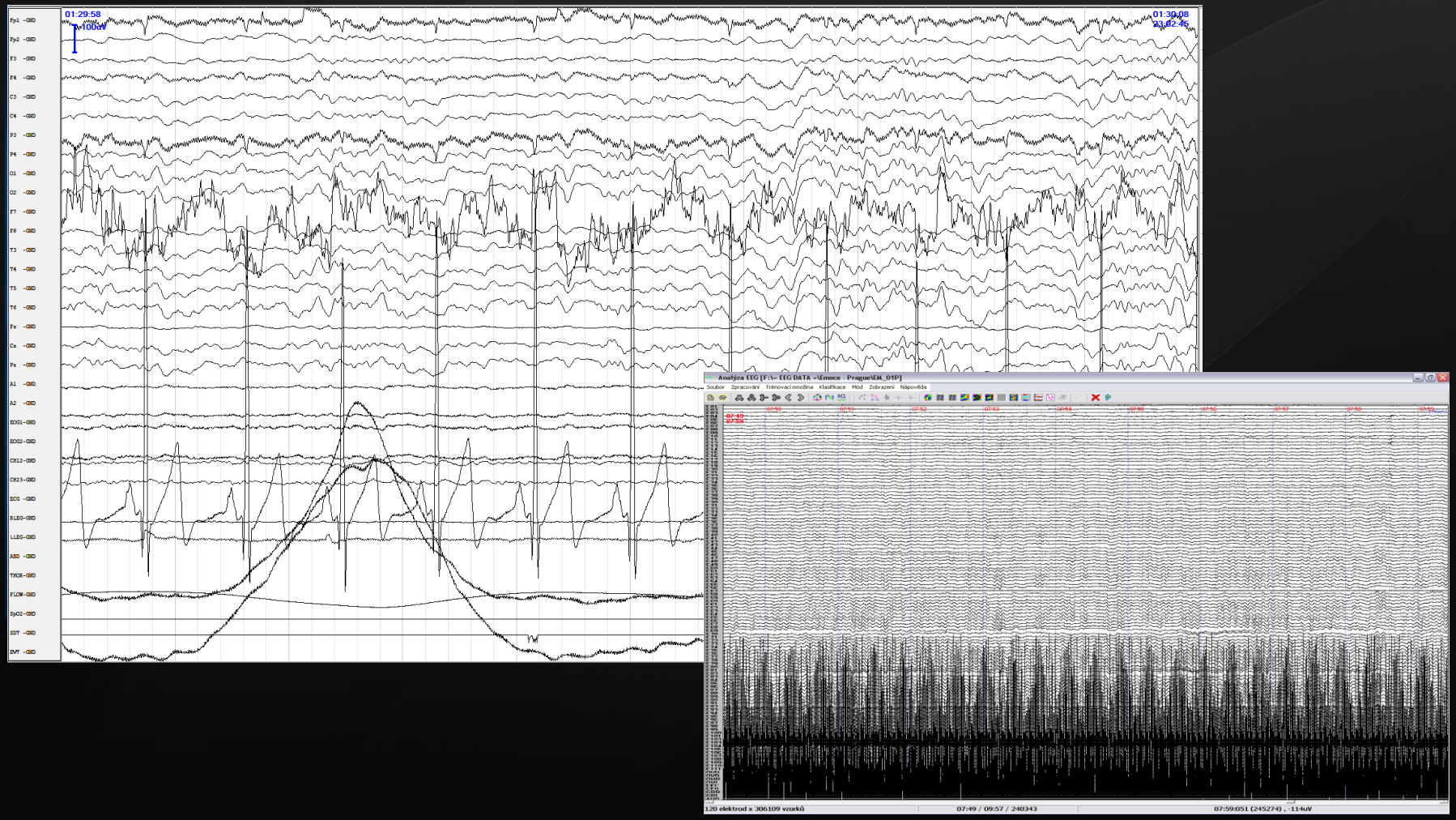
19 EEG, 2 EOG, 2 EMG, ECG, Respiration signal, SpO2 and other



128 EEG

Multilevel Analysis Procedure

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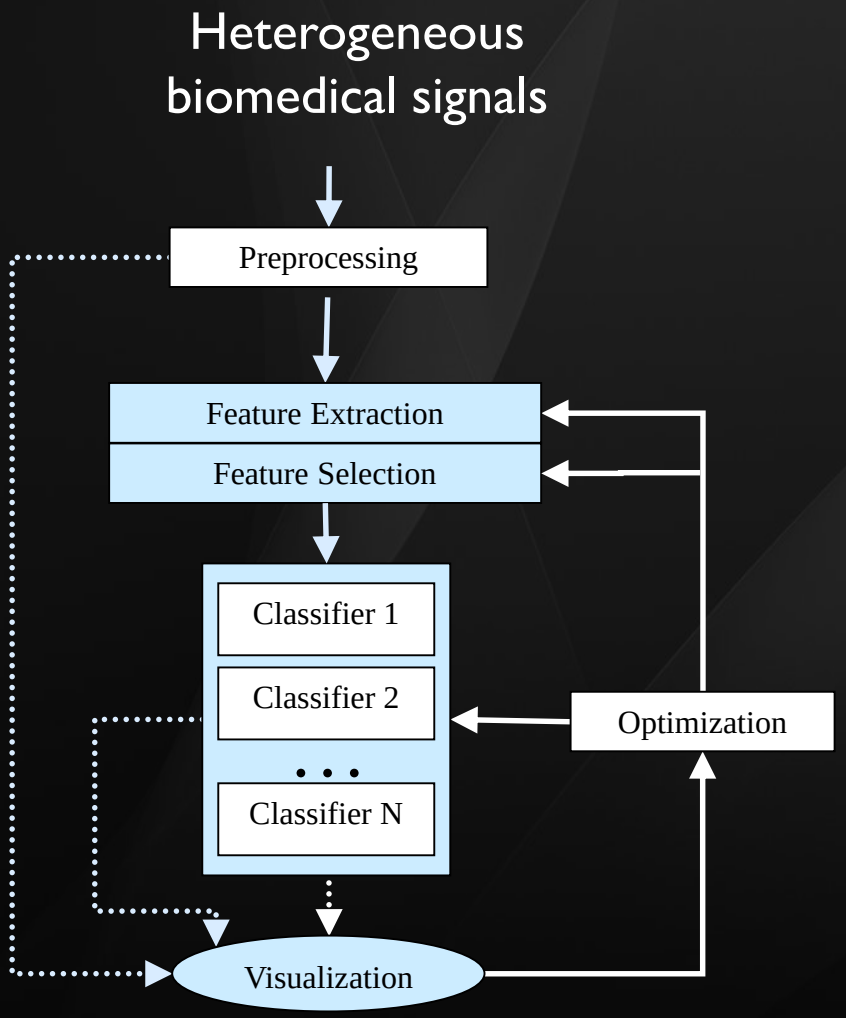

