University Grenoble-Alpes **GIPSA-lab, GSTATS Data Science Chair**
INTERNSHIP PROJECT **Romain COUILLET & Zhenyu LIAO**

2018 - 2019 **Office D1178**

A Random Matrix Study of Echo-State Neural Networks

Project context and application

With the recent compelling showcases of deep learning in performing advanced classfication tasks, neural networks are given more and more attention these days. One particularly interesting neural network structure are the so-called echo-state neural networks [1], which belong to the wider family of recurrent neural networks and provide appropriate models of some structures of the human brain, in particular when it comes to short-term memory and prediction tasks.

Thanks to advanced techniques from random matrix theory, it is today possible to understand the performance dynamics of such networks, however so far only for the simple linear or non-recursive versions of these networks (see [2-4] for a glimpse on these results).

The subject of this internship will be to extend the aforementioned analysis to the more challenging nonlinear echo state networks. The first step will consist in implementing such networks on specific tasks so to get a deeper understanding of the difference between linear and nonlinear. Next, we shall try to provide a random matrix theoretical approach to reach a proper performance analysis, thereby allowing for an accurate understanding of the inner working at play in these networks.

Main steps

- Review of the literature on echo-state-networks with a particular focus on linear versus nonlinear considerations.
- Implementation of such networks for various memorization and prediction tasks.
- Theoretical analysis of the nonlinear performance using random matrix theory.

Associated domains: Random matrix theory, time series, signal processing, neural networks.

Requirements: Good coding skill in Matlab or Python, knowledge of the basics of random matrix theory, good understanding of general signal processing and machine learning concepts.

Location: The internship will take place at GIPSA-lab, University of Grenoble-Alpes, in the Grenoble area.

References

[1] H. Jaeger, **"The echo state approach to analysing and training recurrent neural networks"** *German National Research Center for Information Technology GMD Technical Report* 148.34 (2001): 13.
[2] R. Couillet, G. Wainrib, **"Perspectives en matrices aléatoires et grands réseaux"**, Revue Traitement du Signal, vol. 33, no. 2-3, pp. 351-376, 2016.
[3] R. Couillet, G. Wainrib, H. Sevi, H. Tiomoko Ali, **"The asymptotic performance of linear echo state neural networks"**, Journal of Machine Learning Research, vol. 17, no. 178, pp. 1-35, 2016.
[4] C. Louart, Z. Liao, R. Couillet, **"A Random Matrix Approach to Neural Networks"**, The Annals of Applied Probability, vol. 28, no. 2, pp. 1190-1248, 2018.