A data-driven approach to transfer operators in nonlinear dynamics using neural networks

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Résumé

Non linear dynamical systems arise almost everywhere in science : natural phenomenas, from biology to economics, can be described as a non linear dynamics in some suitable space. In several contexts finding a good dynamical model for the phenomena which is studied is an hard task. Recently, a new trend is taking hold : rather then observing a phenomena trying to model it with (partial differential) equations, this new approach aims to compute (usually) a matrix that should describe, up to some approximation error, the dynamic underling a big set of data (data-driven approach). Functional analysis provide a powerful tool to understand the statistical properties of dynamics, the so-called transfer operator : an infinite dimensional operator associated to a dynamical system, describing how the dynamics governs the evolution of initial probability densities instead of initial points. Under suitable assumptions, it is reasonable to approximate it with a matrix, which can be computed from the data. The goal of this work is to shortly resume the data-driven techniques developed until now, clarify the mathematical theory involved in this approaches, and finally to present a neural network based algorithm for the computation of a finite approximation of the transfer operator.