DS3 DATA SCIENCE SUMMER SCHOOL
Monday, June 25 – Friday, June 29, 2018

ÉCOLE DOCTORALE INTERFACES Approches Interdisciplinaires : Fondements, Applications et Innovation

DaSciM DATA SCIENCE AND MINING TEAM

ÉCOLE POLYTECHNIQUE UNIVERSITÉ PARIS-SACLAY

CHARACTERIZATION OF SLEEP STATES WITH EEG PATTERN DETECTION
PRELIMINARY RESULTS : IMPACT OF SIGNAL QUALITY

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INTRODUCTION : During the past decades, a great body of research has been devoted to automatic sleep stage scoring using the electroencephalogram (EEG). However, the results are not yet satisfactory to be used as a standard procedure in clinical studies, especially on artifact signal that integrate in the Dataset a lot of non expected informations .

Although a lot of methods have been develop ,especially Spectral analysis (Fast Fourrier Transform), or multi-class support vector machine (SVM) classification based on a decision tree approach (2), this issue is still under resolution , especially to build machine learning Algorithm on big Data set . In the mean time , some mathematical techniques to remove artifacts were studied like independent component analysis (ICA) or using signal space projection(SSP).

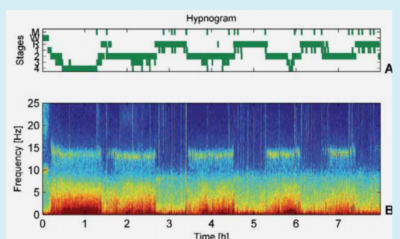
PROBLEM AND OBJECTIVES : Until now, Sleep Classification from Electroencephalography into sleep stages require a good signal and a trained medical practitioner or technician to interpret the signal, it's is time consuming and a lot of more specifics informations are lost for the patient. Among the difficulties in making a good automation of sleep detection , the artifacts are the worst. Artifacts , that we could define as unwanted contamination of the brain's signal by extra-brain signals , complicate the interpretation. The most frequent artifacts are the 50Hz,the eye blinks, the muscles , the movement , sweat, and loss of contact between the electrodes and the scalp. Even in a Sleep Lab we have to deal with although standard protocol use 6 strongly glued Ag-Cl Electrodes with conductive past (F3-M2, C3-M2, 01-M2, F4-M1, C4-M1, 02-M1) in order to decrease the artifacts contamination

The objective of this work is to compare 2 methods of Sleep EEG analysis on ambulatory recording made in an Hospital (Pitié-Salpétrière Hospital – Paris , with standard protocol in order to decrease the artifacts contamination and apply those methods on the best signal recording (little artifact) and the worst (artifact +++) on the basis of a sleep evaluation.

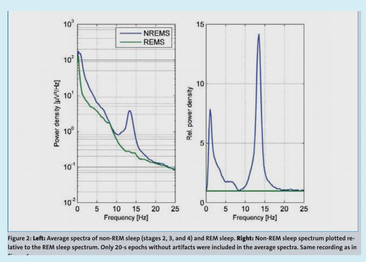
We start this work with a preliminary empiric study comparing an usual Quantitative electroencephalogram analysis with a pattern detection approach using Hankel Matrices on those 2 extreme types of Sleep EEG recording,

This preliminary analysis is part of more global researtch in Sleep pattern detection in a population of 1000 insomniacs patients to calibrate a Machine learning approach.

METHOD 1 : Spectral Analysis – Fast Fourrier Transform (FFT)



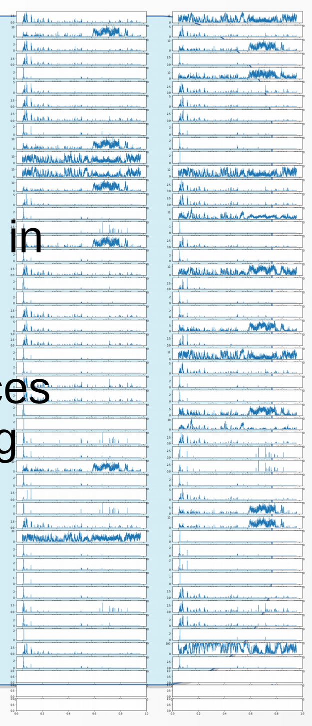
1) Datasets from Raw EEG (256) is filter (0,5 Hz< Signal < 70 Hz + Notch Filtering)
2)displays the distribution of power density (µV2/Hz. over the frequency components of the signal.(alpha, theta, beta, delta)
3) Automatic sleep detection using frequency detection
4) Then we compare the hypnogram generated by the algorithm with expert scoring