- Filtering
- Artefact detection/removing
- Signal segmentation

- Feature extraction
  - statistical features
  - spectral/coherence analysis
  - wavelet transform

- Classification
  - linear models
  - neural networks
  - mixture models
  - fuzzy approches
  - ensemble learning

Classification of Epileptic Patterns

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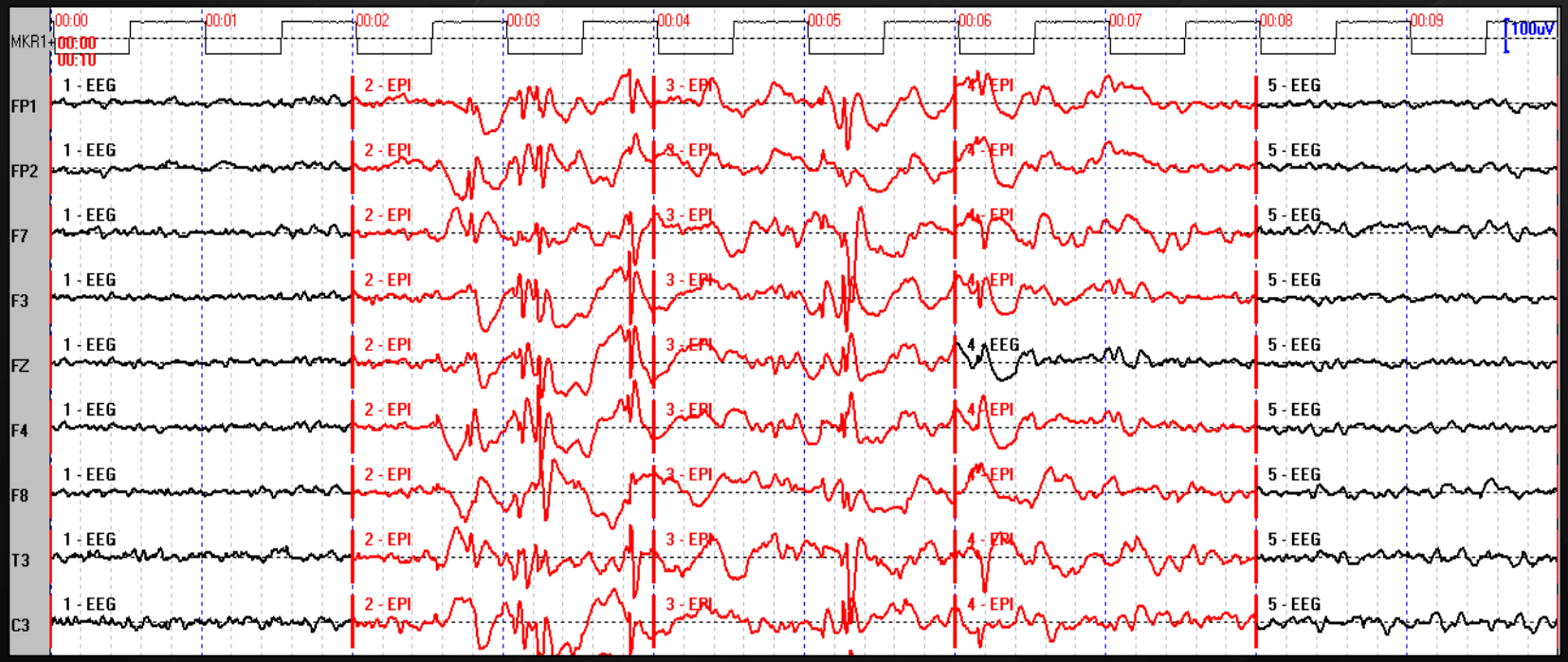
RAW EEG, 10 seconds



Black color: normal EEG activity, Red color: epileptic activity

Detected epileptic activity, 2 hours

Comatose EEG data analysis

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Color coding of comatose classes:

class	1	2	3	4	5	6	7	8	9	10
color										

Long-term trends estimation:

Sleep analysis

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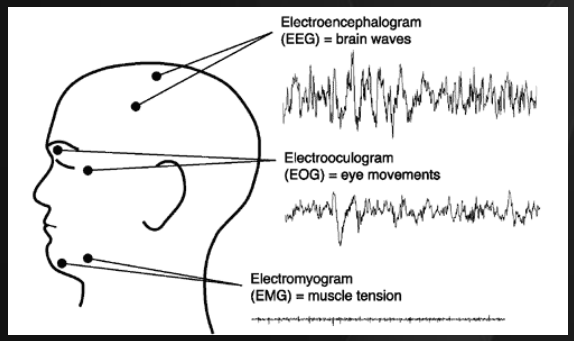
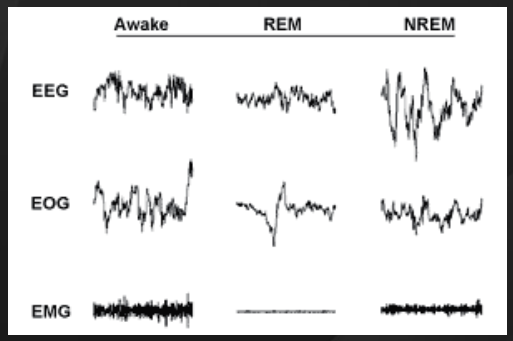
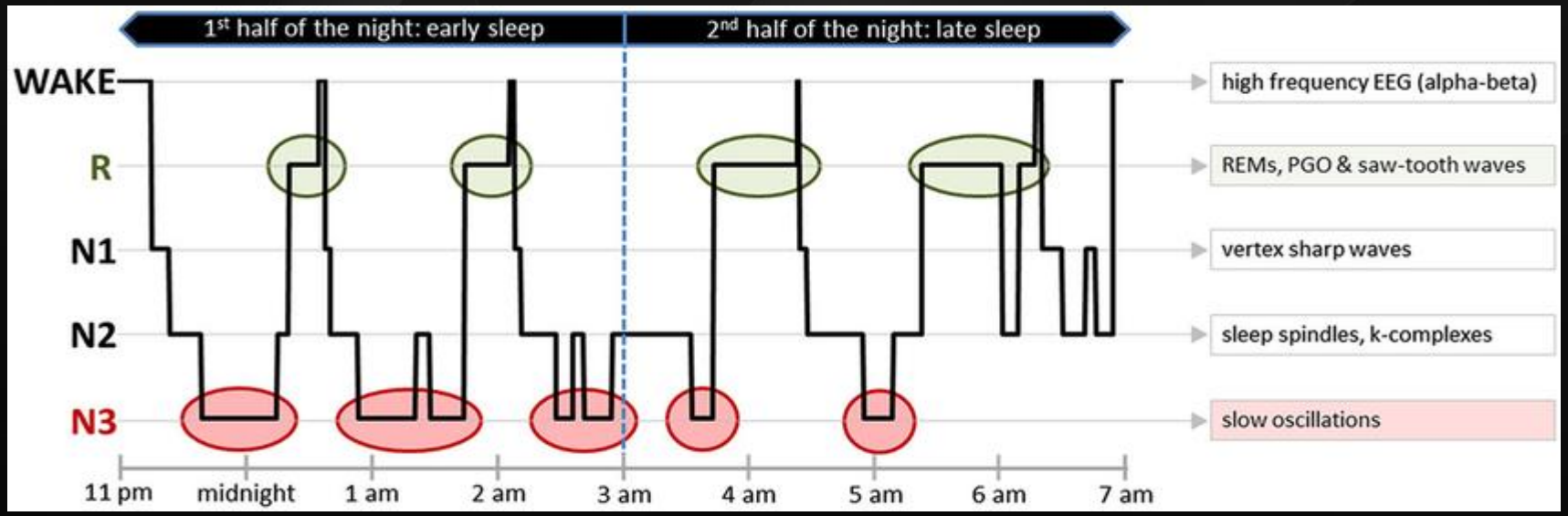
PSG signals:





