Machine Learning usage for prediction of state change in bipolar disorder

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Outline

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    2. Clustering
    3. Prediction of a state change
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    1. Prediction of a state change
    2. Agreement between clusters and psychiatric assessments
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About Bipolar Disorder

- **Bipolar Disorder (BD)** – „mental disorder characterized by manic episodes of elevated mood and overactivity, interspersed with periods of depression” [1]
- It is a chronic and recurrent disease with the highest rate of suicide of all the psychiatric disorders and affecting more than 1% of the world's population [2].

[1] A. P. Association, Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition,
5th ed. Washington, DC, 2000, ch. Bipolar and Related Disorders in Diagnostic.
[2] I. Grande, M. Berk, B. Birmaher, and E. Vieta, Bipolar disorder," The Lancet, vol. 387, no. 10027, pp. 1561-1572, 2016.

Observational study

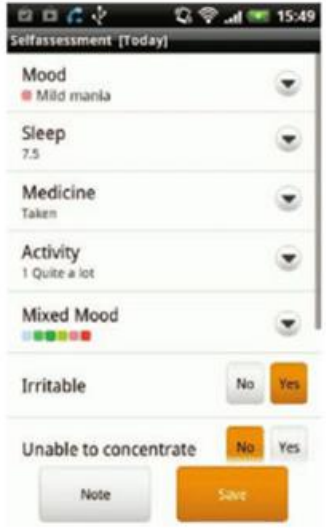
- Observational study included over 49 patients diagnosed with BD
- It was conducted in the Department of Affective Disorders, Institute of Psychiatry and Neurology in Warsaw in 2017-2018
- A dedicated smartphone app was developed and installed on patients' smartphones to work in the background

Observational study (cont.)

- Acoustic features of the patient's voice (such as loudness or pitch) were extracted during phone calls,
- The psychiatric state of each study participant was assessed with Hamilton Depression Rating Scale (HDRS-17) and Young Mania Rating Scale (YMRS) every 3 months or more frequently
- Acoustic data only from 2018

Related work

- Recent studies show that smartphone has become an effective tool for monitoring the BD state and patient's state is usually predicted using the supervised learning approach, see e.g., [3][4]
- Efficiency of speech descriptors in relation to emotion recognition[5]



[3] Grünerbl, A., Muaremi, A., Osmani, V.: Smartphone-based recognition of states and state changes in bipolar disorder patients. IEEE Journal of Biomedical and Health Informatics 19(1) (2015)

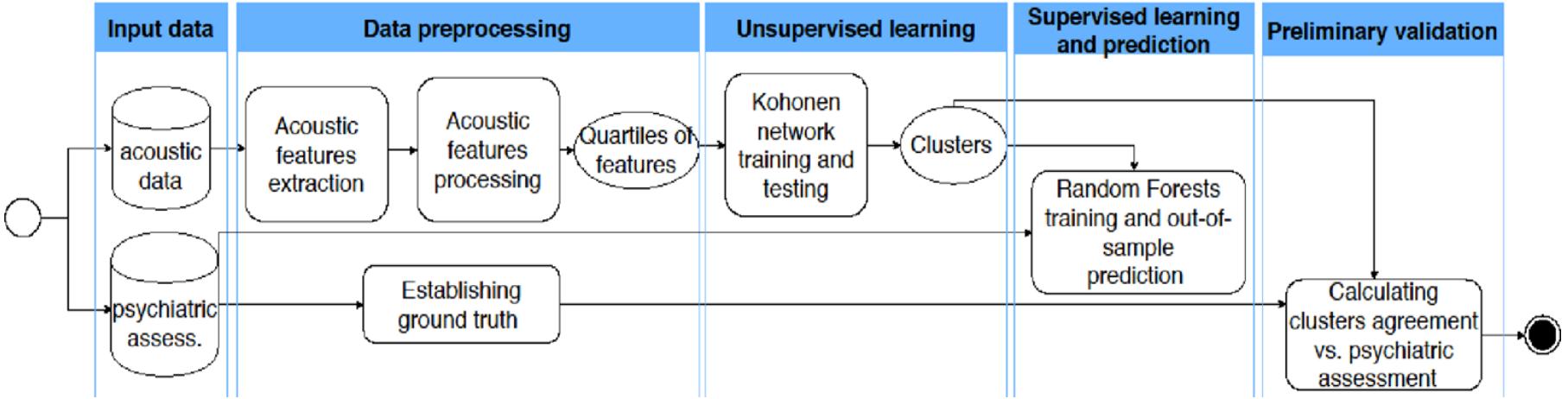
[4] Gideon, J., Provost, E.M., McInnis, M.: Mood state prediction from speech of varying acoustic quality for individuals with bipolar disorder. In: 2016 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). pp. 23592363. IEEE (2016)

