Postdoc: Koopman-based machine learning for turbulence forecasting

Research field: Mathematics for AI

Offer description:

The International Monitoring System (IMS) routinely detects many events that are attributed to atmospheric processes (turbulence, storms, etc.) and referred to as infrasound perturbators or noise. These events, known to cause false detections, are an important source of difficulty in the network processing operated at the National Data Centers (NDC). Similar conclusions hold from regional to large scales, since coherent features of turbulence affect both the detection capability of IMS stations and atmospheric dynamics.

The postdoctoral candidate will study how recent advances in dynamical system theory can be combined to Machine Learning (ML) for modeling and forecasting turbulence, with applications to turbulence-related infrasound noise characterization. The accurate description of turbulence poses a great challenge to numerical simulations in various fields, as well as to the computational algorithms that extract and quantify this behaviour. We will follow the "Koopman operator picture" (Koopman, 1931; Koopman & Neumann, 1932), which shows that for every dynamical system there is a linear operator acting on a function space whose spectral properties completely characterize the dynamical system. The explicit expression of the Koopman operator in closed form, however, is only possible for simple systems amenable to analytical treatment. In some circumstances the Koopman invariant subspaces can be learnt using machine learning techniques. It was further recognized that the adjoint of the Koopman operator, known as the Perron–Frobenius operator, is valuable as it acts on the space of densities of the state space of the system. Whereas the Koopman operator provides information on the evolution of functions of the state (sometimes referred to as observables), its adjoint evolves densities of trajectories of the state space. Both transfer operators can be estimated using practical databased algorithms such as the Extended Dynamic Mode Decomposition (EDMD) and the variational approach of conformation dynamics. A review of these methods can be found in Klus et al. (2018).

The aim of this postdoc is to establish a bridge between the field of dynamical systems and ML techniques so as to provide interpretable and predictive algorithms for predicting real-world times series. This project is related to various applications in the context of IMS data, depending on the data considered: meteorological data collected from technologies such as Lidars (light detection and ranging), acoustic and seismic sensors, sonic anemometers, etc. A significant part of this project will be devoted to approximating the continuous spectrum of transfer operators, which is an important open question in the field of Koopman-based ML. The postdoctoral candidate will collaborate with scientists of the leading Paris-Saclay University, in a motivating environment coordinated by the Graduate School "Mathematics".