Analysis of EEG-based Depression Biomarkers

Using Machine Learning

Miroslav Kovář

FJFI

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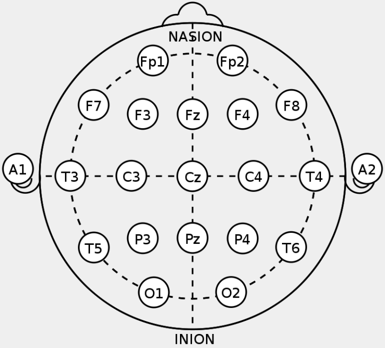
Problem Statement and Approach

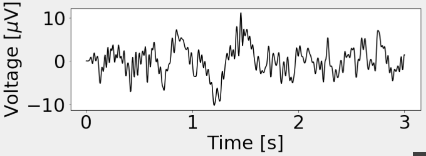
- MDD

- EEG



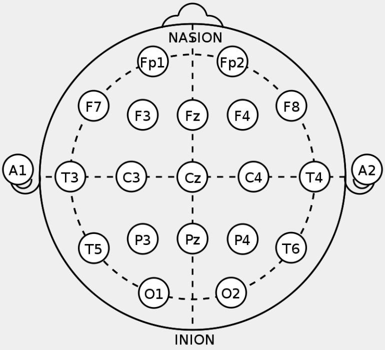
NASION
Fp1
Fp2
F7
F3
Fz
F4
F8
A1
T3
C3
Cz
C4
T4
A2
T5
P3
Pz
P4
T6
O1
O2
INION

[1]



Voltage [μV]
10
0
−10
0
1
2
3
Time [s]

- MDD
  - 300 million suffering worldwide [2, 3]
- EEG



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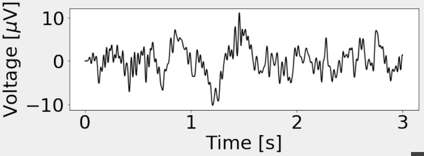
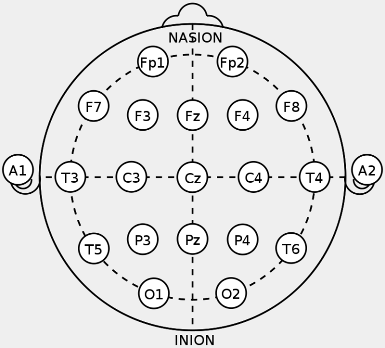


Depression Treatment is Expensive

- MDD
  - 300 million suffering worldwide [2, 3]
  - diagnosis requires time of trained professionals [3]
- EEG



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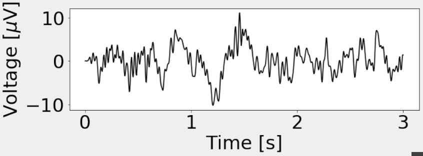

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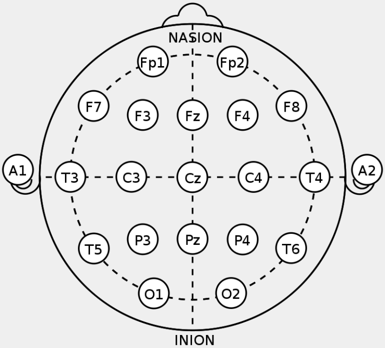
  - accessible diagnosis-aid tool [4]?



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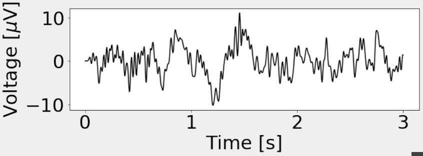

Depression Treatment is Expensive

- MDD
  - 300 million suffering worldwide [2, 3]
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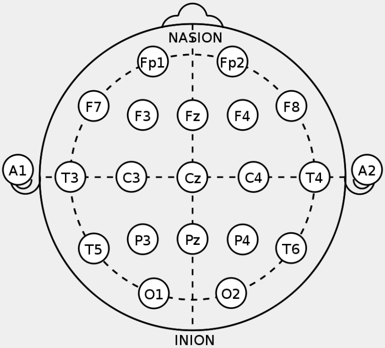
- EEG
  - accessible diagnosis-aid tool [4]?
  - also effective at prognosis? studied very little!