[5] Kamińska, D., Sapiński, T., Anbarjafari, G.: Efficiency of chosen speech descriptors in relation to emotion recognition. EURASIP Journal on Audio, Speech, and Music Processing 2017(1), 3 (Feb 2017)

Motivation for unsupervised approach

Observed problems	Consequence
▪ Patient's state (assessed occasionally by a psychiatrist) is **not continuously** observed	**small** number of labeled data is available
▪ Patient's state is **continuously but indirectly observed** with smartphone-based data, such as acoustic features	**large** number of acoustic data is available
▪ Significant variability between patients	need for **patient-dependent** model
▪ Imperfection of data collection	**missing** data

Proposed approach



- We introduced a new approach to predict the phase change of BD patients using acoustic features and a combination of the Kohonen's self-organizing maps and random forests

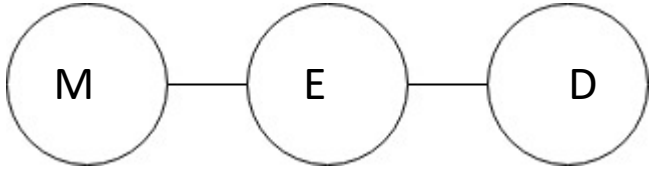
Acoustic data preprocessing

- Mobile recording split into frames (10ms)
- For each frame:
  - 85 parameters describing the voice characteristics extracted using OPEN SMILE library [6]
  - 12 parameters selected based on manual analysis
  - Quartiles from rolling window of 3 days calculated
  - Quartiles normalized

Spectrum slope in 500-1500 Hz range, pcm_fftMag_fband0-650_sma - Energy in the 0-650 Hz band, Alpharatio_sma3 - Energy ratio in the band 50-1000 Hz to energy in the band 1-5 kHz, pcm_fftmag_spectralentropy_sma_ compare - Entropy spectrum, audspecrasta_lengthl1norm_sma - Relative volume counted with RASTA

[6] Eyben, F., Weninger, F., Gross, F., Schuller, B.: Recent developments in openSMILE, the Munich open-source multimedia feature extractor. In: Proceedings of the 21st ACM international conference on Multimedia. pp. 835838. ACM (2013)

Unsupervised learning



- Self-organizing neural network
  - (self-organizing map) - Kohonen algorithm [7]
  - applied due to behavior of the class neighborhood
- Topology 3x1 was selected based on the fact that states are very different from each other, therefore they lie on the opposite sides
- Alternative topologies (rectangular, hexagonal) were also considered
- Package ("kohonen") from the CRAN repository

[7] Kohonen, T.: Self-Organizing Maps. Springer-Verlag Berlin Heidelberg (1995)

Supervised learning & prediction

- Prediction of forthcoming cluster of the self organizing map
- Random Forest („caret" package) [8] was selected based on overall satisfactory results on benchmarks
- Future research assumes comparative analysis including other methods
- Classification of the state of patients in the third day after the last date of measurement

[8] Kuhn, M.: Building predictive models in r using the caret package. Journal of Statistical Software, Articles 28(5), 126 (2008), https://www.jstatsoft.org/v028/ i05

Preliminary results: Prediction Accuracy

Clusters obtained using the Kohonen network algorithm (cluster) are compared with the forecasted states (cluster_next_3day) using random forest 3 days ahead.

Current_day	Day	Cluster	Cluster_next_3day	Next_3day
2018-07-01	2018-07-01	1	2	2018-07-04

100%

Current_day	Day	Cluster	Cluster_next_3day	Next_3day
2018-07-02	2018-07-01	1	2	2018-07-04
2018-07-02	2018-07-02	2	2	2018-07-05

~50%

Current_day	Day	Cluster	Cluster_next_3day	Next_3day
2018-07-03	2018-07-01	1	2	2018-07-04
2018-07-03	2018-07-02	2	2	2018-07-05
2018-07-03	2018-07-03	1	1	2018-07-06

0%

Preliminary results: Prediction Accuracy

- **Training set:**

  Data from January to September 2018

- **Test set:**

  Data from October to December 2018

The average accuracy of prediction using random forests of future clusters is 0.82

patient_id	prediction accuracy
2582	0.67
4923	1.00
5656	0.70
5659	0.70
5736	1.00
5768	0.65
6601	0.69
6754	0.88
8292	1.00
9829	0.91
Mean ± SD	**0.82 ± 0.14**

Preliminary results: Prediction Accuracy

- Agreement between clusters and psychiatric assessment
- Extracting the data from around every pair of visits and assigning assesements to clusters. Training was done on the remaining data
- Comparing two groupings of the same data (daily aggregates), one done by the clustering algorithm and the other by psychiatric assessments extrapolated to 7 days before and 2 after the visit