Hypnogram:



Blume et al., 2015

Spectral analysis of sleep EEG

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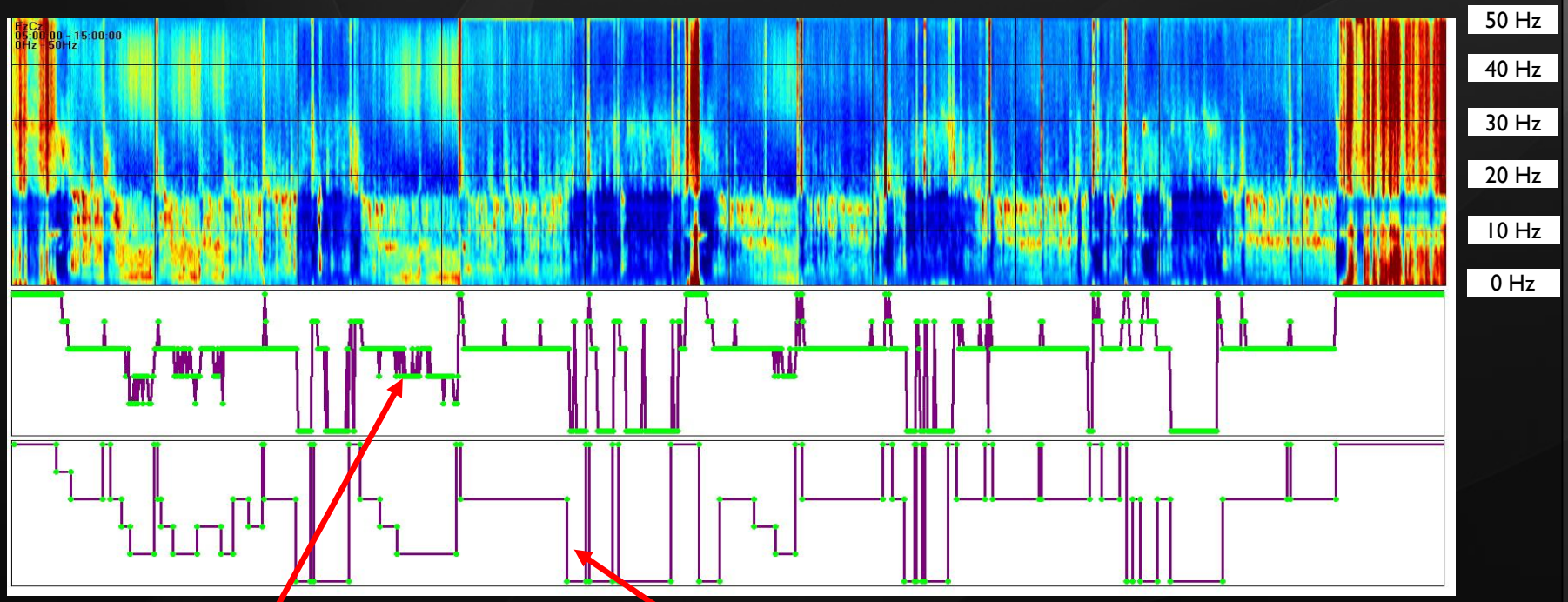

Spectrogram is computed for one EEG channel (Fz-Cz)

classification made by neurologist

classification made by semi-automated method

2D/3D spectrograms

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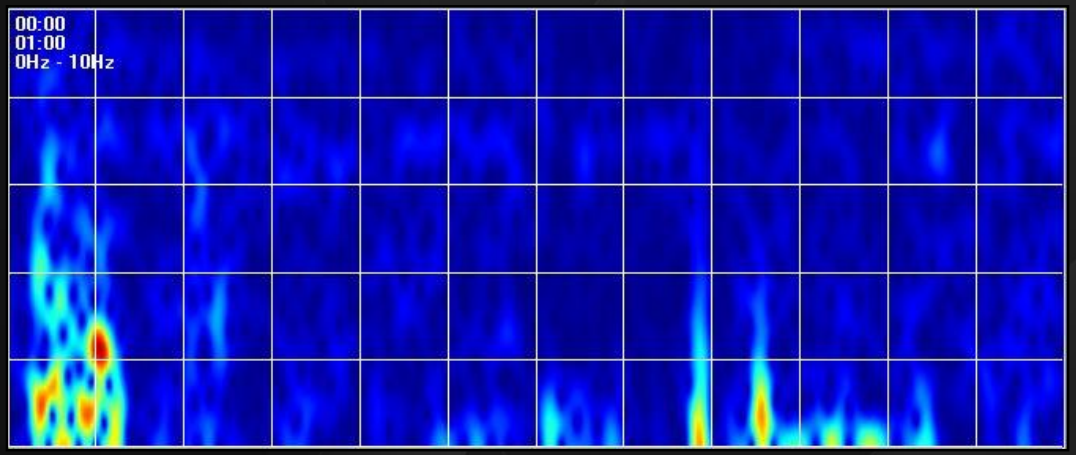
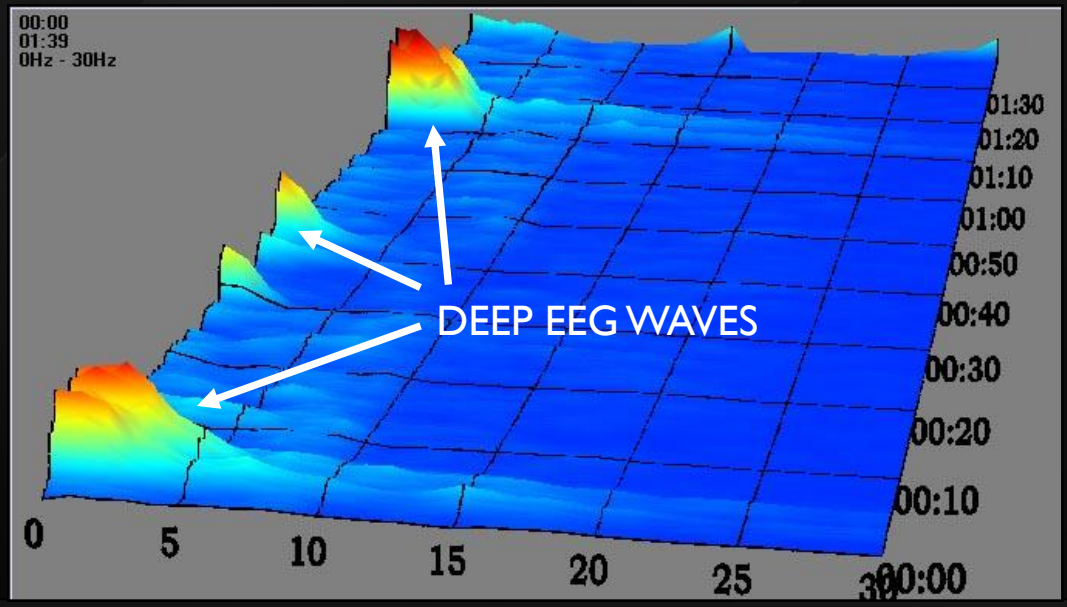