Research into effective analysis techniques is ongoing…



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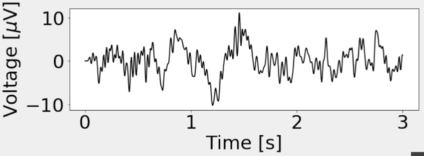
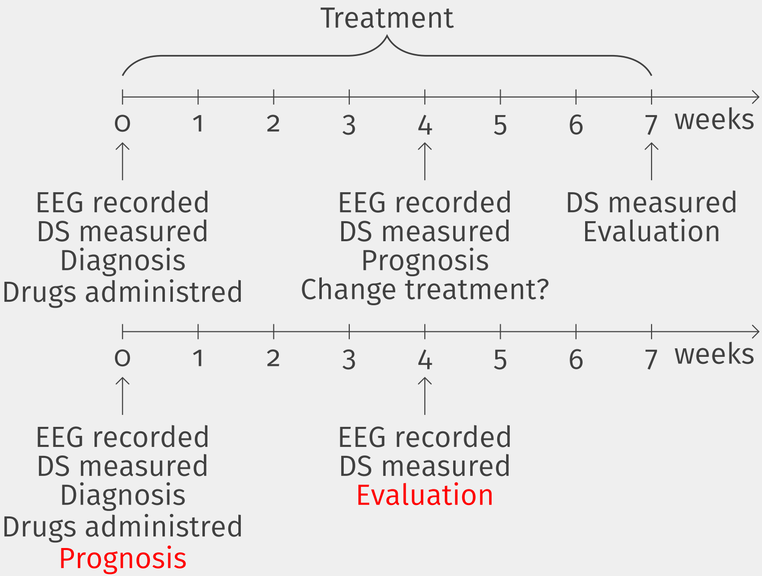
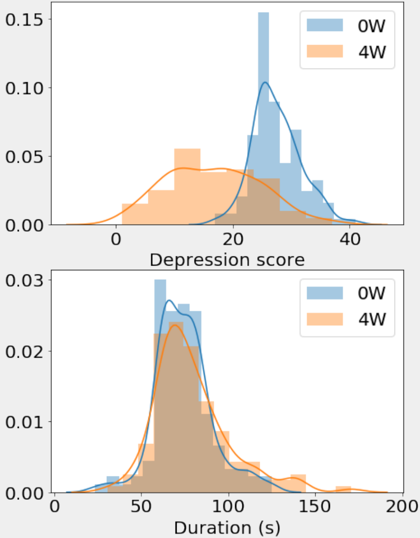


Our Goals


Treatment
0
1
2
3
4
5
6
7
weeks
EEG recorded
DS measured
Diagnosis
Drugs administred
EEG recorded
DS measured
Prognosis
Change treatment?
DS measured
Evaluation
0
1
2
3
4
5
6
7
weeks
EEG recorded
DS measured
Diagnosis
Drugs administred
Prognosis
EEG recorded
DS measured
Evaluation

Our Dataset

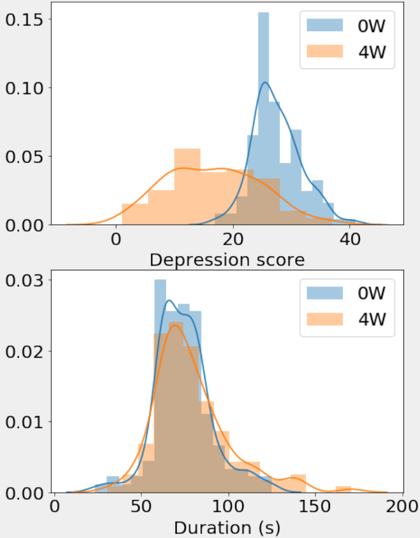
Relatively large:



Our Dataset

Relatively large:

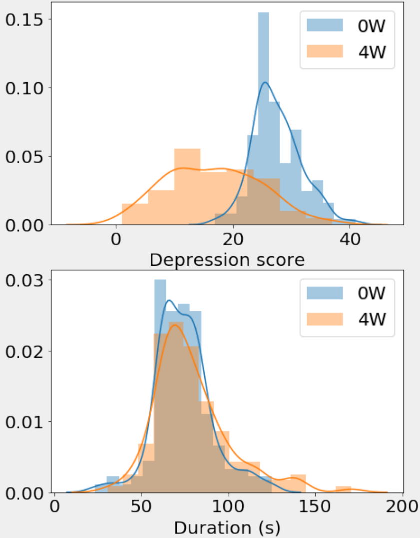
- 133 patients



Our Dataset

Relatively large:

- 133 patients
- EEG recordings
  - 19 channels
  - 250 Hz or 1000 Hz
  - Various duration



Our Dataset

Relatively large:

- 133 patients
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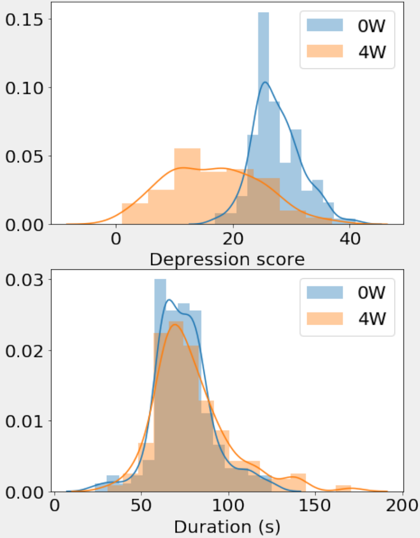
- Metadata
  - Depression scores
    - Week 0
    - Week 4
  - Age, gender, drugs



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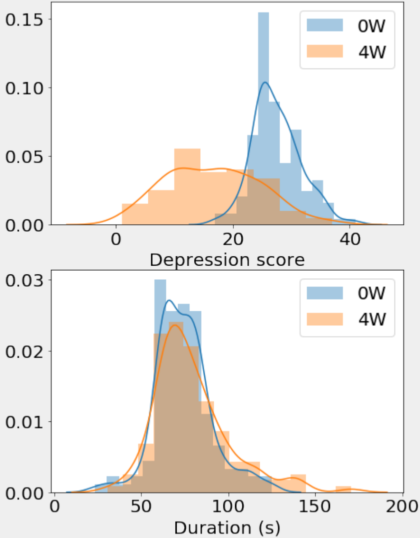
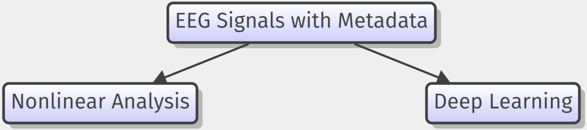
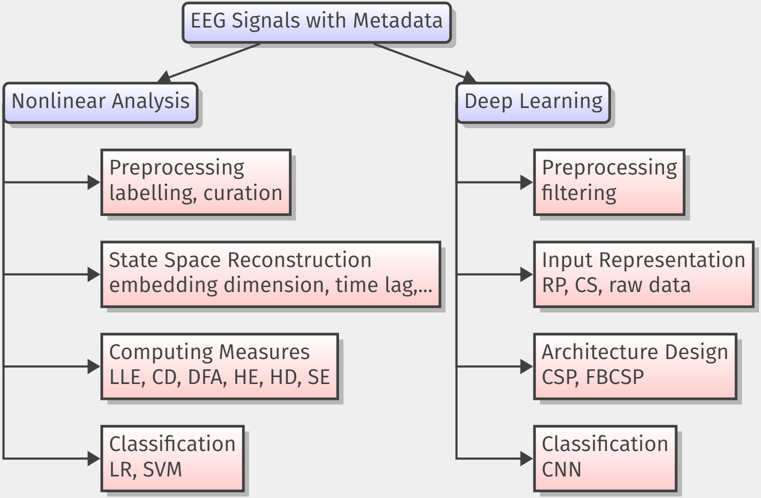
Obtained from Czech National Institute of Mental Health



