PhD Research Proposal Form
China Scholarship Council (CSC) - ENS Group

FIELD: Data Science

Thesis subject title: **Sparse deep learning for fetal heart rate characterization**

Name of the French doctoral school : EDPHAST

Name of the Research team :

SYSIPH team, Laboratoire de Physique de l'ENS Lyon
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Lab Language : French

Research Proposal Abstract :

Fetal Heart Rate (FHR) monitoring is used during delivery for fetal well-being assessment (cf. Fig1 for associated signals). Classically based on the visual evaluation of FIGO criteria, FHR characterization remains a challenging task that continuously receives intensive research efforts, which are performed in close collaboration with HCL (Hospices Civils de Lyon). Research works aimed at devising automated acidosis prediction procedures are either based on designing new advanced signal processing analyses or on effciently combining a large number of features proposed in the literature. In a previous work [1], we consider sparse learning to perform jointly feature selection and acidosis prediction, hence producing an optimal decision rule based on few features among a set of 20 features (gathering "FIGO-like" features, classical spectral features and recently proposed scale-free features).

Considering recent advances combining nonsmooth optimization and deep learning, we aim to revisit the sparse learning procedure we proposed as a deep learning framework by unfolding the primal-dual proximal iterations as in [2], possibly with quadratic interaction following [3]. Each layer of the network corresponds to one iteration of the proximal algorithm and the learned parameters are the algorithm step-sizes, the regularization parameter, and possibly the interaction matrice. Behind such a formulation, several theoretical questions are arised such as : the specific design of the network, the design of the backpropagation procedure, the choice of the stochastic gradient procedure to learn the parameters, the stability of the network.

The advantage of such a proposed deep learning procedure is to benefit from the best of both worlds : standard learning (and its associated knowledge obtained during the last 20 years) and the efficiency of deep learning, especially when the size of the database is small as for the FHR database.

This PhD is devoted to the design of a neural network for the specific task of sparse learning and its application to FHR monitoring including :

- evaluation of sparse learning including quadratic interactions and compare it to standard sparse learning considered in [1] for classification and regression tasks;
- dthe esign of the deep neural network using unfolded primal-dual proximal algorithm and the study of its stability both theoretically and numerically;
- performance evaluation of the proposed unfolded primal-dual proximal algorithm on synthetic and real data;
- the comparison with previous sparse learning method and standard CNNs.

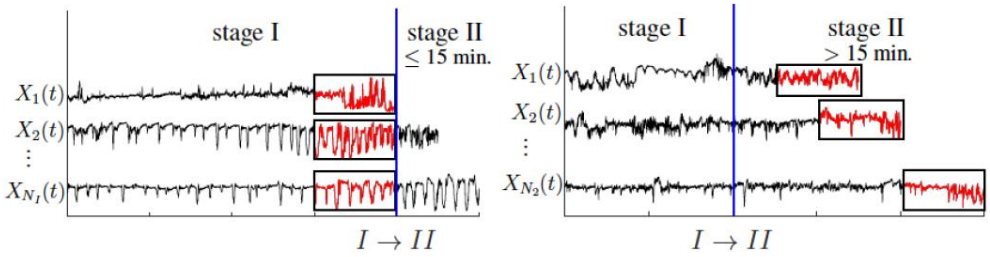

Figure 1. Stage splitting. Analyzed FHR data are marked by the time windows framed in rectangles boxes, corresponding to the last 20min of StageI (for StageI dataset, left) and the last 20 min before delivery for StageII dataset (right).

This PhD will benefit from established collaborations between N. Pustelnik, M. Jiu, and P. Abry as specified by the publications below.

References :

[1] P. Abry, J. Spilka, R. Leonarduzzi, V. Chudacek, N. Pustelnik, M. Doret, Sparse learning for Intrapartum fetal heart rate analysis, Biomedical Physics & Engineering Express, vol. 4, no. 3, 034002, 2018. (PDF).
[2] M. Jiu, N. Pustelnik, A deep primal-dual proximal network for image restoration, submitted, 2020. (PDF).
[3] M. Jiu, N. Pustelnik, S. Janaqi, M. Chebre, P. Ricoux, Sparse hierarchical interaction learning with epigraphical projection, Journal of Signal Processing Systems, 92, pp. 637-654, 2019 . (PDF)

Type of PhD :

Full PhD - Regular PhD (leading to a single French diploma)

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