frequency

time

time

frequency



STFT vers. CWT (sleep EEG data)

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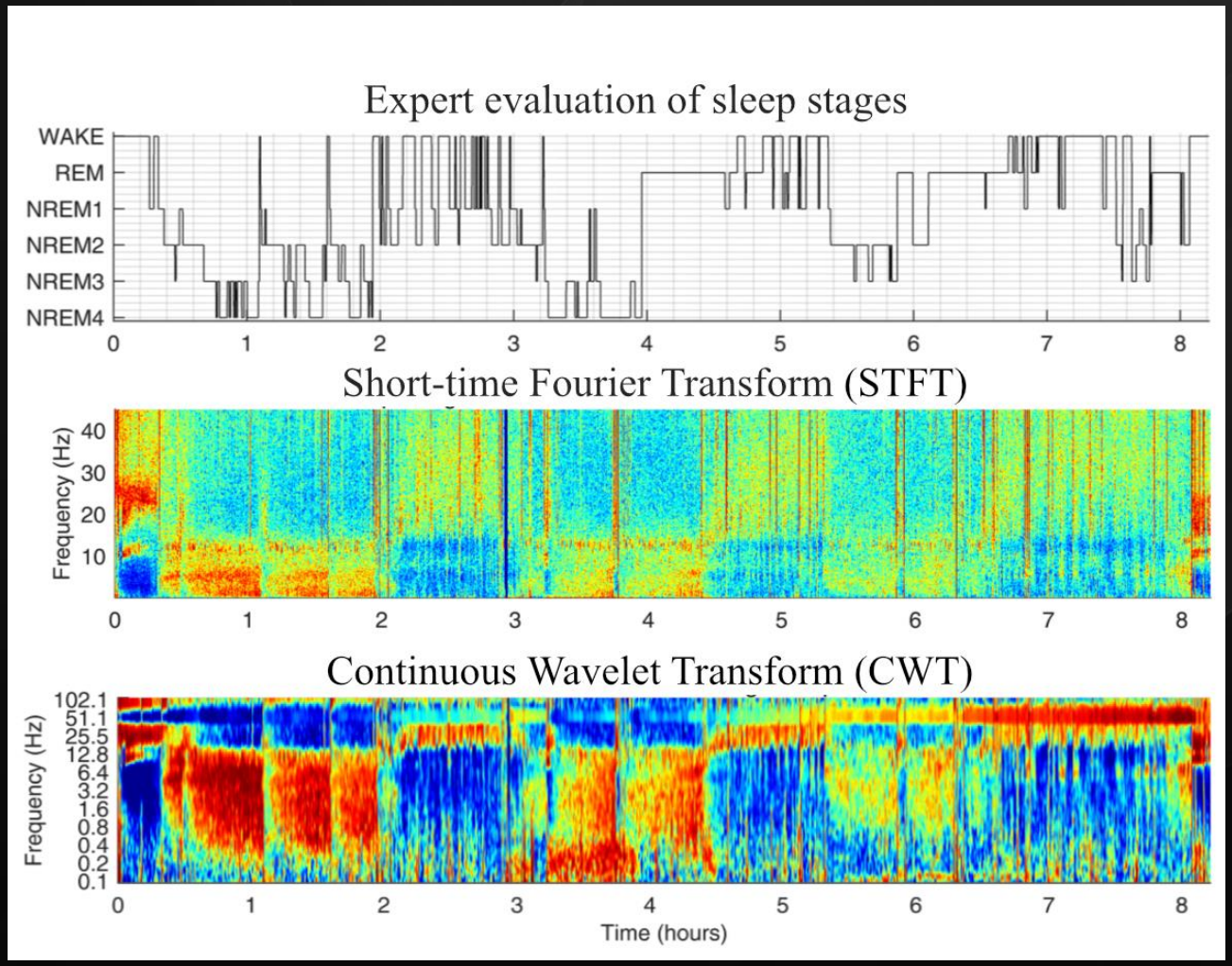

nonlinear frequency axis

These approaches may facilitate the visual evaluation of long-term recordings, or allow effective analysis of an unknown EEG signal structure.

Automatic detection of artifacts (Sleep data)

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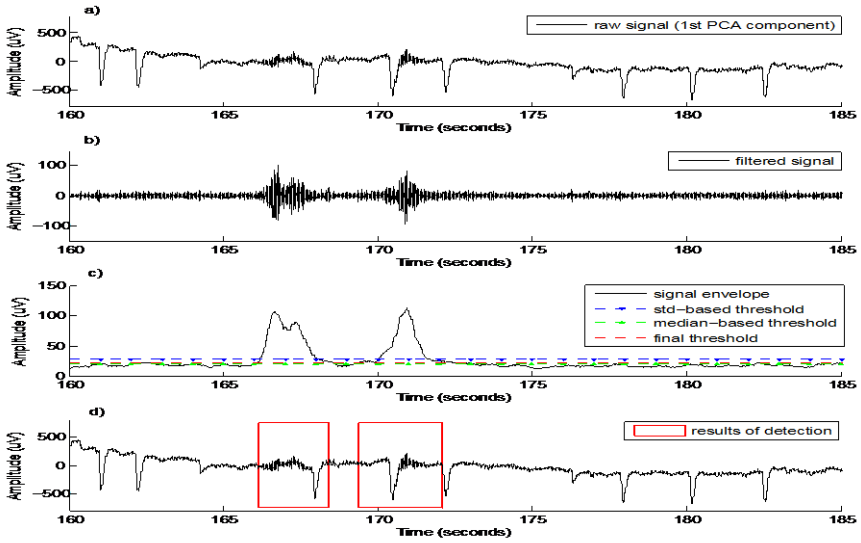

