Machine Learning Approaches for the Analysis of Functional Brain Connectivity Patterns in Depression

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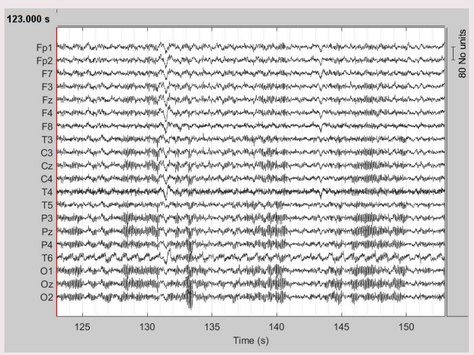
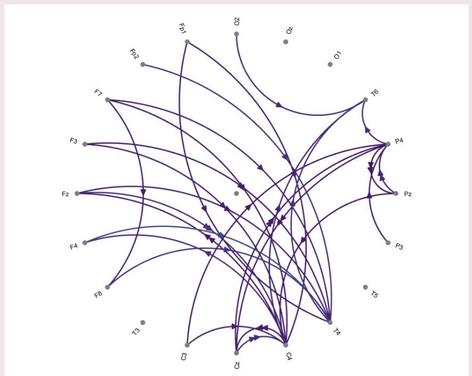
Introduction

In Lithuania 24 per 1000 residents suffer any kind of **depression**, which is one of key **suicide** risks.
Improvement of prevention and treatment is crucial for **life quality, mental health, well-being**.
During depression not only behaviour changes, but also brain bioelectric activity. The latter is detectable using neuroimaging methods such as EEG, MEG, fNIRS, fMRI. With **functional neuroimaging** methods we can calculate **functional brain connectivity**, which is researched as a biomarker of depression.
Machine learning methods are often applied to classify patients and healthy subjects, to distinguish depressed patients from patients with other mental disorders, to predict the symptom change and treatment efficacy.



(a) EEG record



(b) Functional brain connectivity as a graph

Figure: Data example
Source: created by the author.

Goals Most Often Chosen for Researchers

- Classification of major depressive disorder (MDD) patients and healthy subjects (control group, healthy controls, HC)
- Differentiation of MDD into subgroups
- Prediction models for MDD patients

Classification (MDD vs. HC)

Method	Neuroimaging	ACC/SENS/SPEC,%	Author
AdaBoost	fMRI	59/59/59	Zhi, 2021
AMNI	fMRI	65/65/31	Wang, 2022
BNCPL	fMRI	71/69/73	Zhi, 2021
DNN	fMRI	68/66/70	Zhi, 2021
DUG	fMRI	81/89/68	Li, 2022
GCN	fMRI	84/89/68	Kong, 2021
LR	fMRI	84/80/88	Ichikawa, 2020
SLR	fMRI	80/70/85	Sato, 2023
unFEPG	fMRI	93/93/86	Li, 2022
RF	fMRI	77/87/64	Xu, 2022
	EEG	99.6/99.6/99.6	Zhang, 2022
CNN	fMRI	71/66/72	Chun, 2020
	EEG	94/96/94	Duan, 2020
	fNIRS	90/NA/NA	Wang, 2021
XGBoost	fMRI	73/72/74	Shi, 2021
SVM	fMRI	98/100/97	Guo, 2017
	EEG	99.95/99.92/99.98	Zhang, 2022
KNN	EEG	99/99/99.5	Zhang, 2022
LC-KSVD	EEG	99/99/99	Mohaved, 2022
BPNN	EEG	100/99/99	Zhang, 2022

Prediction

Of brain bioelectric activity

Method	Neuroimaging	ACC/SENS/SPEC,%	Author
SVM	MEG	91/91/92	Bailey,2018
LRM	fMRI	82/100/50	Li, 2023
DMN+nCPM	fMRI	80/46/91	Ju, 2022

Of depression severity

For fMRI data were applied such methods as RF (Wade, 2022), SVM (66/72/65; Yamashita, 2021), ADTree (87/89/86; Patel, 2015), SVR (Li, 2021).