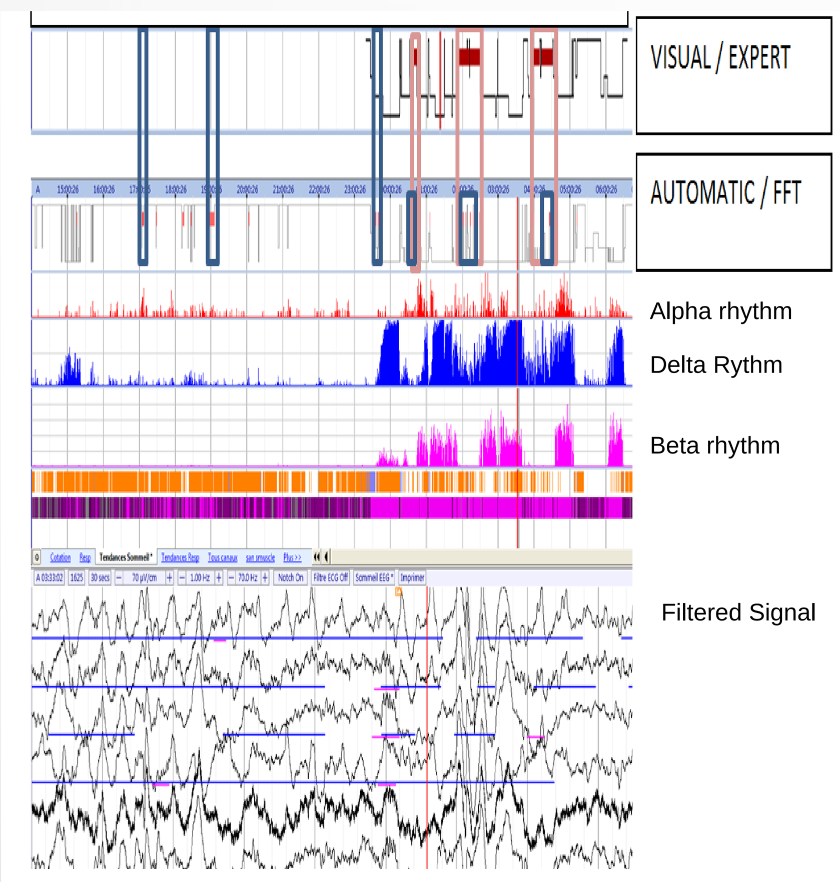
METHOD 2 : HANKEL Matrix Clustering

1) Datasets from Raw EEG (time series from t0 to tn) was transform in Hankel Matrix
2) A clustering method is apply (using euclidean distance)
3) We compute clusters sizes evolution over the entire EEG sequences
4) Then we compare the clusters sizes evolution with real EEG scoring

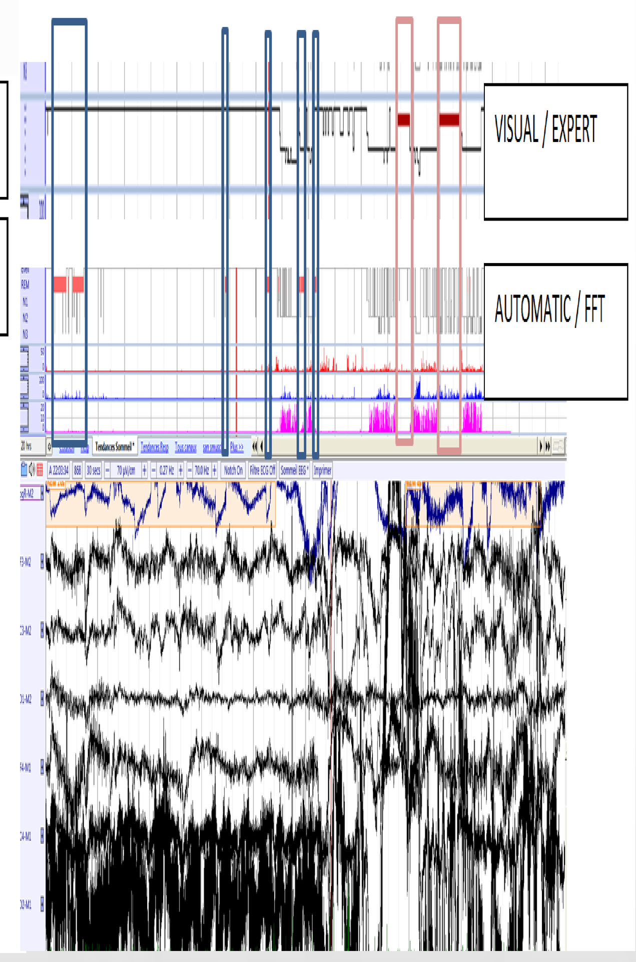
$$T = (t^0\ t^1 \ldots.\ t^n) \Rightarrow H_m = \begin{bmatrix} t^0 & \cdots & t^m \\ t^1 \vdots & \ddots & t^{m+1} \\ t^{n-m} & \cdots & t^n \end{bmatrix}$$