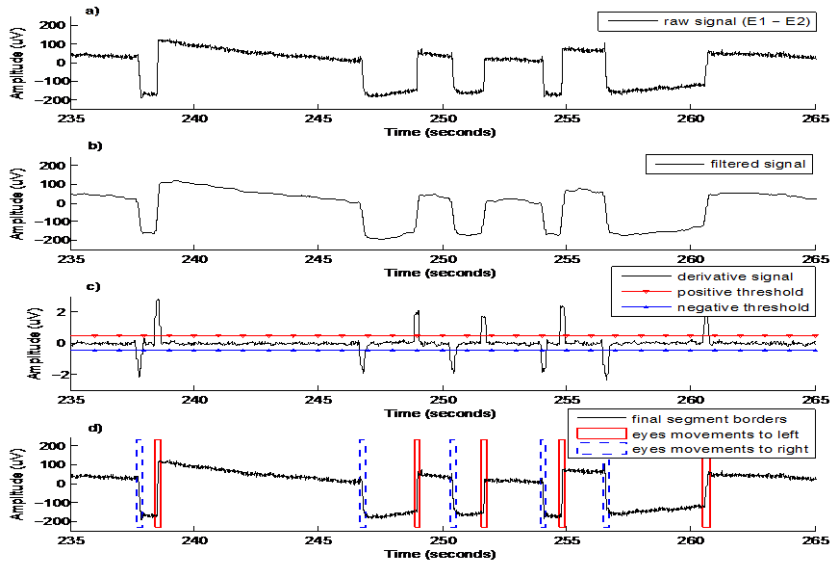

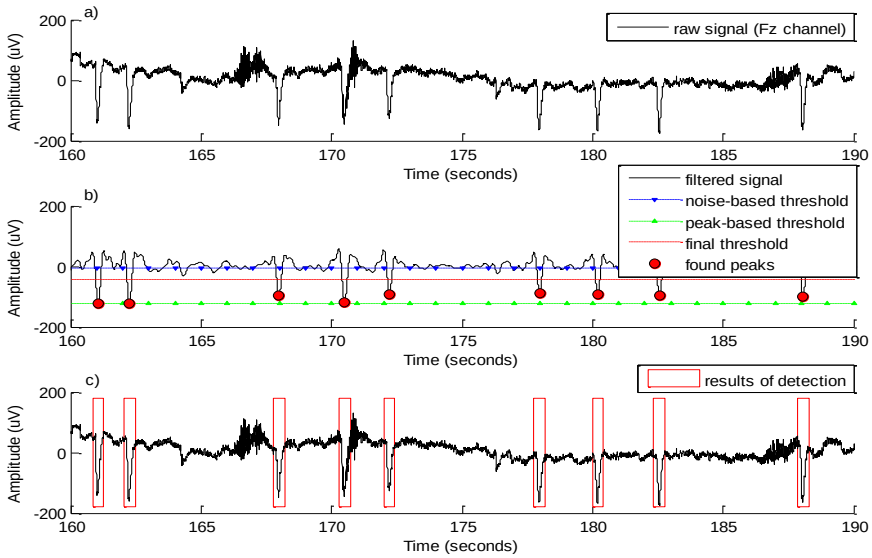

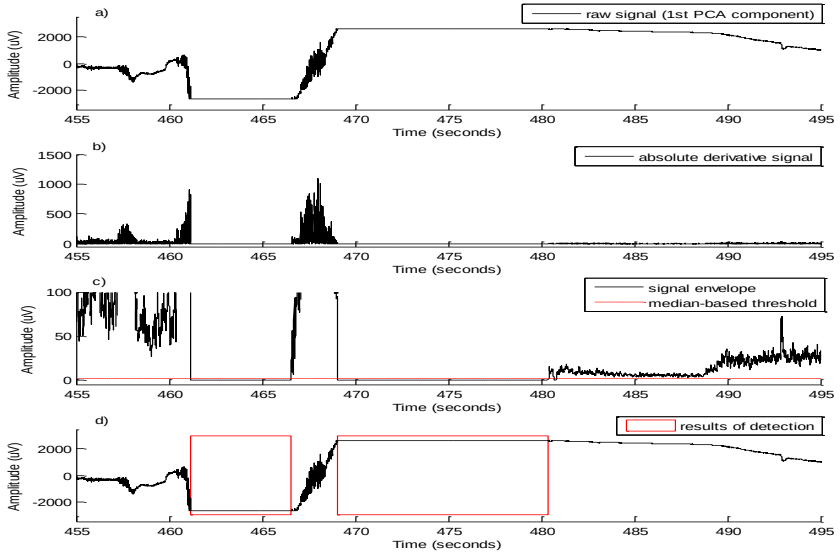

Feature profile (Neonatal data)

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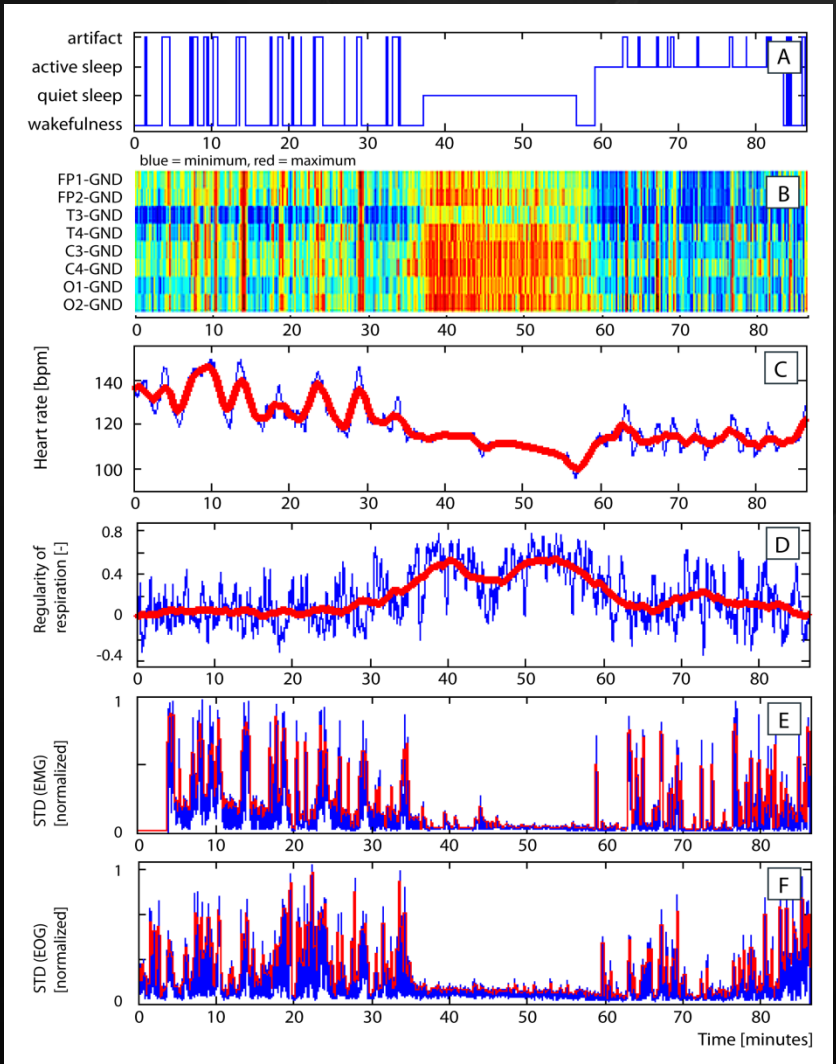

90-minute sleep study of the parameters of a healthy full-term infant. The figure
shows clearly that the features are correlated with the neurologist's classication.