Our Approach



Our Approach



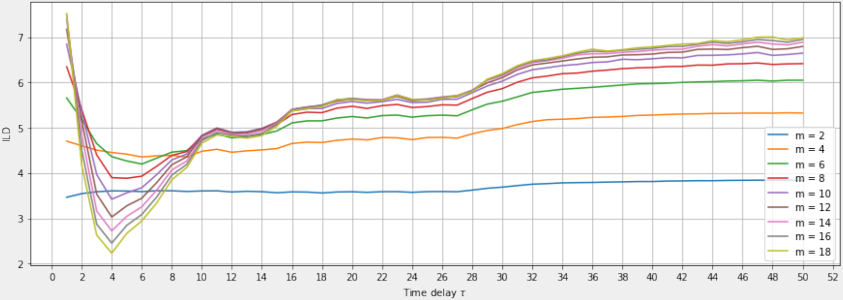
Nonlinear Analysis Approach

Nonlinear Measures

LLE Largest Lyapunov exponent
SE Sample entropy
} "stability"

CD Correlation dimension
HD Higuchi fractal dimension
} "complexity"

DFA Detrended fluctuation analysis
HE Hurst exponent
} LRTC



Parameters

- Embedding dimension
- Time delay
- Scaling regions
- ...

Methods

- Literature review
- Estimation algorithms (FNN, AFN, ADFD, ILD, ...)
- Statistical tests

-> automated procedure

Results

Measure	Classifier	Accuracy	
		Mean	Std
LLE, CD	SVM (lin.)	**0.74**	0.04
LLE, SE	SVM (lin.)	0.75	0.10
LLE, HE	SVM (lin.)	0.73	0.06
LLE, SE, DFA	SVM (lin.)	0.73	0.09
CD, HD	LR	0.73	0.10
LLE	SVM (lin.)	**0.72**	0.04
CD	SVM (lin.)	0.71	0.05
SE	LR	0.68	0.12
HD	SVM (rbf)	0.67	0.11
DFA	LR	0.67	0.16
HE	LR	0.67	0.17

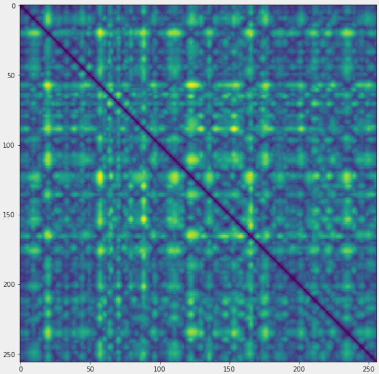
(a) Depression

Measure	Classifier	Accuracy	
		Mean	Std
LLE, CD	SVM (lin.)	**0.75**	0.11
LLE, SE	SVM (lin.)	0.75	0.10
LLE	LR	**0.71**	0.08
CD	LR	0.67	0.09
HD	LR	0.66	0.05
SE	LR	0.66	0.09
DFA	SVM (lin.)	0.64	0.15
HE	SVM (rbf)	0.63	0.09