Sleep EEG without Artifact



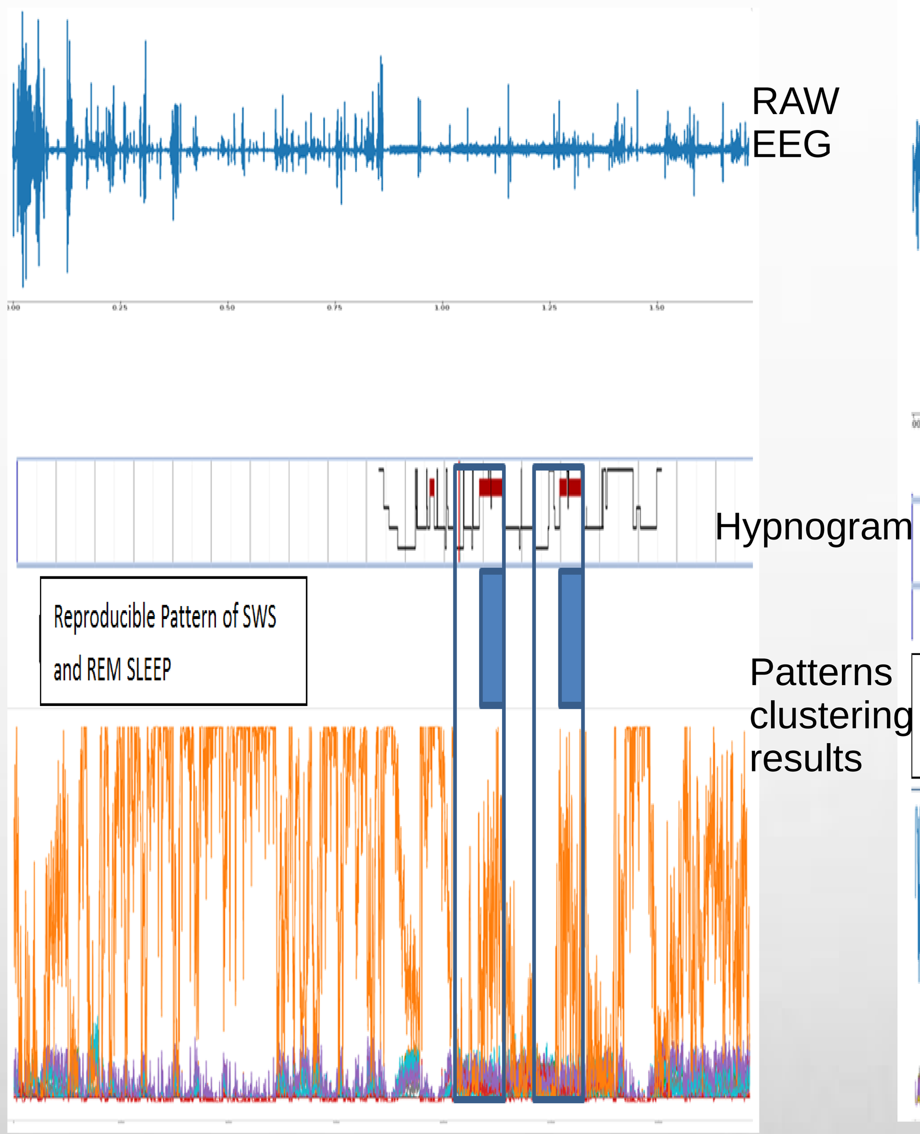
Sleep EEG with persistent artifact after applying band-filter