A) Sleep profile, as evaluated by an experienced physician.
B) FFT ABS DELTA for all EEG channels.
C) Heart rate computed from the windowed ECG signal.
D) Regularity of respiration.
E) Standard deviation of the windowed EMG signal normalized to the interval <0, 1>
F) Standard deviation of the windowed EOG signal normalized to the interval <0, 1> .

The red color curves represent the moving average, the window size is 5 minutes.

Coherence analysis (Neonatal EEG)

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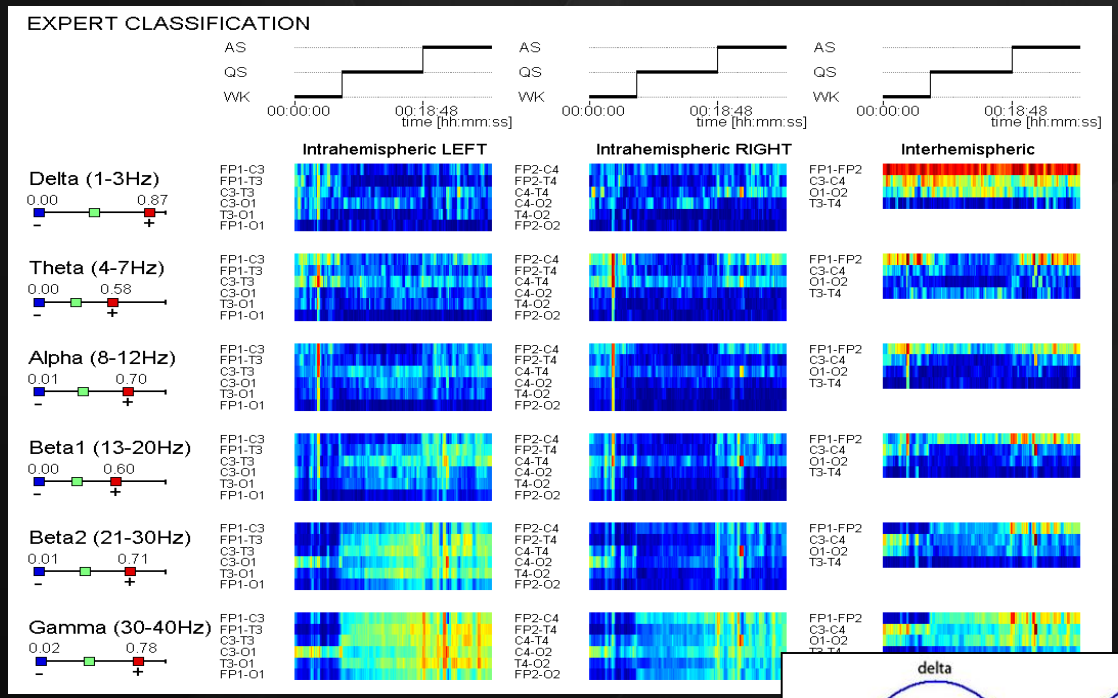
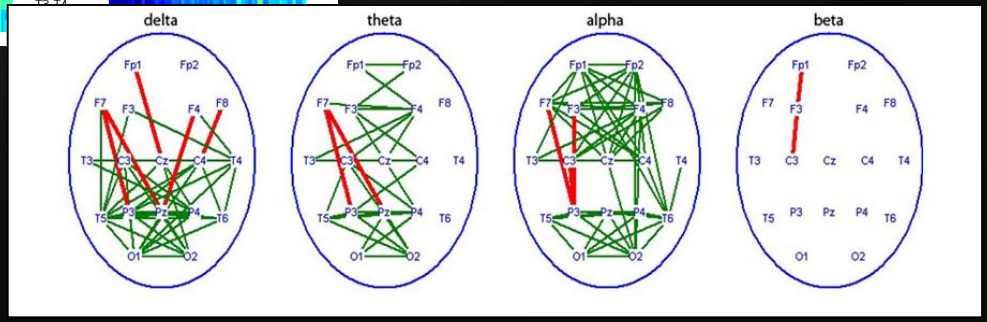


Intra- and inter- hemispheric coherence of neonatal EEG signals

The magnitude-squared coherence is a function of the power spectral densities, Pxx(f) and Pyy(f), and the cross power spectral density, Pxy(f), of x and y:

$$C_{xy}(f) = \frac{|P_{xy}(f)|^2}{P_{xx}(f)P_{yy}(f)}$$



Zhavoronkova et al.,2013

2D topographical mapping

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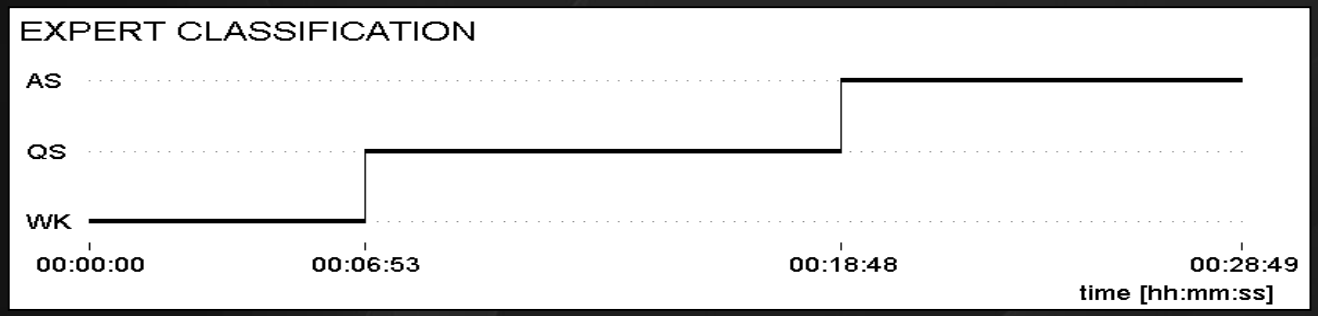

