PiAI Seminar Series: Physics informed AI in Plasma Science
10:00-11:00, 31 May 2021 (CET)
17:00-18:00, 31 May 2021 (JST)
Web Seminar

Parametric Validation of the Reservoir-Computing-Based Machine Learning Algorithm Applied to Lorenz System Reconstructed Dynamics

Samuele Mazzi

Aix-Marseille Université, CNRS PIIM, UMR 7345 Marseille, France

The numerical modelling of multi-scale and complex systems, such as turbulent transport in nuclear fusion plasmas, has been continuously growing in the last decade, reaching very high levels of fidelity and accuracy. In some practical applications, however, the elapsed computational time for the exploitation of these numerical modellings still represent the bottleneck. For these reasons, the application of the rapidly advancing Machine Learning (ML) algorithms has gained a lot of attraction in the framework of the data-driven modelling of complex dynamical systems.

Recently, the application of a specific ML technique to study and predict chaotic trajectories has been reported [1,2]. This technique is the so-called Reservoir Computing ML approach, which takes inspiration from the Recurrent Neural Network (RNN) architectures [3,4]. Reservoir computers differ from the usual RNNs in being composed by two levels: the *reservoir*, which is a randomly initialized RNN, and the *readout*, which is a feed-forward layer realizing an optimized function trained to predict the chaotic behaviour of the system. In these recent publications [1,2], the RC technique has been applied to the well-known Lorenz system, reporting promising results in predicting its dynamics.

In this study, we report a detailed statistical analysis based on the Projection of Proper elements (PoPe) method [5] to evaluate the accuracy of the RC algorithm applied to the prediction of the Lorenz trajectories. Therefore, an exhaustive study of the hyperparameters of the ML technique is carried out, revealing that extremely large variation of the measured error between the ground truth and the predicted dynamics is observed for a broad range of RC configurations [6]. This large variation is essentially caused by the random initialization of the *reservoir* layers. Indeed, good accuracy is obtained only for a small range of hyperparameters. However, such range is furtherly narrowed by additional considerations on the training phase length.

In conclusion, it is shown that the RC approach may represent an appealing application to the prediction of complex dynamical systems, here simplified with the Lorenz trajectories, but further developments of this paradigm are required to solidly achieve good accuracy.

[1] Z. Lu *et al.*, Chaos : An Interdisciplinary Journal of Nonlinear Science **27**, 041102 (2017)
[2] J. Pathak *et al.*, Physical Review Letters **120**, 024102 (2018)
[3] H. Jaeger, Science **304**, 78-80 (2004)
[4] W. Maass *et al.*, Neural Computation **14**, 2531-2560 (2002)
[5] T. Cartier-Michaud *et al.*, Physics of Plasmas **23**, 020702 (2016)
[6] S. Mazzi and D. Zarzoso, *Submitted to* Physical Review E (2021)