Of medication response

Method	Neuroimaging	ACC/SENS/SPEC,%	Author
GCN	fMRI	90/85/93	Kong, 2021
SVM	fMRI	68/62/74	Leaver, 2018

Other predictions

Prediction of behavioral changes: SVR by fMRI data (Yin, 2019)
Prediction of MDD development: SVM (92/90/93) by fMRI data (Hirshfeld-Becker,2019)
Prediction based on a single scan: SVR by fMRI data (Chen, 2022)
Prediction of "brain age": EN, Bayesian ridge, ridge regression by fMRI data (Chen, 2022); MML by fMRI data (77/88/32; Maglanoc, 2020)

Aim

To evaluate machine learning methods used in this field, what results were achieved and what are the strengths and limitations by analysis of related articles found using PubMed database from 2000 to 2023.
Potential enhancements to these methods can lead to improved diagnostic and therapeutic approaches for depression.

Methods

Articles from 2000 to 2023 found in PubMed:
87 suitable for research, 207 rejected.
In all articles subjects had major depressive disorder as a diagnosis.
4 neuroimaging methods – electroencephalography (EEG), magnetoencephalography (MEG) and functional magnetic resonance imaging (fMRI), functional near-infrared spectroscopy (fNIRS).

Differentiation into MMD subgroups

Responders or non-responders to treatment

Method	Neuroimaging	ACC/SENS/SPEC,%	Author
SVM	fMRI	93/95/92	Cash, 2019
	EEG	87/84/89	Bailey, 2019
CNN-LSTM	EEG	99/NA/98	Shahabi, 2023
EN	EEG	87/88/85	Corlier, 2019
RF	EEG	80/80/81	Oakley, 2023

Medicated or not medicated patients

Method	Neuroimaging	ACC/SENS/SPEC,%	Author
LR (MDD placebo / HC placebo)	fMRI	77/84/72	Liu, 2020
LR (MDD placebo / MDD)	fMRI	80/89/67	Liu, 2020

MDD or different disorder

Disorder	Method	Neuroimaging	ACC/SENS/SPEC,%	Author
bipolar	KNN	EEG	99/99/100	Ravan, 2023
	RF	EEG	85/83/90	Sanchez, 2022
	SVM	EEG	89/89/87	Sanchez, 2022
		fMRI	91/NA/NA	Yu, 2020
	GPC	fMRI	70/ NA/ NA	Cha, 2022
PTSD	RVM	fMRI	84/86/81	Zhang, 2021
schizophrenia	SVM	fMRI	83/84/81	Han, 2019

MDD by suicidal ideation

Method	Neuroimaging	ACC/SENS/SPEC,%	Author
Bayesian algorithm	fMRI	85/75/88	Xu, 2022
DL	fMRI	91/100/84	Xu, 2022
RF	fMRI	88/94/85	Q. Li, 2023
SVM	fMRI	85/85/78	Lin, 2023

MDD by depression types

Method	Neuroimaging	ACC/SENS/SPEC,%	Author
K-Means	fMRI	80/46/91	Liang, 2020

MDD by brain bioelectric activity

Method	Neuroimaging	ACC/SENS/SPEC,%	Author
SVM	MEG	90/88/94	Bi, 2018

Other classifications

First episode vs reccurent: GNN by fMRI data (Yin, 2019)
MDD subtypes based on connectivity: K-means by fMRI data (80/46/91; Liang, 2020; Zendehrouh, 2020), SVM by fMRI (73/74/72; Nakano, 2020; Frässle, 2020)
Response to treatment: by TMS, fMRI data for SVM (Hopman, 2021)
By symptoms of depression in HC: fNIRS data for diffpool and GCN methods (Yu, 2022)

Summary

- Functional brain connectivity in depression can be researched to find the most effective model to classify MDD patients and healthy controls, to differentiate MDD subtypes, to predict the course of MDD, to differentiate MDD from other disorders.
- SVM is the most used and versatile method for different goals, classification or prediction.
- EEG and MEG data was rarely used, most articles contained research on fMRI data.
- Machine learning methods used for fMRI data could be applied to EEG and MEG data.
- To improve accuracy of classification results deep learning methods could be used.

Abbreviations

References