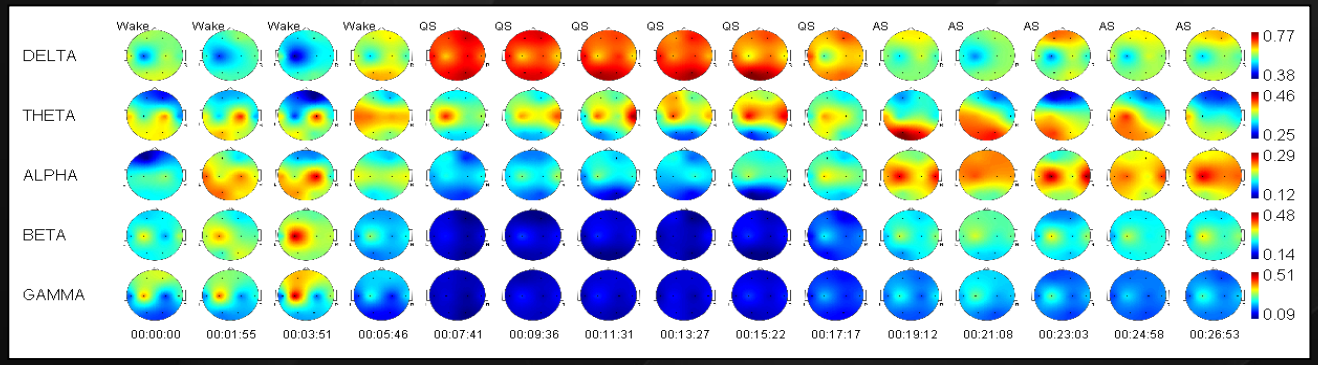

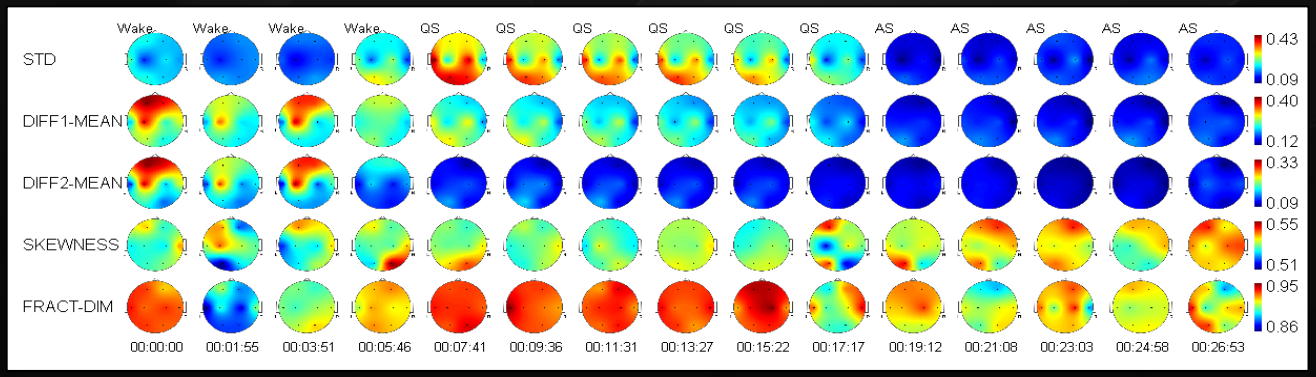

Neonatal EEG
- WK
- Quiet sleep
- Active sleep

3D topographical mapping

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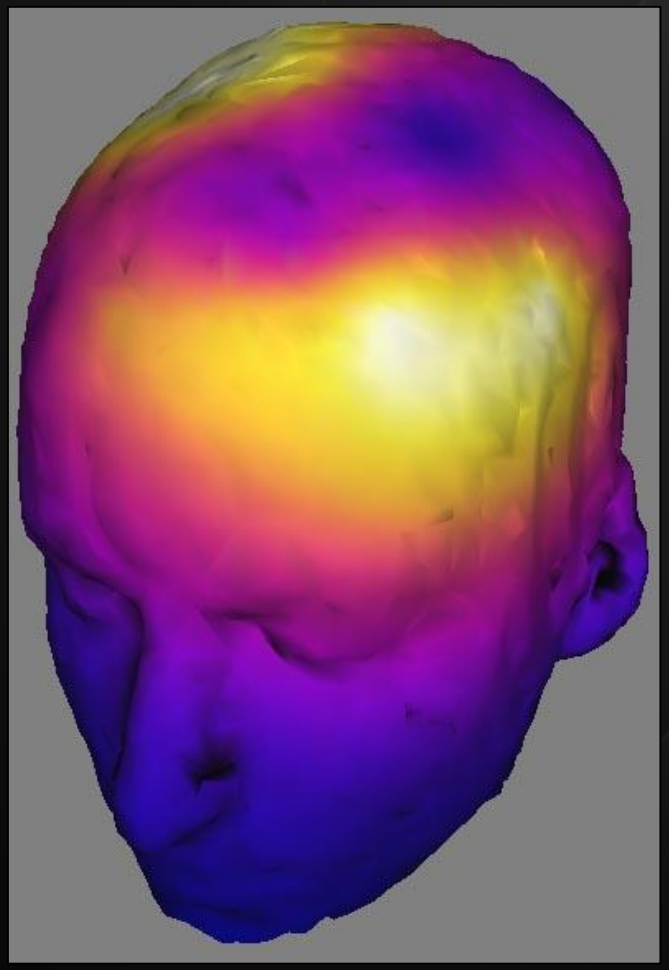