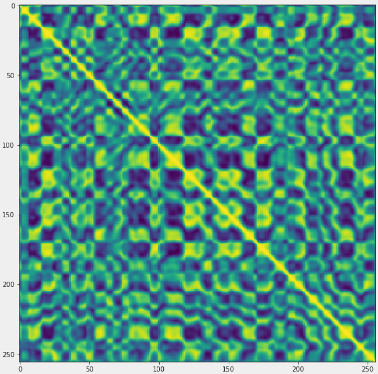
(b) Remission

Deep Learning Approach

Input Representation



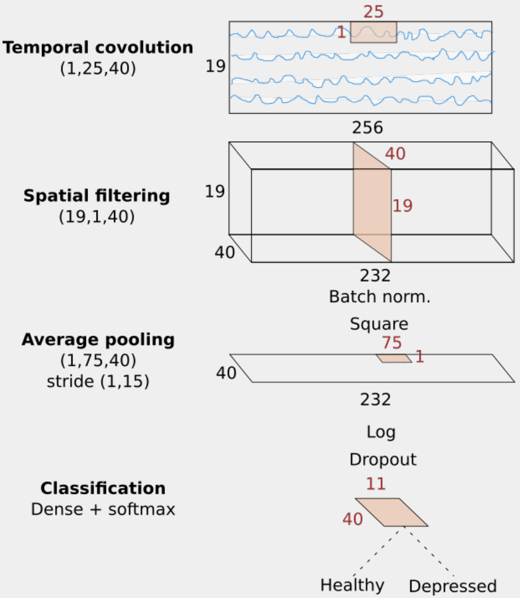
(a) Recurrence plot



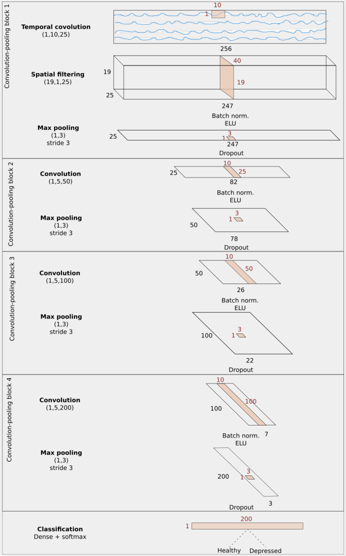
(b) Cosine similarity

(c) Raw

Architecture Design - Shallow



Architecture Design - Deep



Results

Lab.	Freq.	Arch.	Accuracy	
			Mean	**Std**
DEP	$0 - f_{\text{fin}}$	SHAL	0.85	0.13
	$4 - f_{\text{fin}}$	SHAL	0.84	0.11
	$0 - f_{\text{fin}}$	DEEP	**0.86**	0.01
	$4 - f_{\text{fin}}$	DEEP	0.85	0.02
REM	$0 - f_{\text{fin}}$	SHAL	**0.94**	0.02
	$4 - f_{\text{fin}}$	SHAL	0.94	0.03
	$0 - f_{\text{fin}}$	DEEP	0.88	0.01
	$4 - f_{\text{fin}}$	DEEP	0.86	0.02

(a) Raw data

Lab.	Freq.	Arch.	Accuracy	
			Mean	**Std**
DEP	$0 - f_{\text{fin}}$	RP	**0.63**	0.02
	$4 - f_{\text{fin}}$	RP	0.61	0.01
	$0 - f_{\text{fin}}$	CS	0.59	0.02
	$4 - f_{\text{fin}}$	CS	0.58	0.01
REM	$0 - f_{\text{fin}}$	RP	0.61	0.03
	$4 - f_{\text{fin}}$	RP	**0.65**	0.02
	$0 - f_{\text{fin}}$	CS	0.55	0.02
	$4 - f_{\text{fin}}$	CS	0.63	0.01

(b) Image-encoded data

Conclusion

Summary

1. NL measures are potentially effective methods for depression diagnosis and prognosis (despite nonstationarity)
2. CD and LLE seem most discriminative (out of evaluated)
3. FBCSP-inspired CNN models seem more effective than common models
4. ILD seems most effective embedding parameters estimation algorithm (out of evaluated)
5. RP and CS do not seem effective data encoding methods for EEG analysis

Summary

Limitations

- Binary output
- Most patients in remission

NL approach

- Nonstationarity (windowing?)
- Spatially local
- Temporally global
- Inconclusive surrogate tests
- "Theoretically too ambitious"

DL approach

- Short samples
- Simple models

Future Work

- Implement application to aid treatment
- Generalization to other datasets (sample bias)
- Output depression severity measure
- Ensemble of models combining (neuroimaging) modalities
- Incorporate information about treatment details (drugs,...)

NL approach

- Compare with spatial embedding
- New (spatiotemporal) measures

DL approach

- Model interpretation
- Compare with FBCSP
- Dimensionality reduction techniques

Questions

References I

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