Cluster agreement measure

- Selecting data around 2 visits (7 days back and 2 days forward)

$$f_{t_v,i} = \frac{\sum_{t=t_v-7}^{t_v+2} I\{c_t = \mathrm{i}\}}{\sum_{t=t_v-7}^{t_v+2} I\{c_t \; is \; not \; missing\}}$$

$$a_{t_A,t_B} = 1 - \frac{1}{2}\sum_{i=1}^{3} \left| f_{t_A,i} - f_{t_B,i} \right|$$

$f_{t_v,i} =$ frequencies of each cluster

I - indicator function taking value:

1 - if the predicateis true

0 - otherwise

a_{t_A,t_B} - normalized absolute dierence

Preliminary results: Cluster agreement

- Selecting data around visits (7 days backward and 2 days forward)
- Comparison of clusters received between all combinations of visits

ID patient	Visit date 1	Visit state 1	Kohonen cluster 1	Visit date 2	Visit state 2	Kohonen cluster 2
9341	2018-05-30	Mania	1	2018-06-22	Euthymia	1
9341	2018-05-31	Mania	2	2018-06-23	Euthymia	1
9341	2018-06-01	Mania	2	2018-06-24	Euthymia	1
9341	2018-06-02	Mania	2	2018-06-25	Euthymia	1
9341	2018-06-03	Mania	2	2018-06-26	Euthymia	1

Cluster agreement: $a_{1,2} = 0,2$

Preliminary results: Cluster agreement

- **Training set:**

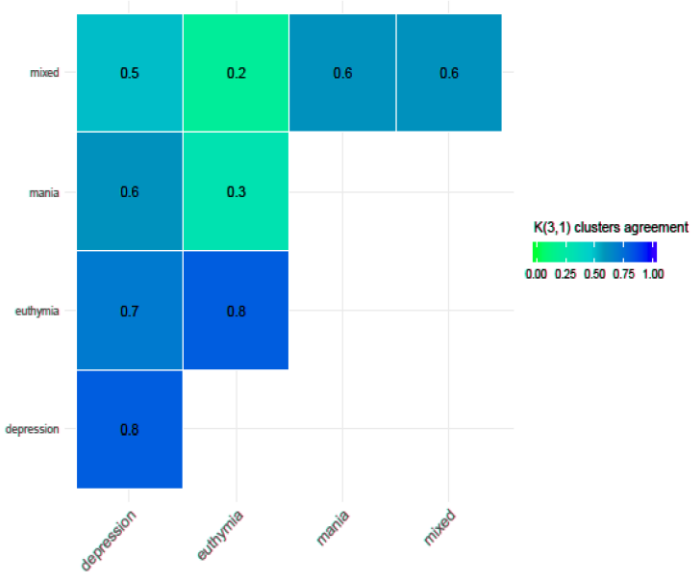
Data except for the period of 7 days before to 2 days after visit

- **Test set:**

10 days surrounding considered testing visits

Patient ID	VISIT 1	VISIT 2	Diagnosis 1	Diagnosis 2	Agreement	Valid Days 1	Valid Days 2
1472	2	3	mania	mixed	0.7	9	10
1472	2	4	mania	mixed	0.7	9	6
1472	3	4	mixed	mixed	0.6	10	6
2004	1	2	euthymia	euthymia	0.0	3	10
2004	1	3	euthymia	depression	0.3	3	10
2004	2	3	euthymia	depression	0.7	10	10
2582	2	3	mixed	mania	0.8	10	10
2582	2	4	mixed	euthymia	0.5	10	6
2582	2	5	mixed	depression	0.5	10	10
2582	3	4	mania	euthymia	0.4	10	6
2582	3	5	mania	depression	0.4	10	10
2582	4	5	euthymia	depression	0.7	6	10

Preliminary results: Cluster agreement



Degree of agreement between clusters with possible combinations of the patient's condition

The most important conclusions:

- For the same diagnoses, the average agreement is approximately 0.8 (very high)
- Mixed - the most difficult condition to detect patients the most ill
- Patients in mania stop using the phone

Conclusions

- Mobile phones enable collecting large amounts of data
- The proposed approach combines unsupervised learning, prediction of future patient status and validation of the results obtained with medical diagnoses
- The results of used methods are promising
  - The average prediction accuracy of future clusters using random forests is 0.82
  - For the same diagnoses, the average agreement is approximately 0.8

Future work

- Increasing the range of data used for the analysis
  - Changing the way data is aggregated, e.g. by connection instead of days
- Use other neural networks and unsupervised learning algorithms
- Use semi-supervised learning
- Use other predictive models and comparative analysis using cross-validation
- Selection of variables used to teach the algorithm (features engineering)

Thank you
for your attention

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