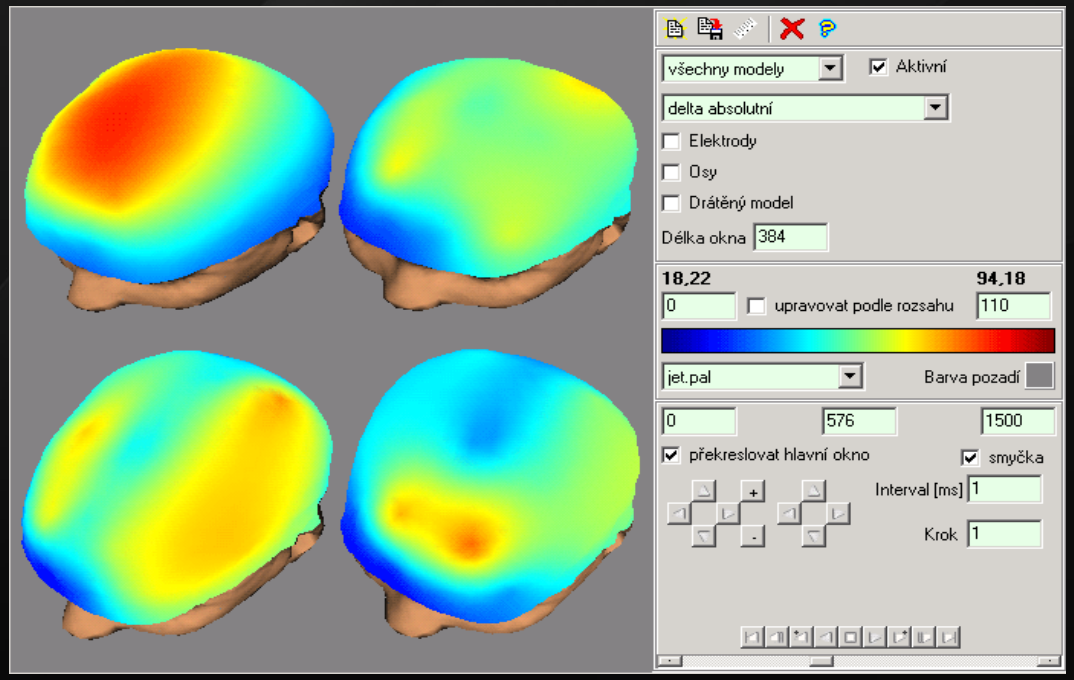

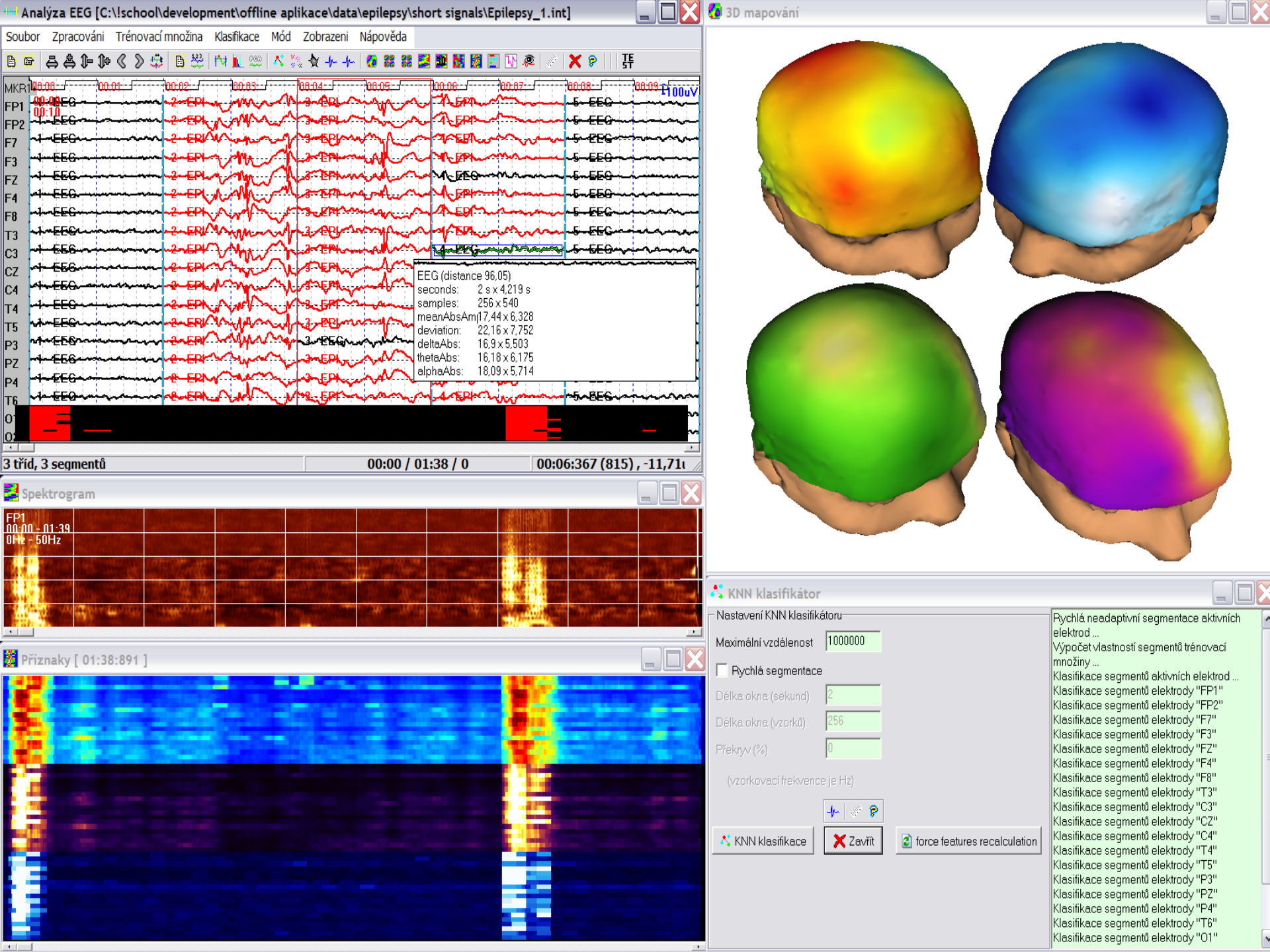
Analýza EEG [C:\!school\development\offline aplikace\data\epilepsy\short signals\Epilepsy_1.int]
Soubor Zpracování Trénovací množina Klasifikace Mód Zobrazení Nápověda
EEG (distance 96,05)
seconds: 2 s x 4,219 s
samples: 256 x 540
meanAbsAm 17,44 x 6,328
deviation: 22,16 x 7,752
deltaAbs: 16,9 x 5,503
thetaAbs: 16,18 x 6,175
alphaAbs: 18,09 x 5,714
3 tříd, 3 segmentů
00:00 / 01:38 / 0
00:06:367 (815) , -11,71
3D mapování
Spektrogram
FP1
00:00 - 01:39
0Hz - 50Hz
Příznaky [01:38:891]
KNN klasifikátor
Nastavení KNN klasifikátoru
Maximální vzdálenost
1000000
Rychlá segmentace
Délka okna (sekund)
Délka okna (vzorků)
Překryv (%)
(vzorkovací frekvence je Hz)
KNN klasifikace
Zavřít
force features recalculation
Rychlá neadaptivní segmentace aktivních elektrod ...
Výpočet vlastností segmentů trénovací množiny ...
Klasifikace segmentů aktivních elektrod ...
Klasifikace segmentů elektrody "FP1"
Klasifikace segmentů elektrody "FP2"
Klasifikace segmentů elektrody "F7"
Klasifikace segmentů elektrody "F3"
Klasifikace segmentů elektrody "FZ"
Klasifikace segmentů elektrody "F4"
Klasifikace segmentů elektrody "F8"
Klasifikace segmentů elektrody "T3"
Klasifikace segmentů elektrody "C3"
Klasifikace segmentů elektrody "CZ"
Klasifikace segmentů elektrody "C4"
Klasifikace segmentů elektrody "T4"
Klasifikace segmentů elektrody "T5"
Klasifikace segmentů elektrody "P3"
Klasifikace segmentů elektrody "PZ"
Klasifikace segmentů elektrody "P4"
Klasifikace segmentů elektrody "T6"
Klasifikace segmentů elektrody "O1"

Conclusion

What is successfully performed in automatic mode?

- signal filtration
- segmentation
- feature computation
- clustering
- visualization methods (spectrogram, koherence, mapping)

What is not yet successfully performed in automatic mode?

- classification to classes

Why is fully automatic classification not successful?

- good quality traning set is not available
- artefacts – complicate classification
- medical knowledge and experience representation is complex
- high number of channels and long-term recordings $\Rightarrow$ high temporal demands