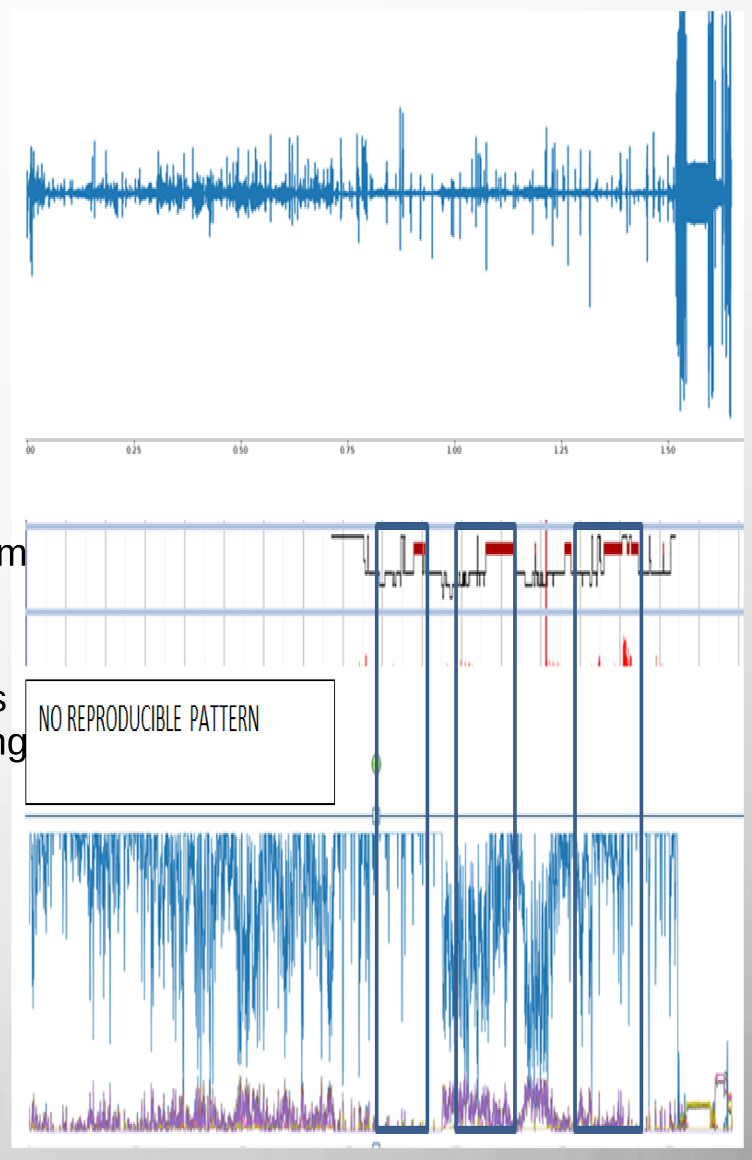
scorage automatique par FFT			par expert		index A/E
Stade	Temps total en TPS	%/TPS	Temps total en TPS	%/TPS	Index des temps de scorage auto/expert
Éveil	528,5 min	53,5 %	627,5 min	63,5 %	0.84 underest
REM	38,0 min	3,9 %	70,5 min	7,1 %	0.55 underest +
N1	24,0 min	2,4 %	26,0 min	2,6 %	0.92 underest
N2	79,5 min	8,1 %	192,0 min	19,4 %	0.41 underest
N3	317,0 min	32,1 %	70,5 min	7,1 %	4.52 surestim +++

scorage automatique par FFT			par expert		index A/E
Stade	Temps total en TPS	%/TPS	Temps total en TPS	%/TPS	Index des temps de scorage auto/expert
Éveil	676,0 min	69,2 %	635,5 min	63,2 %	1.06 surestim
REM	83,5 min	8,6 %	78,0 min	22,1 %	1.07 surestim
N1	12,5 min	1,3 %	26,5 min	7,5 %	0.47 underest
N2	151,5 min	15,5 %	207,5 min	58,7 %	0.73 underest
N3	53,0 min	5,4 %	41,5 min	11,7 %	1.27 surestim

Sleep EEG without Artifact



Sleep EEG with Artifact



RESULTS METHOD 1 Very preliminary results with spectral analysis algorithm on a few representatives datasets of filtered sleep EEG show :
-1) Even in case of poor artefacted dataset, the correlation between automatic algorithm and expert on sleep stages percentage is poor (bad specificity) ,with big under and overestimation of each sleep stage (especially in the SWS classification) , but the sensibility is quite good according to the sleep period detection.
-2) But more surpisingly , in case of very artefacted dataset , the correlations are better on sleep stages percentage, but the sensibility is very low with totally invented sleep stages and unrecognised ones, that could make think that the sleep quantity are normal when the real sleep detection , especially for REM sleep, is almost zero !.

RESULTS METHOD 2

Very preliminary results with pattern detection algorithm with Hankel matrices on 2 representatives datasets of RAW sleep EEG show :
-1) Good specificity of pattern detection when RawEEG is poor artefacted with good reproductibility on specific sleep pattern . Good sensibiliy also. .
-2) Very bad specificity and sensibility on very artefacted rawEEG , although a sleep expert could interpret the sleep stages.

CONCLUSION: So this very preliminary work on a few sleeplab datasets using 2 very differents approachs to characterize sleep pattern show very low reliability of the 2 methods on signal with a lot of artifacts . This preliminary result confirm the difficulty to build a machine learning approach on sleep EEG in order to detect sleep stages , especially on artefacted EEG . The FFT approach seems to generate much more false negative in sleep stage detection than Hankel Matrices approach.
On a poor artefacted EEG , FFT is showing good sensibility but low specificity , when Hankel matrices appraoch seems more specific .
Further experiment will follow this empiric work , especially using more Datasets in order to build a Machine Learning Algorithm.