Deep Learning for data driven understanding and control of complex systems

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Abstract

Given the continuous progress in instrumentation and storage technologies, the analysts are increasingly faced with the challenge of analysing time series generated by complex systems, whose physics is poorly known at best. The understanding and control of such systems requires at least the determination of the system dimensionality and the assessment of the cause-effect relationships between the various signals. Deep autoencoders of various architecture and training procedure have been develop to perform all these tasks.

Firstly, they allow defining an operational concept of dimension, more susceptible of practical application than the traditional intrinsic or fractal dimensions. The devised autoencoders allow estimating such a type of dimensionality much more accurately than the most widely accepted techniques. In particular they remain effective in high dimensions and are much more robust against noise and outliers.

Secondly, a particular architecture, the so called Interaction AutoEncoders (IAEs), has been developed to determine the causal relationships between time series. Adopting the Granger causality framework, based on predictability, the devised IAEs can assess the mutual influence between two or more signals and are fully capable of detecting nonlinear interactions much more reliably than alternative approaches.

Finally, the trained autoencoders can be deployed to implement data driven feedback of nonlinear systems in a very effective and simple way.

The aforementioned potentials of the developed deep autoencoders are substantiated with a systematic battery of numerical tests based on complex systems in the chaotic regime of operation (Lorenz, Chua, Rössler, Henon, Duffin equations and more). Their properties are also exemplified by experimental applications to signals generated by tokamak plasmas including the recent DT campaigns on JET.

Key words: deep learning, autoencoders, complex systems, diagnostics, tokamaks

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