Stage Master M2 (6 months)

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Team : ARMEDIA/SAMOVAR

Subject : Deep Learning-based Voice Digital Markers for Early Detection and Stratification of Parkinson Disease

Context

Parkinson's disease (PD) is the second most common neurodegenerative disease after Alzheimer's. This disease results in motor disorders worsening over time, caused by a progressive loss of dopaminergic neurons in the substantia nigra, located in the midbrain. The standard diagnosis, mainly based on clinical examination, is usually made when at least two of the following three symptoms are observed: akinesia (slowness of initiation of movement), rigidity, and tremors at rest. These symptoms, unfortunately, appear once 50 to 60% of dopaminergic neurons in the substantia nigra are destroyed. That is why PD detection at an early stage is key for testing treatments before the occurrence of large irreversible brain damages, and for slowing down, or even stopping, its progression. Nowadays, new neuroimaging methods, such as Magnetic Resonance Imaging (MRI), are used to detect PD. Such methods, however, are costly, have limited availability, and some are associated with radiation. Consequently, the clinical evaluation of PD remains the gold standard. It is, therefore, important to develop innovative methods that are less costly, non-invasive, and can be carried out remotely.

Besides hospitals' screening tests, Digital biomarkers (DMs) from everyday sensors and devices have the potential to change fundamentally our understanding of Parkinson's Disease (PD). They allow for a quantitative and continuous monitoring of disease symptoms, including outside clinics/hospital monitoring (telemedicine). Such DMs can be helpful for early PD detection. They also provide a possibility to monitor the response to treatments, hence opening the opportunity to adapt medication pathways quickly, if necessary.

Objectives

This main aim is to develop robust deep-learning digital biomarkers for early-stage Parkinson detection based on voice alterations such as Dysarthria. A special emphasis will be put on making our deep neural networks interpretable [De Bois-IJPRAI2021]. A strong competitive positioning w.r.t current state of the art is that we will develop digital biomarkers not only on transversal voice data, but also on longitudinal ones, as our datasets consist of recordings acquired over long periods. This will allow us to not only detect PD, but also to stratify PD patients into different groups, which will be key for the medical staff to design specific treatment and therapy for each group. Finally, our digital markers will be assessed against Neuroimaging and clinical scores.

Compared to our previous work [Jeancolas-interspeech-2019][Jeancolas-PhD-2019][Jeancolas-2021] that discriminate PD patients by learning X vectors features from standard MFCC voice features through a TDNN network or by considering global voice features, we propose new research directions by considering two deep networks that learn respectively from spectrograms and raw audio waveforms. Our rationale is that spectrograms and above all the raw voice signal may comprise characteristics that are discriminant of PD, but which are not contained in MFCC. Most existing techniques are based only on standard voice features used for speech/speaker recognition. Only one

work has considered spectrograms [Wodzinski-2019]. A spectrogram is a visual representation of the signal's frequencies spectrum that encodes the frequencies changes over time. However, they used a pretrained neural net on the ImageNet dataset that consists of natural images, and fine-tuned it on the spectrograms which is not sound as the latter are virtual images not consisting of natural pixel distributions. Our proposal of learning directly from the raw signal, inspired by [Ravanelli-2020] used for speech recognition, has never been investigated in the context of PD. It has the potential to extract fine local sound features unlike spectrograms, for which good frequency representations requires large voice segments. To make these new neural networks models robust, nonetheless, effective transfer learning schemes should be devised by harnessing other voice datasets [De Bois-CMPB2021].

Profile

- Master2 thesis : Bac +5 in Data science or equivalent
- Interest in Research
- Skills :
    - Data Science, machine learning, deep learning
    - Programming in Python and in particular the libraries of machine learning and deep learning (PyTorch, Tensorflow, Scikit-learn, etc.)
    - Good Level in English
    - (Optional) Background in the medical field

References

[De Bois-CMPB2021] M. De Bois, M.A. El Yacoubi, M. Ammi, Adversarial multi-source transfer learning in healthcare: Application to glucose prediction for diabetic people, Computer Methods and Programs in Biomedicine, 2021.

[De Bois-IJPRAI2021] M. De Bois, M.A. El Yacoubi and M. Ammi, Enhancing the Interpretability of Deep Models in Heathcare Through Attention: Application to Glucose Forecasting for Diabetic People, ICPRAI 2020 and IJPRAI Journal, 2021.

[Jeancolas-interspeech-2019] Jeancolas, L., Petrovska-Delacrétaz, D., Benkelfat, B.-E., et al., Comparison of Telephone Recordings and Professional Microphone Recordings for Early Detection of Parkinson's Disease, Using Mel-Frequency Cepstral Coefficients with Gaussian Mixture Models. Interspeech 2019.

[Jeancolas-PhD-2019] Laetitia Jeancolas. Détection précoce de la maladie de Parkinson par l'analyse de la voix et corrélations avec la neuroimagerie. Université Paris-Saclay, 2019.

[Jeancolas-2021] L. Jeancolas, D. Petrovska, et al., Vectors: New Quantitative Biomarkers for Early Parkinson's Disease Detection From Speech, Frontiers in Neuroinformatics, 2021.

[Ravanelli-2020] M. Ravanelli and Y. Bengio, "Speaker Recognition from Raw Waveform with SincNet," IEEE Spoken Language Technology Workshop (SLT), 2018.

[Vinokurov-2015] N Vinokurov et al., Quantifying hypomimia in Parkinson patients using a depth camera. Int. Symposium on Pervasive Computing Paradigms for Mental Health 2015.

[Wodzinski-2019] M. Wodzinski, et al., CNN Dedicated to Image Classification, 2019 EMBC.